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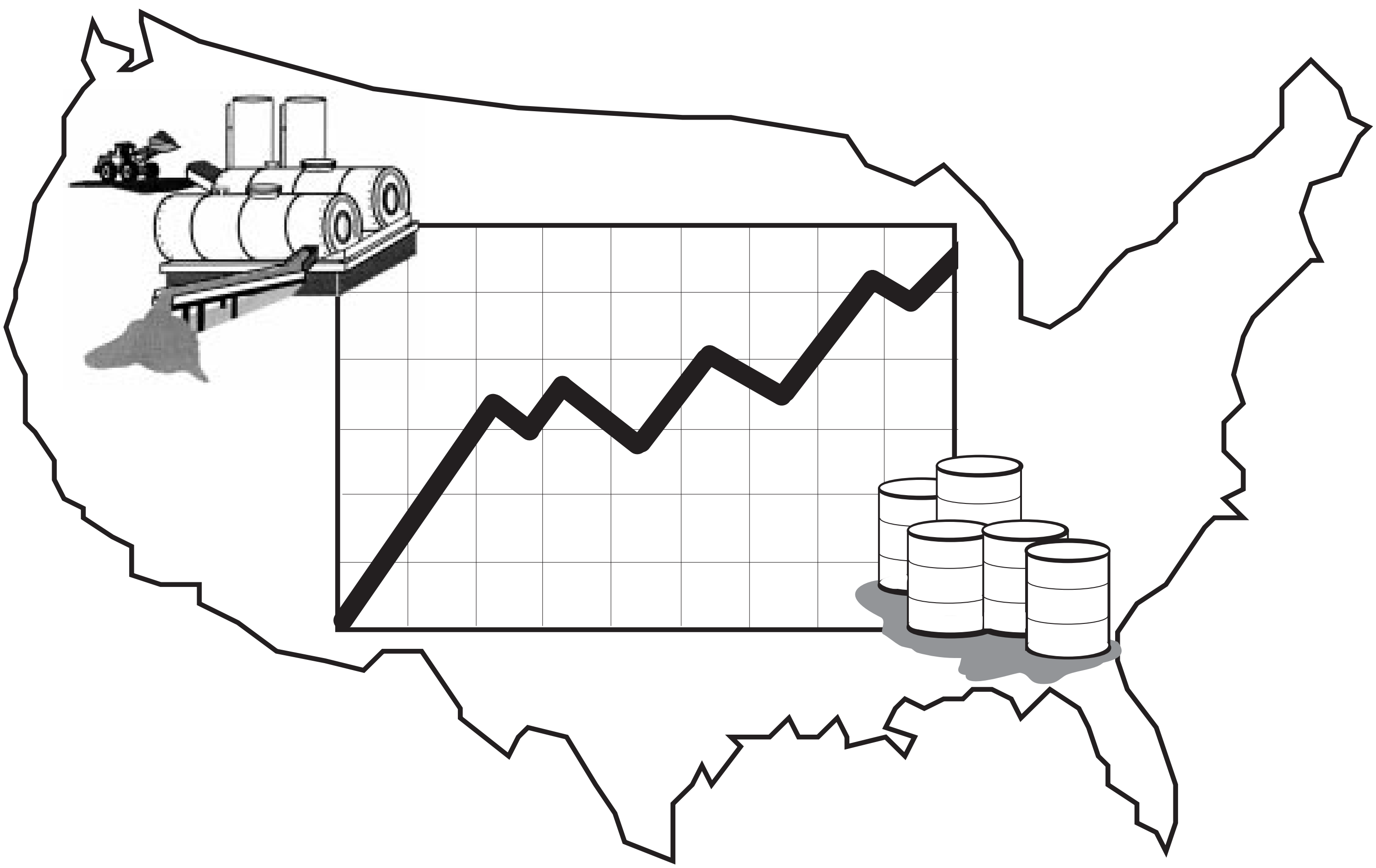
Clean Up the Nation's Waste Sites: Markets and Technology Trends

1996 Edition



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Markets and Technology Trends

1996 Edition

U.S. Environmental Protection Agency
Office of Solid Waste and Emergency Response
Technology Innovation Office
Washington, D.C. 20460

NOTICE

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FOREWORD

Over the next several decades, federal, state, and local governments and private industry will commit billions of dollars annually to clean up sites contaminated with hazardous waste and petroleum products. This planned investment will result in a continuing demand for site remediation services and technologies that provide better, faster, cheaper environmental cleanup. The purpose of this report is to provide technology vendors, developers and investors, and government officials with improved information on the demand for cleanup services so that they may better identify business opportunities and plan technology research and development efforts. EPA believes that more readily available information on the cleanup market will further the development and use of new techniques for site remediation.

The study describes the future demand for remediation services in all of the major cleanup programs in the U.S., including Superfund, Resource Conservation and Recovery Act (RCRA) corrective action, underground storage tanks, state programs, and federal agencies such as the Departments of Defense and Energy (DOD and DOE). The study updates and expands a 1993 analysis that brought together for the first time valuable information on site characteristics, market size, and other factors that affect the demand for remediation services and technologies in these programs. In addition to providing updates of data in the original version, this report includes significant new information on cleanup needs related to underground storage tanks, RCRA corrective actions, and sites administered by DOD, DOE, and other federal agencies. It identifies several technology gaps, and highlights technology development priorities set by public and private sector problem owners.

Comments or questions concerning this report may be directed to the U.S. EPA, Technology Innovation Office (5102G), 401 M Street, SW, Washington, DC 20460, (703) 603-9910.

ACKNOWLEDGEMENTS

This document was prepared for the U.S. Environmental Protection Agency's Technology Innovation Office (TIO). The report would not have been possible without the assistance of staff throughout EPA, the Department of Defense (DOD), and the Department of Energy (DOE). Special thanks go to staff in EPA's Office of Emergency and Remedial Response; Office of Solid Waste; Office of Underground Storage Tanks; Federal Facilities Restoration and Reuse Office; and Office of Federal Facilities Enforcement. DOD's Office of the Assistant Under Secretary of Defense for Environmental Security, DOE's Office of Environmental Restoration, and DOE's Office of Technology Development were exceptionally generous with their time and expertise.

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EXECUTIVE SUMMARY

1.1 Introduction

Over the next several decades, federal, state, and local governments and private industry will commit billions of dollars annually to clean up sites contaminated with hazardous waste and petroleum products. This commitment will result in a continuing demand for site remediation services and technologies. This report was prepared to aid those who are developing and commercializing new technologies to meet the future cleanup demand. It provides an overview of the market to help industry and government officials develop research, development, and marketing strategies.

This report updates and expands a 1993 analysis that brought together for the first time valuable information on site characteristics, market size, and other factors that affect the demand for remediation services.[a] As with the previous report, the focus of this study is on the potential future applications of remediation technologies. To provide a realistic estimate of expected contracting opportunities, the demand estimates are limited to remaining cleanup work and do not include projects that are underway or completed. While the report considers a broad range of remediation services required in the future, its purpose is to provide insight into the potential application of new treatment technologies.

The national cleanup market is comprised of the following seven segments:

- National Priorities List (Superfund)
- Resource Conservation and Recovery Act (RCRA) Corrective Action
- Underground Storage Tanks (UST)
- Department of Defense (DOD)
- Department of Energy (DOE)
- Other Federal Agencies
- States and Private Parties (including brownfields)

Most of the data used for this report are from federal databases and published sources. Some of these sources are current through fiscal years (FYs) 1994 and FY 1995, while others are current through FY 1996. Many sites are still undergoing investigation and engineering analyses, and data availability differs from one market segment to another. In addition to providing updates of data in the 1993 analysis, this report includes significant new information on cleanup needs related to RCRA corrective actions, and sites administered by DOD, DOE, and other federal agencies.

[a] U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Technology Innovation Office, *Cleaning Up the Nation's Waste Sites: Markets and Technology Trends*, EPA 542-R-92-012, April 1993.

1.2 Market Size

This section describes the estimated size of the market for contaminated site remediation services in terms of the "remaining" number of sites that require cleanup and the "remaining" cost of these cleanups. Sites where cleanup is completed or ongoing are excluded in this definition of the market. Under the current requirements of federal and state regulations, the remediation of over 217,000 sites in the seven market segments will cost about $187 billion, in 1996 dollars. The estimated time to complete most of these cleanup programs ranges from 10 to 30 years, while others, such as DOE, will take considerably longer. In addition, monitoring and groundwater treatment programs may continue for longer periods. Many of the sites to be remediated in the different programs contain similar types of contamination. In most programs, about two-thirds of the sites have contaminated soil or groundwater, or both, and contain volatile organic compounds (VOCs). Metals and semivolatile organic compounds (SVOCs) are most prevalent at Superfund and DOD sites, although they also are present at many of the sites in the other programs.

Over 217,000 contaminated sites in the U.S. still require remediation under current state and federal regulations.

The reliability of the estimates in this report differs from one market segment to another because of the availability of data, and because each of the seven programs is at a different stage of development. Some programs, such as Superfund, UST, and DOD, are well into the actual cleanup of contaminated properties. Other programs, such as DOE, have significant numbers of sites that are not yet fully characterized. In addition, definitions of basic terms such as "sites," "facilities," "installations," and "operable units" differ among the programs. Consideration of the narrative explanations and footnotes in the exhibits is necessary to fully understand the implications of the estimates.

1.2.1 Number of Sites

Almost half a million sites with potential contamination have been reported to state or federal authorities over the past 15 years. Of these, over 217,000 still require remediation (Exhibit 1-1). Almost 300,000 other sites were either cleaned up or were found to require no further action. Regulatory authorities have identified most of the contaminated sites. Nevertheless, new ones continue to be reported each year, but at a declining rate. The "estimated year of completion" shown in the exhibit is approximately the year in which almost all of the contamination will be remediated, according to current plans or agency estimates. The definitions of sites and facilities differ somewhat from one market segment to another. In this report, the term "site" is used to indicate an individual area of contamination, which can be small or large. The terms "facility" and "installation" identify an entire tract, including all contiguous land within the borders of a property. A "facility" may contain one or more contaminated areas or "sites." The status of the sites to be remediated in each market segment is discussed below.

Regulatory authorities have identified most hazardous waste sites.

Exhibit 1-1: Estimated Number of Sites to be Remediated

Market Segment	Sites Remaining to be Remediated	Estimated Year of Completion	Explanation
Superfund (NPL)	547	Not available	The number of sites includes non-federal proposed and final National Priorities List (NPL) sites that still required at least one further remedial action (RA), as of September 30, 1996. The NPL also includes 124 federally owned sites with future remedial actions planned. In addition to currently listed sites, EPA expects to add up to 30 sites to the NPL each year for the next several years.
RCRA, Corrective Action	3,000	2025	The number of sites represents the middle of a range of 2,600 to 3,700 from two EPA studies of all corrective action facilities that will require cleanup. The year of completion estimate is an assumption used by EPA in developing the cost estimates. It includes 30 years to complete construction. An estimated 128 years is required for monitoring and groundwater treatment. RCRA corrective action costs related to large federal facilities are included in the DOD, DOE, and civilian federal agencies market segments below.
RCRA, UST	165,000	Not available	The underground storage tank site cleanup market may be underestimated because sites where "cleanups are initiated" are not included, but some of these sites may not yet have designated cleanup contractors.
DOD	8,336	2015	The year of completion estimate is for the installation with the longest cleanup period.
DOE	10,500	2070	DOE has fully characterized about 46% of the sites, and may have completed the evaluation or cleanup of a few hundred sites. The year of completion estimate does not include cleaning up wastes for which no proven cleanup technology currently exists, such as contamination at nuclear test sites and much of the groundwater that needs to be remediated. The estimates also are based on the assumption that there will be a greater emphasis on containment than on treatment and other remediation strategies.
Civilian Federal Agencies	> 700	Varies	The number represents **number of facilities**, and a facility may contain one or more sites. The year of completion estimates vary among the agencies.
States	29,000	Varies	The number of sites represents sites needing attention, which may not all need remediation. The year of completion estimates vary among the states.
TOTAL	217,083		The total represents sites requiring cleanup, and excludes sites where cleanup work is ongoing or complete.

- The 547 non-federal NPL sites that require one or more future remedial actions (RAs) make up a relatively well-defined market for remedial technologies. These sites contain an estimated 33 million cubic yards of soil. The NPL also includes 124 federally owned sites with future RAs planned. These sites are included in the market estimates for federal agencies. EPA has recently implemented reforms designed to accelerate the assessment and cleanup of Superfund sites. Until the results of these reforms are evaluated, EPA cannot estimate when the remediation of currently listed and proposed NPL sites will be completed.

- EPA estimates that between 2,600 and 3,700 of the regulated hazardous waste treatment, storage, and disposal facilities (TSDFs) eventually will require remediation under the RCRA corrective action program. For this report, a middle value of 3,000 sites is used. The number of sites to require remediation is less than half of the approximately 6,200 TSDFs that currently operate or have operated. Although EPA has not estimated the time to complete this cleanup, it assumes that most of the construction would be completed by about 2025 and that monitoring and groundwater treatment could continue for 128 years.

- EPA estimates that at least 165,000 UST sites, containing at least 31 million cubic yards of soil and debris, require cleanup under the RCRA underground storage tank regulations. This estimate includes 65,000 confirmed releases that have not yet been cleaned up plus 100,000 projected releases. The estimate may understate the actual market because it does not include all sites without designated cleanup contractors. UST sites average an estimated 2.7 tanks per site, although the number varies widely from one site to another. Although USTs account for 76 percent of all future cleanup sites, they are typically the smallest and least costly to remediate.

Although USTs account for 76% of all cleanup sites, they are typically the smallest and least costly to remediate.

- DOD estimated that, as of September 1995, 8,336 sites on 1,561 installations will require remediation of contaminated materials. DOD has not yet selected contractors for most of these sites. The sites are distributed almost evenly among the Air Force, Army, Navy, and formerly used defense sites (FUDS). Of the 8,336 sites that need remediation, 3,705 (44 percent) are in six states: California, Alaska, Maryland, Florida, Texas, and Virginia. DOD estimates that all of these sites will be cleaned up by 2015. Of all DOD installations, including those where remedial action has begun, 130 are on the NPL. DOD has been placing greater emphasis on evaluating or cleaning up properties that are to be transferred to other government or private uses.

Federal and state agencies have increased their emphasis on cleaning up sites needed for the closure or reassignment of government facilities or economic development.

- DOE has identified about 10,500 contaminated sites at 137 installations and other locations that require some remediation, and the number may grow as assessment and characterization activities continue. Twenty-five DOE installations and other locations in 15 states are on the NPL. About 70 percent of the value of the remediation work is expected to be at five installations: Rocky Flats Environmental

Technology Site, Colorado; Idaho National Engineering Laboratory, Idaho; Savannah River Site, South Carolina; Oak Ridge Reservation, Tennessee; and Hanford Reservation, Washington. DOE expects to have all its sites cleaned up by 2070, although monitoring and groundwater treatment programs may continue beyond that period.

- As of April 1995, over 700 facilities, distributed among 17 civilian federal agencies (non-DOD and non-DOE), were potentially in need of remediation. The term "facility" identifies an entire tract, including all contiguous land, that is the responsibility of the subject agency. A facility may contain one or more contaminated areas or "sites." Because investigations of many of these facilities are not complete, the exact number of facilities and sites to be remediated has yet to be determined and reported to EPA. The Department of Interior (DOI), Department of Agriculture (USDA), and National Aeronautics and Space Administration (NASA) together account for about 70 percent of the civilian federal facilities that potentially need remediation. The estimated year of completion varies from one agency to another, with the longest period, 50 years, reported by the Department of Agriculture.

Interest has grown in the redevelopment of brownfield sites. EPA has awarded grants for 76 projects, as of October 1996.

- Based on data provided by the states in 1995, EPA has estimated that about 29,000 sites listed in state files require some action beyond a preliminary assessment. However, the actual number of sites that will need remediation and the extent of contamination at these sites is largely unknown, since some of these data are derived from preliminary assessments. In addition, the U.S. General Accounting Office (GAO) estimated that there are between 130,000 and 450,000 "brownfield" sites, although the number that will require remediation is unknown. Brownfields are abandoned, idle, or under-used industrial and commercial facilities where real or perceived environmental contamination may be hampering expansion or redevelopment. The cleanup of most of these sites will be the responsibility of the property owners. Recently, interest in the redevelopment of potentially contaminated sites has grown. As of October 1996, EPA had awarded grants to support the evaluation and cleanup of 76 brownfield sites and plans to award additional grants in 1997.

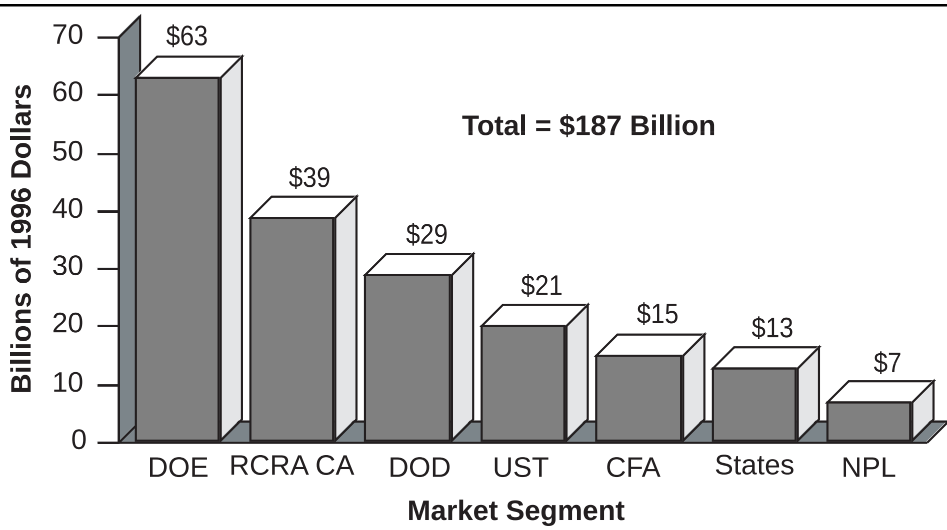
1.2.2 Estimated Cleanup Costs

Under current regulations and cleanup goals, the cleanup of all known sites will cost $187 billion, in 1996 dollars, and will take at least several decades to complete.

The estimated cost for all future work to clean up the 217,000 sites is about $187 billion, in 1996 dollars (Exhibit 1-2). Because this estimate does not include inflation for future years, the amount expended probably will be higher than $187 billion. This estimate represents the midpoint of a range that results from uncertainty regarding the extent and type of contamination at many sites, and the kind of cleanup methods that will be used.

Although most of the activities underlying this cost estimate are for remedial action, they also include some site assessment and administrative work where costs are not reported separately. As a cleanup program matures, a greater portion of the funding shifts from site assessment and investigation to actual cleanup.

Exhibit 1-2: Estimated Remaining Remediation Cost in 1996 Dollars



Notes:

- Because these costs do not include inflation over the life of the cleanup programs, actual expenditures ultimately will be greater.
- These estimates are based on assumptions and rationale explained in the text.
- Cost for remedial action at NPL sites does not include: federal facilities, site assessments and studies, designs, operations and maintenance, long-term response actions, removals, site management, administrative costs (*e.g.*, payrolls), other federal agency support (*e.g.*, ATSDR, NIEHS), oversight of PRP-lead cleanups, and enforcement activities.
- Environmental restoration accounts for 28% of the $227 billion life-cycle cost DOE has estimated for all environmental management activities at its facilities. The other 72% of the costs are for activities listed in footnote b of the text.

The cost estimate for each market segment is explained below:

- The future remedial action cost for currently listed and proposed NPL sites not owned by the federal government (non-federal) from the end of FY 1997 onward, is estimated to be $6.7 billion. This estimate is based on an estimated average cost of $10 million per Fund-lead remedial action and $8.5 million for private party-lead sites. About 70 percent of site cleanups are the responsibility of private parties. The NPL site cost estimate does not include costs for site assessments and studies, designs, operation and maintenance, long-term response actions, removals, site management, administrative costs such as payrolls, other federal agency support, oversight of potentially responsible party (PRP)-lead cleanups, and enforcement activities. The estimated costs of cleaning up federal facility NPL sites are included under the other market segments below.

- Under current regulations, the cost of corrective action for soil and groundwater for RCRA characteristic or listed waste will be $38.8 billion, or an average of $14.9 million per facility, 1996 dollars. This cost estimate is based on a regulatory impact analysis (RIA) prepared in 1993. Approximately 89 percent of this amount will be incurred by privately-owned facilities and the remaining 11 percent by federal facilities. This estimate does not include costs for the very large DOD and DOE facilities. However, since it includes costs for some smaller ones, there is some overlap with the costs estimated for DOD and DOE below. Roughly half of the total cost of corrective action will be incurred by slightly more than 10 percent of the facilities that require cleanup. The program life-cycle-costs are likely to be lower under regulations now being developed than were estimated in the 1993 RIA, because implementation of the corrective action program has been shifting toward more risk-based cleanups. In addition, program costs in the near term will likely be lower than previously estimated, because of the emphasis on initial efforts to stabilize the site.

- The remaining UST cleanup market could reach $20.6 billion, or an average of $125,000 per UST site. This estimate does not include costs related to replacing, testing, or upgrading tanks, pipes, and related equipment. Previous studies indicate that the remediation portion of the cost to clean up one UST site ranges from $2,000 to over $400,000.

- DOD estimates that the cost of completing the remaining remediation work at all DOD sites from FY 1997 onward will be over $28.6 billion, or over $3.4 million per site, distributed as follows: Army $10.6 billion; Air Force $7.4 billion; Navy $5.6 billion; Defense Logistics Agency (DLA) $0.4 billion; Defense Nuclear Agency $0.1 billion; and FUDS $4.5 billion. While most past DOD expenditures for restoration have gone for site investigation and analysis, most future funds will be used for cleanup. DOD's cleanup budget for FY 1997 is $2.1 billion.

DOE and DOD, combined, account for one-half of the total cleanup market.

- DOE estimates that environmental restoration of its properties will cost $63 billion and take about 75 years.[b] The estimates do not include the cost of cleaning up wastes for which no proven cleanup technology currently exists, such as wastes at nuclear test sites and much of the groundwater contamination the agency is responsible for addressing. The estimates also are based on the assumption that there will be greater emphasis on containment than on treatment and other remediation strategies. Seventy percent of the total estimated cost of environmental management activities over the 75-year period will be expended at the five major installations listed in the previous section. These costs include those for all environmental restoration required under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), RCRA, other federal statutes, and state laws. DOE's FY 1997 restoration budget is $2.1 billion, and is expected decline gradually until the program is substantially complete in 2070.

- The $15 billion estimated cost for the cleanup of about 700 civilian federal facilities is based on an extrapolation of life-cycle-costs

[b] Environmental restoration accounts for 28 percent of the $227 billion life-cycle-cost DOE has estimated for all environmental management activities at its facilities. The other 72% of DOE's environmental management costs are for the following types of activities: waste management, nuclear material and facility stabilization, national program planning and management, landlord activities, and technology development.

estimated by DOI, USDA, and NASA, which together account for about 500 facilities. The estimate is a midpoint of a range of estimates, and includes both administrative and remediation costs. Most of these federal facilities are still being assessed and have not yet progressed to the site remediation stage. The ultimate level and timing of these expenditures will depend upon the availability of resources and technologies. Some agencies may take 50 years or more to complete the cleanup of all their hazardous waste sites. The transfer of public properties to private use may require agencies to reallocate resources to clean up properties designated for transfer. As of December 1996, budget data for FY 1996 and FY 1997 were available for 14 civilian federal agencies. These 14 agencies reported spending a total of $317 million for cleanup activities in FY 1996, and estimated their combined 1997 budgetary needs to be approximately $288 million.

- The cost of state remediation programs is uncertain because of a lack of data and the diverse nature of the various state programs. Based on 1995 annual expenditure data for 37 states, EPA estimates that these states and private parties in these states spent a combined $418 million annually for non-NPL site cleanups under state programs, in 1996 dollars. At this rate, these expenditures will total $12.5 billion through 2025. Estimates for the remaining 13 states are not available. The level of these expenditures also is dependent upon the funds available in state cleanup trust funds or other mechanisms used to pay for cleanup activities at non-NPL sites. As of the end of FY 1995, state fund balances totaled $1.5 billion. These values indicate that states have the capability to continue their current level of expenditures. Based on a survey of state officials published in 1994, about half of the cleanup expenditures for non-NPL and non-RCRA sites between 1980 and 1992 were paid by responsible parties.

1.3 Site Characteristics

The selection of remedies at contaminated sites depends largely on the types of media and contaminants present. This section describes the types of contaminants and media that are to be remediated in the various market segments.

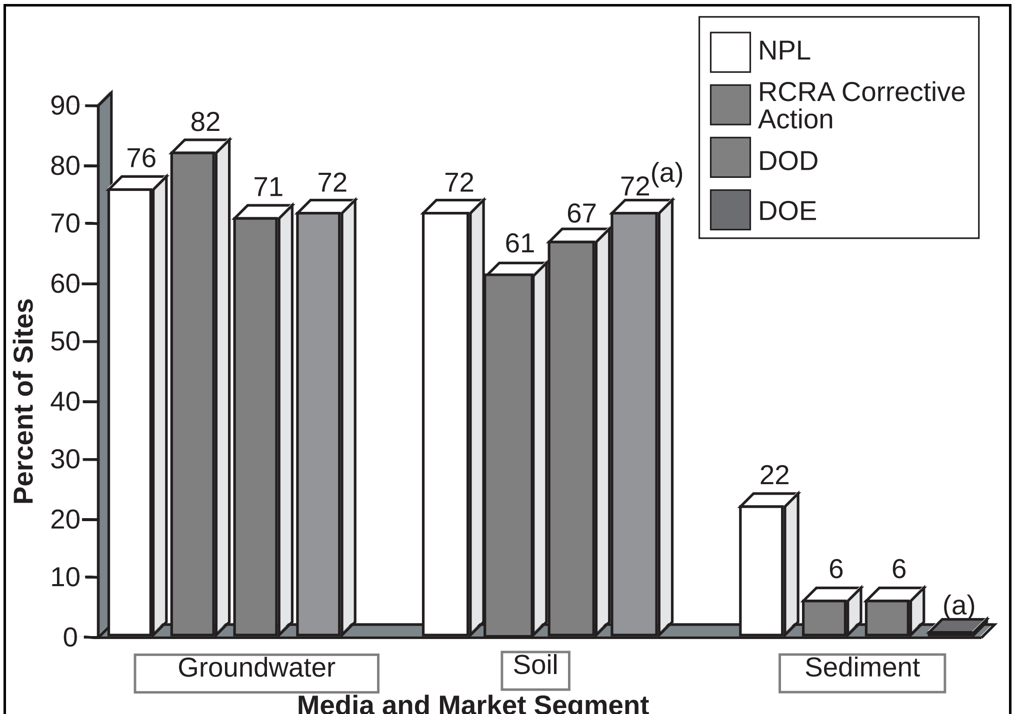
The data used to develop these estimates vary widely among the market segments. The Superfund (NPL) data are available from the Records of Decision (RODs) for over 900 sites. The characteristics of these sites are assumed to be representative of all NPL sites, including those needing further remediation. The DOD media and contaminant data are based on information from over 3,000 of about 9,000 sites to be remediated as of September 30, 1994. The RCRA estimates are based on data from fewer than 300 of the estimated 3,000 sites to be remediated. Although the DOE estimates are based on data from all 137 installations, the data do not include information from all 10,500 sites at these installations and other properties.

1.3.1 Media

Groundwater and soil are the most prevalent contaminated media. In addition, large quantities of other contaminated material, such as sediments, landfill waste, and slag, are present at many sites. Exhibit 1-3 shows the most common contaminated media for each market segment. About 70 percent of NPL, RCRA, DOD and DOE sites have contaminated soil or groundwater, or both. Contaminated sediment, sludge, and surface water also are present, but at fewer sites. Soil and groundwater also are a primary concern for UST sites.

About 70 percent of Superfund, RCRA, DOD, and DOE sites have contaminated soil or groundwater, or both. Contaminated sediment, sludge, and surface water also are present, but at fewer sites.

Exhibit 1-3: Media to be Remediated



Notes:
- [a]DOE soil percentages also include sediment and sludge data.
- 12% of NPL sites contain contaminated sludge; 11% of the surveyed RCRA sites contain contaminated sludge, and 10% contain contaminated surface water; 9% of the DOE sites contain contaminated surface water; and about half of the DOE installations contain contaminated rubble and debris.
- The datasets from which these percentages are estimated are explained in the text.

1.3.2 Contaminants

Many contamination problems and, therefore, technology needs are similar across the major remediation programs. The contaminant groups that are common to most programs are solvents, petroleum products, and metals. Some markets also have more specialized needs arising from wastes that are unique to a particular industrial practice. For example, DOE has a need for technologies to characterize, treat, and dispose of mixed waste; remediate radioactive tank waste; stabilize landfills; and deactivate facilities. DOD is concerned with remediating soils contaminated with explosives and unexploded ordnance.

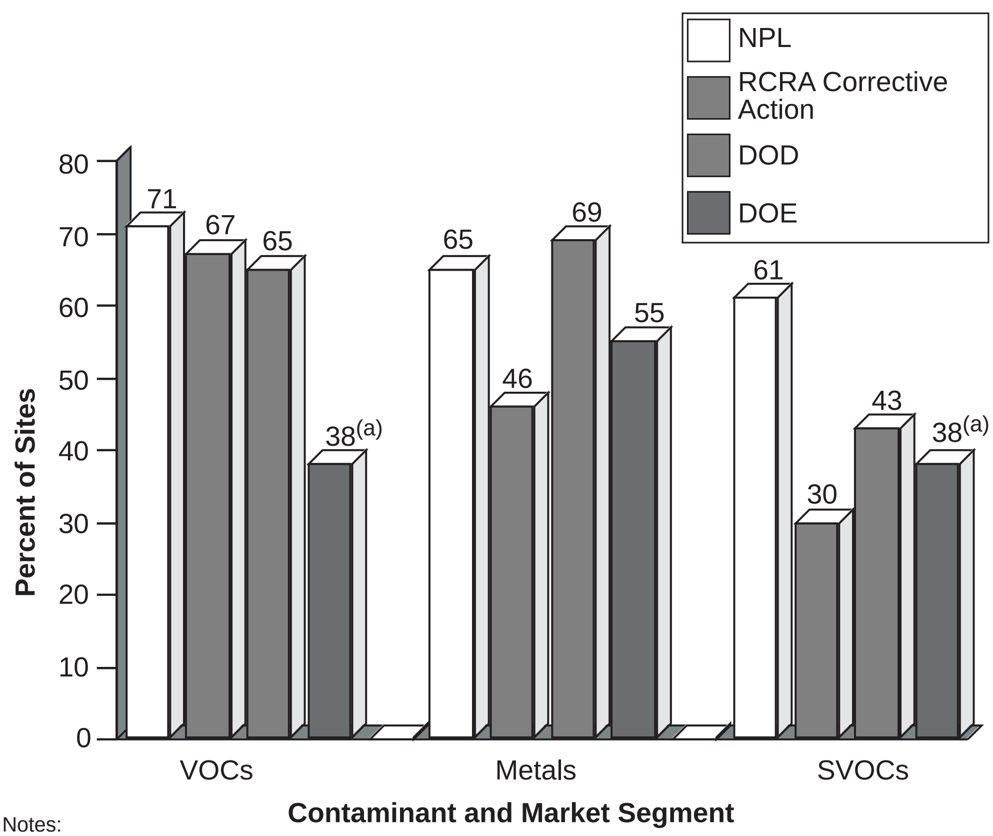
Exhibit 1-4 shows the frequency of occurrence of the most prevalent contaminant groups. VOCs, the most frequently occurring contaminant type, are present at more than two-thirds of Superfund, RCRA, and DOD sites, and almost half of the DOE sites.

VOCs, the most frequently occurring contaminant type, are present at more than two-thirds of Superfund, RCRA, and DOD sites, and almost half of the DOE installations. VOCs (BTEX) also are the primary contaminants at UST sites.

VOCs, primarily in the form of BTEX (benzene, toluene, ethylbenzene, and xylene) also are the primary contaminants at UST sites. Large numbers of sites to be remediated by other federal agencies and states also are believed to contain VOCs, but only sparse data for these programs are available.

Metals are prevalent in almost all of the major market sectors. Metals, not including radioactive metals, are present at more than two-thirds of the Superfund and DOD sites, and about half of the RCRA and DOE sites. They also are likely to be found in the other market segments. Of the 10 contaminants most frequently found at Superfund and DOD sites, more than half are metals, primarily lead, cadmium, zinc, nickel, chromium, and arsenic.

Exhibit 1-4: Contaminants to be Remediated



Notes:

- (a)DOE figures for VOCs and SVOCs are combined.
- 22% of the DOD sites contain fuels, 8% explosives, and 1% radioactive contaminants; 90% of the DOE installations contain radioactive elements.
- The datasets from which these percentages are estimated are explained in the text.

Almost all of the market sectors have substantial numbers of sites with metals and VOCs.

The contamination characteristics of each market segment are discussed below.

- For NPL sites VOCs is the most common contaminant group remediated, followed by metals, and SVOCs. Most sites require remediation for more than one of these contaminant groups: 25 percent of the sites contain two contaminant groups and 41 percent contain all three. These contaminants are not necessarily in the same contaminated material. Halogenated VOCs are by far the most common subgroup of organic contaminants, followed by pesticides, polynuclear aromatic hydrocarbons (PAHs) non-halogenated VOCs, polychlorinated biphenyls (PCBs), and phenols. The most common metal cleaned up at NPL sites is lead, followed by chromium, arsenic, and cadmium. NPL data are based on contaminants for which remedies have been selected in the past.

- The most common contaminant groups at RCRA sites are: halogenated VOCs, found at 60 percent of sites; metals, found at 46 percent of sites; and non-halogenated VOCs, found at 32 percent of sites. These estimates are based on two separate studies that used data from fewer than nine percent of all the likely corrective action projects.

- Approximately 96 percent of USTs contain petroleum products and about one percent contain hazardous materials. For USTs containing petroleum products, gasoline accounts for 66 percent and diesel fuel for 21 percent. The most likely constituents of these products that are of concern are BTEX and SVOCs, such as PAHs, creosols, and phenols.

Eight percent of the DOD sites with available data contain explosives and one percent contain radioactive contaminants. In addition, information from some installations indicates that the presence of unexploded ordnance may be significantly greater than these percentages indicate.

- Based on information on 34 percent of the over 9,000 DOD sites that needed remediation as of September 1994, metals are found at 69 percent of the sites, followed by VOCs at 65 percent of the sites, and SVOCs at 43 percent of the sites. Although many similar contaminants also are frequently found at non-defense related sites, some DOD sites contain contaminants that present unique problems for selecting remediation approaches. For example, about eight percent of the over 3,000 DOD sites with available data contain explosives, and about one percent contain radioactive contaminants. The most frequently found specific contaminants in all media are lead, zinc, barium, nickel, cadmium, and copper. The most common organic chemicals are trichloroethylene (TCE) and benzene. In addition, information from some DOD installations indicates that the presence of unexploded ordnance may be significantly larger than the above available information indicates. DOD currently is investigating the potential extent of unexploded ordnance contamination.

- Site assessment and characterization are still in progress at 86 DOE installations and other locations. Although information about the extent of contamination at these installations is incomplete, DOE has made substantial progress in identifying specific contaminants of concern. Radioactive contaminants are found at 90 percent of the installations and include uranium, tritium, thorium, and plutonium. The most frequently present non-radioactive metals, which are found at 55 percent of the installations, include lead, beryllium, mercury, arsenic, and chromium. Organic chemicals are found at 38 percent of DOE installations and include PCBs, hydrocarbons from fuel and other petroleum products, and TCE. Mixed waste, containing radioactive and hazardous contaminants, also is a problem at many installations. The available data do not indicate if a specific contaminant has been identified at only one site or at more than one site on an installation.

Radioactive contaminants are found at 90 percent of the DOE installations and non-radioactive metals are found at 55 percent.

- Waste at civilian federal agency and state sites is typical of industrial facilities and include organic chemicals, metals, and solvents. However, no national compilation of the specific contaminants at these sites is available.

Technologies

Site characteristics, technology development efforts, and trends in remedial technology use for Superfund sites provide some indication of future technology demands. This section describes the historical use of specific technologies; active technology development programs that have identified and begun to address specific technology gaps; and the outlook for the use of technologies.

In the Superfund program, the selection of treatment has been declining for the past two years, while containment-only remedies have increased. In the UST program, the use of *in situ* technologies has been increasing. Some innovative technologies, primarily soil vapor extraction, thermal desorption, and bioremediation, now are more routinely used.

Technology development programs have become significantly more focussed and, in the next few years, may introduce new or improved methods in the high-demand areas of *in situ* soil and groundwater treatment, biotechnology, and metals treatment.

1.3.3 History and Outlook for Technology Applications

General Trends

The most comprehensive information on technology use at waste sites is available for the Superfund program. Although Superfund sites represent a small percentage of all contaminated sites, experience with technology applications at these sites is likely to influence technology selection in the other market segments.

With the enactment of the 1986 amendments to CERCLA, remedies selected in RODs that address the source of contamination (primarily contaminated soil, sludge, and sediment) shifted away from containment towards treatment to reduce the toxicity, mobility, or volume of a waste. Between FY 1988 and FY 1993, some treatment for part of the site was selected for almost three-quarters of these source control RODs (source control RODs account for about two-thirds of all RODs).

Although the use of containment-only remedies at Superfund sites has recently increased, treatment remedies are still more common.

In FY 1994 and FY 1995, treatment declined to 59 percent and 53 percent of the sites, respectively (Exhibit 1-5). Containment-only remedies (capping and landfilling) at these sites increased to 36 percent and 41 percent, respectively. The shifts in the distribution of remedies selected may be explained, in part, by an increase in the number of remedies selected for landfills. The concurrent drop in the selection of solidification / stabilization remedies suggests that, in some cases, containment may be replacing this technology as a remedy for metals in soil.

The selection frequencies for 11 types of source control treatment technologies are illustrated in Exhibit 1-6. Solidification / stabilization (also called "fixation" and "immobilization") has been the most common technology to treat soil and other wastes. It has been the favored technology to treat metal-containing waste, although its selection has declined in the last two years. Relatively few alternative technologies have been selected for metals. In some cases, solidification / stabilization is selected to treat organic contaminants, primarily SVOCs.

Incineration has been the second most frequently selected of any technology for treating soil, sludge, and sediment in Superfund. The major advantage of incineration is its ability to achieve stringent cleanup standards for highly concentrated mixtures. The selection of on-site incineration has declined to less than four percent of source control technologies selected from FY 1993 through 1995, primarily because of its cost and a lack of public acceptance. Off-site incineration, the use of which also has dropped, is feasible for only relatively small waste quantities.

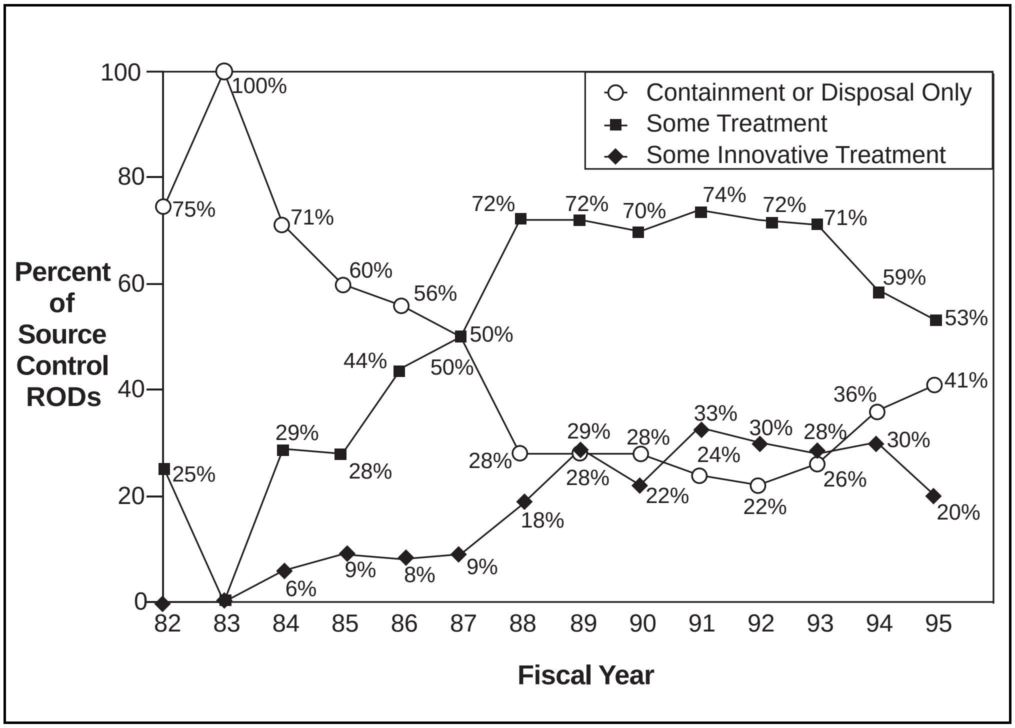
New Technologies

New technologies offer the potential to be more cost-effective than conventional approaches. *In situ* technologies, in particular, are in large demand because they are usually less expensive and more acceptable than above-ground options. For example, state UST program managers report significant increases in the use of *in situ* processes, especially bioremediation, which is effective because of the inherent biodegradability of petroleum hydrocarbons. New technology development programs (Section 1.5.2) include efforts to help meet this demand by emphasizing *in situ* technologies, in particular bioremediation and enhancements to soil vapor extraction (SVE).

SVE has become the preferred technology for both chlorinated and nonchlorinated VOCs in soil.

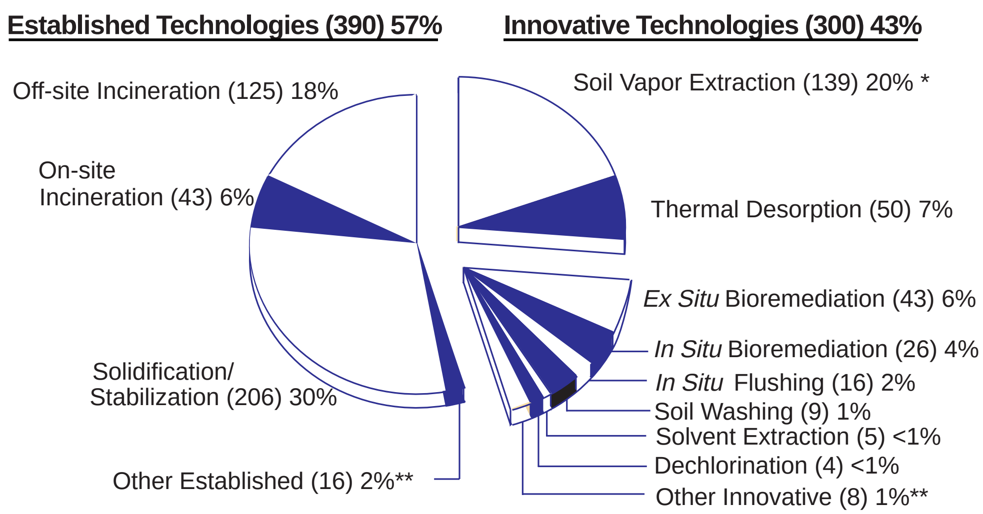
SVE is a flexible *in situ* process that has become much less costly than competing *ex situ* methods. SVE has become the preferred technology for both chlorinated and nonchlorinated VOCs in soil. While the selection of SVE for Superfund sites had recently decreased, its applicability may expand as a result of ongoing efforts to develop enhancements, such as

Exhibit 1-5: Treatment and Disposal Decisions for Source Control at NPL Sites



Although the use of SVE, bioremediation, and thermal desorption at NPL sites has leveled off, these technologies have potential for the other market segments.

Exhibit 1-6: Source Control Technologies Selected for NPL Sites Through FY 1995



Notes:

* Includes two dual-phase extraction projects also listed as *in situ* groundwater technologies.

** "Other" established technologies: soil aeration, open detonation, and chemical neutralization. "Other" innovative technologies: physical separation, contained recovery of oily wastes (CROW™), cyanide oxidation, vitrification, hot air injection, and plasma high-temperature metals recovery.

methods to increase soil permeability or contaminant volatility. Examples of some enhanced applications include bioventing, directional drilling, and thermal processes. Also, because the other market segments contain VOCs, they may represent a significant market for SVE.

Bioremediation is one of the few alternatives to incineration for actually destroying organic contaminants. The selection of this technology for Superfund sites has remained relatively constant in recent years. Industry and government environmental officials have expressed a strong interest in continuing the development of biotechnology. A large number of laboratory and field tests are under way on the use of bioremediation to degrade commonly occurring chlorinated organics such as TCE and vinyl chloride.

The selection of thermal desorption also has remained relatively constant over the past several years. Applications for thermal desorption include soil contaminated with VOCs (particularly when SVE is not feasible), SVOCs (particularly PCBs and PAHs), and potentially for soils containing both metals and organics. Because other market segments have similar contamination problems, bioremediation and thermal desorption are likely to have applications outside the Superfund program.

Although metals are common at waste sites, treatment alternatives are limited. More effective technologies are needed to treat metals in soil.

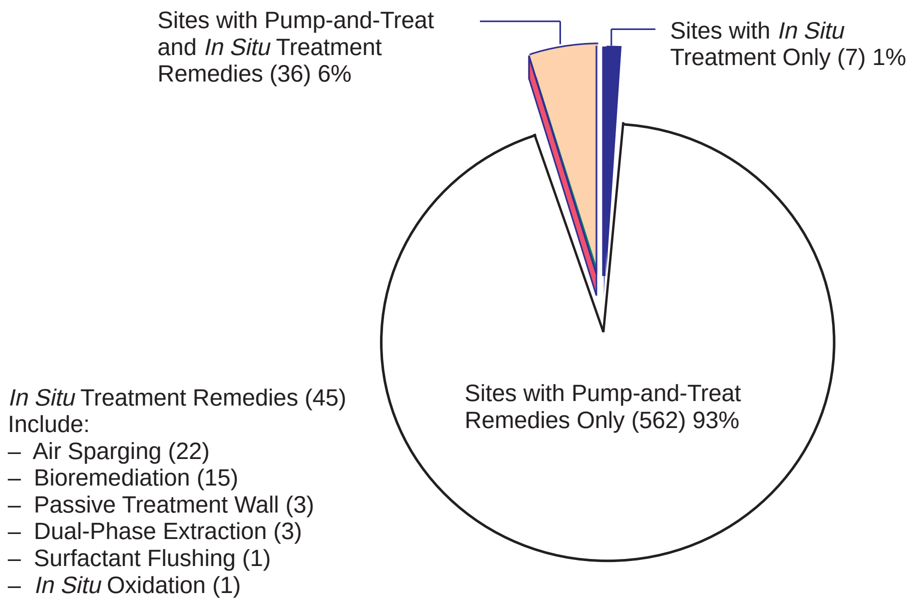
Although metals are common at sites in most of the market segments, alternatives to treat metals are limited. Government and corporate owners of contaminated sites have targeted several technologies to treat metals in soil for further development, including electrokinetics and phytoremediation. Although solidification/stabilization has been the most widely used technology to treat metals, its use in the Superfund program has dropped. The decline in the selection of this technology may signal an opportunity for more cost-effective treatment alternatives.

If more effective in situ *groundwater technologies were available, a larger portion of contaminated groundwater sites could be fully remediated.*

Groundwater is contaminated at more than 70 percent of the sites in most of the market segments. However, not all of these sites will be actively remediated. Available technology cannot always meet the desired cleanup goals for a site, because the methods leave residual aquifer contamination, known as non-aqueous phase liquids (NAPLs). The most frequently used method for groundwater remediation at Superfund sites is conventional pump-and-treat technology, which has been selected for 98 percent of the over 600 NPL sites where groundwater is to be treated (Exhibit 1-7). The goal of many of these cleanups is to restore the aquifer to beneficial use. Other projects are designed to keep the contamination from spreading. *In situ* treatment technologies, primarily bioremediation and air sparging, have been selected at only six percent of Superfund groundwater treatment sites, most of which also are using pump-and-treat. New management approaches recently receiving more attention include treatment walls and selective application of natural attenuation. If more effective *in situ* groundwater technologies were available, a larger portion of contaminated groundwater sites could be fully remediated.

Comprehensive data on remedy use for UST sites have been compiled from the responses of state officials to a written survey. Although the respondents were asked only to provide estimates, without necessarily

Exhibit 1-7: Groundwater Treatment Remedies at NPL Sites Through FY 1995



Note:
- Does not include groundwater sites with nontreatment remedies (*i.e.*, monitoring, institutional controls, alternate water supply, well-head treatment, closing wells, containment, or natural attenuation).

The use of in situ *processes at UST sites has been rapidly increasing. More biological processes are used for UST sites than for the other market segments.*

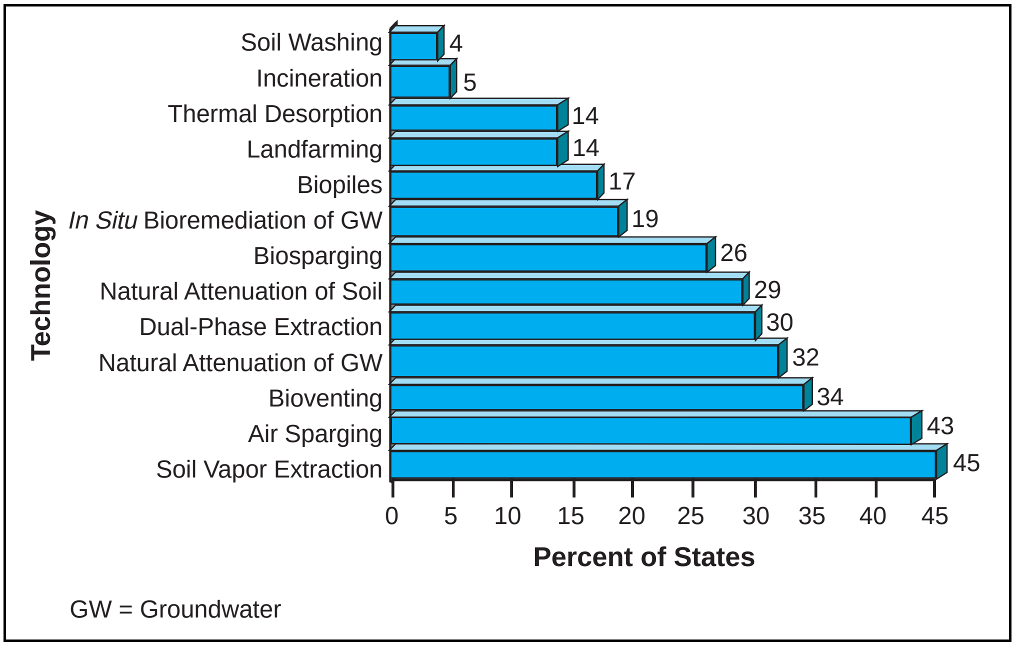
conducting rigorous file searches, the information is extensive, reflecting responses from 49 states. For UST sites undergoing remediation of soil at the time of the survey, the remedial methods used were: landfilling (34 percent of sites), natural attenuation (28 percent), biopiles (16 percent), SVE (9 percent), landfarming (7 percent), thermal desorption (3 percent), incineration (2 percent), bioventing (0.8 percent), and soil washing (0.2 percent). For sites with groundwater contamination, the most commonly used methods were natural attenuation (47 percent), pump-and-treat (29 percent), air sparging (13 percent), *in situ* bioremediation (5 percent), dual-phase extraction (5 percent), and biosparging (2 percent).

Although many of these percentages appear low, this market segment includes a substantial number of sites, since over 165,000 UST sites will require cleanup in the future. Moreover, the relative usage levels for many of these technologies have increased substantially over the years prior to the survey. According to the survey respondents, the use of *in situ* processes increased significantly from 1993 to 1995 (Exhibit 1-8). The UST program technologies include more biological processes due to the inherent biodegradability of petroleum hydrocarbons.

1.3.4 Technology Development Efforts

Future technology use will be influenced by current and planned technology development efforts and the expressed needs of industry and other entities with responsibility for site cleanups. Federal agencies

Exhibit 1-8: Percent of States With Increased Use of Treatment Technologies at UST Sites: 1993 to 1995



currently are coordinating several technology development and commercialization programs. Of these, two cooperative public-private initiatives are particularly noteworthy because they focus on processes that private "problem holders" view as most promising for the future. The involvement of technology users helps to assure that the processes selected for development reflect actual needs and have a high potential for future application. The technologies identified by these programs and federal agencies provide a useful overview of future trends (Exhibit 1-9).

Government and private organizations have developed formal programs to cooperatively ensure that technology development efforts are directly related to cleanup needs.

The Remediation Technologies Development Forum (RTDF) is a consortium of partners from industry, government agencies, and academia, who share the common goal of developing more effective, less costly hazardous waste characterization and treatment technologies. RTDF achieves this goal by identifying high priority needs for remediation technology development. For each need, RTDF organizes an Action Team, comprised of organizations who share that interest, to plan and conduct collaborative laboratory and field research and development. Although federal agencies provide in-kind contributions and funding, the formation of teams is driven by the organizations responsible for site cleanups. Five Action Teams have been established to date.

Through the Clean Sites Public-Private Partnerships for technology acceptance, EPA and Clean Sites, Inc., a nonprofit firm, develop partnerships between federal agencies (such as DOD and DOE) and private site owners (responsible parties, owners/operators) for the joint evaluation of full-scale remediation technologies. The purpose of this program is to create a demand among potential users of new technologies by allowing

Exhibit 1-9: Examples of Technology Needs Identified by Users in Selected Federal Programs

Medium	Clean Sites Public-Private Partnerships	Remediation Technologies Development Forum	Department of Energy
In Situ Management of Soils	· Lasagna™ (electroosmosis, hydrofracturing treatment zones)	· Lasagna™ · Co-metabolic bioventing · Phytoremediation for metals	· Electrokinetics · Vitrification
In Situ Management of Groundwater	· Anaerobic bioremediation · Permeable treatment walls · Air sparging	· Accelerated anaerobic bioremediation · Permeable treatment walls · Intrinsic bioremediation	· Recirculating wells · Microbial filters · Bioremediation · Biosorption of uranium
In Situ Management of Soil and Groundwater	· Rotary steam drilling · Dual-phase extraction	· Not applicable	· Dynamic underground stripping
Ex Situ Management of Soil	· Enhanced bioslurry reactors	· Not applicable	· Innovative soil washing
Ex Situ Management of Groundwater	· Membrane separation	· Not applicable	· Not applicable

the end-users of the technologies to be involved throughout the demonstration process. Typically, Clean Sites, with the assistance of federal agencies, identifies and characterizes a candidate federal facility, solicits industry participation, and brings together the facility and private companies. Based on common problems identified by these partners, the host facility arranges for the procurement of technologies for demonstration. The partners develop evaluation plans and conduct the demonstrations. Currently, there are six evaluation projects in this program.

A recent DOE report enumerated 15 new technologies, scheduled to be available by the year 2000, that may potentially lead to cost savings in cleaning up DOE sites. These technologies are specific examples of the types of technologies that DOE expects to need in the near future, such as bioremediation, electrokinetics, and biosorption of uranium.

Prospective technology users are interested in applying in situ *processes for future cleanups, because they are cheaper, more acceptable to the public, and pose lower risk to workers.*

The technologies selected for development in these three programs demonstrate that prospective users are interested in using *in situ* processes and biotechnology to meet their future needs (Exhibit 1-9). Various biological methods often are cited, especially for chlorinated solvents. Several technologies rely on SVE as a component, including dual-phase extraction, air sparging, dynamic underground stripping, and rotary steam drilling. Also, several processes entail the creation of treatment zones (permeable barriers, microbial filters, and the Lasagna™ process) and the use of electric fields to mobilize both organics and inorganics.

DOD also has been active in developing and commercializing technologies. DOD's high priority cleanup technology needs include: detection, monitoring and modeling (primarily related to unexploded ordnance

[UXO] and DNAPLS); treatment for soil, sediment, and sludge (primarily related to UXO, white phosphorous contaminated sediments, inorganics, explosives in soil, explosives / organic contaminants in sediments); groundwater treatment (explosives, solvents, organics, alternatives to pump-and-treat, and DNAPLS); and removal of UXO on land and under water.

1.4 Cleanup Program Status and Factors Affecting Demand

The demand for remediation services is driven largely by federal and state requirements and public and private expenditures. Changes in these conditions will affect each of the seven market segments in a different way, since each market has its own priorities and operating procedures. Thus, successful planning for technology development and marketing of remediation services should include consideration of the program structure, requirements, and site characteristics of the specific market sectors as well as the shifting requirements and budgets. For example, both government and industry are showing an interest in using risk assessment to determine cleanup priorities, as may be done under the Risk Based Corrective Action initiative in the UST program. Similarly, cleanup program decision-making may become more dependent upon exposure assessments that consider future land use and bioavailability. The most prevalent factors that could alter the scope of the cleanup effort, as well as the technologies to be used in each market, are described below.

1.4.1 Superfund Sites

Superfund is now facing reauthorization, and budgetary and regulatory changes are likely to affect the extent and types of cleanup actions.

The Superfund program is the federal program to clean up releases of hazardous substances at abandoned or uncontrolled hazardous waste sites. Superfund is administered by EPA and the states under the authority of the CERCLA. The procedures for implementing the provisions of CERCLA substantially affect those used by other federal and state cleanup programs. These procedures are spelled out in the National Oil and Hazardous Substances Pollution Contingency Plan, commonly referred to as the National Contingency Plan (NCP). The NCP outlines the steps that EPA and other federal agencies must follow in responding to “releases” of hazardous substances or oil into the environment. Although the terminology may differ from one market segment to another, each follows a process more-or-less similar to this one. Thus, in addition to comprising a defined market segment, activities in the Superfund program substantially influence the implementation of the other market segments.

The Superfund Amendments and Reauthorization Act of 1986 (SARA) made important changes to the Superfund program that are of particular importance to technology vendors. These changes stressed the importance of permanent remedies and support the use of new, unproven treatment technologies. Superfund is facing reauthorization again, and it is likely that budgetary and regulatory changes will occur during the next few years. Some of the Superfund program changes that have been proposed in Congress could significantly impact the markets for remediation technologies. For example, proposed modifications would require greater consideration of land use in setting cleanup standards, emphasize the treatment and disposal of only the highly contaminated and highly mobile media, limit the addition of new sites to the NPL, and change the liability aspect of CERCLA to reduce the cost and time needed to assign the liability for a cleanup project. Some of these changes are already being implemented, to some extent, under EPA administrative reforms.

In the past four years, the number of Superfund sites that have progressed from study and evaluation to actual cleanup has risen steadily. Thus, a greater portion of the effort is going to the actual cleanup of sites as compared to study and evaluation. Over its 17 year history, the primary responsibility for construction contracting at NPL site cleanups has shifted from EPA to responsible parties. In the past few years, 70 percent of remedial action starts (*i.e.*, actual cleanup activities) have been implemented by responsible parties with EPA or state oversight.

1.4.2 RCRA Corrective Action Sites

The remediation of RCRA "characteristic" or listed waste is addressed under the RCRA corrective action program, which is administered by EPA and authorized states. The current program strategy stresses stabilizing contaminated media to prevent the further spread of contamination before long-term cleanups can be undertaken, and developing priorities for directing resources to the highest priority facilities. High-priority facilities are the main focus of EPA's program to stabilize contaminated media because of their perceived risk to human health and the environment.

The demand for remediation of RCRA corrective action sites is likely to be influenced by a major rulemaking and forthcoming reauthorization.

The demand for remediation of RCRA corrective action sites is likely to be influenced by a new rulemaking called the *Hazardous Waste Identification Rule for Contaminated Media* (HWIR-Media), which was proposed on April 29, 1996. This proposed rule would modify the RCRA Subtitle C management requirements that apply to hazardous remediation wastes generated as a part of government-overseen cleanups (such as RCRA corrective action, Superfund, and cleanup under other state programs). The proposal addressed a number of issues such as: exempting remediation wastes from certain Subtitle C management requirements; modifying land disposal restrictions; streamlining requirements for cleanup permits (including exempting cleanup-only permits from the requirement for facility-wide corrective action); and streamlining state authorization. EPA expects that the final HWIR-Media rule will be an essential complement to the final RCRA Subpart S corrective action regulations.

As part of the President's initiative for reinventing environmental regulations, the Administration has, with input from interested parties, identified potential legislative amendments to provide appropriate relief for high-cost, low-benefit RCRA provisions. The administration believes any reforms to RCRA should proceed separately from CERCLA reauthorization. A key area identified for potential reform is the application of RCRA Subtitle C to remediation wastes.

1.4.3 Underground Storage Tank Sites

Contamination resulting from leaks and spills from underground storage tanks (USTs) are addressed primarily by the tank owners under state UST programs established pursuant to Subtitle I of the 1984 Hazardous and Solid Waste Amendments to RCRA. This law has compelled cleanup activities at many UST sites, providing opportunities for the application of a variety of remedial technologies. It is expected that cleanup activities will increase as a result of the December 1998 deadline for upgrading tanks for corrosion protection.

Because the program is primarily implemented by the states, funding and programmatic considerations at the state level determine the extent and timing of the remediation. All states and territories have passed legislation for UST cleanups, and 45 have state trust funds. Some states have more active enforcement programs than others and some have promulgated UST requirements that are more stringent than the federal standards, such as a requirement for double-lined tanks, more stringent monitoring procedures, or earlier upgrading compliance dates. Although such requirements may increase the magnitude of the remediation work or change its timing, the requirements of specific states were not included in the estimates of market size presented in this report.

1.4.4 Department of Defense Sites

After dropping 16% in FY 1995, the DOD cleanup budget has remained steady, and is expected to continue at its current level. Program activities have been shifting from site investigations to remediation, and from general site restoration to the cleanup of facilities scheduled to close.

The Department of Defense (DOD) is responsible for cleaning up contamination from numerous industrial, commercial, training, and weapons testing activities. DOD installations typically have multiple contaminated sites regulated by either CERCLA, RCRA, state laws, two federal statutes that mandate base realignments and closings, or a combination of these. The rate of realignment and closure of DOD facilities and installations will affect the scheduling of site cleanup. DOD is cleaning up closing military bases so that the properties can be transferred to local communities for economic revitalization. Prior to closing or realigning a base, DOD may be required to clean up the site, although cleanup activity may continue after closure.

DOD annual funding for site cleanup grew from $150 million in FY 1984 to $2.5 billion in FY 1994 and declined to $2.1 billion in FY 1995 and 1996. Although the total budget is expected to remain at this level through FY 1997, the proportion allocated to remedial design and remedial action will increase. The proportion of restoration funds targeted for remedial design and remedial action grew from 48 percent in FY 1994 to 61 percent in FY 1995, 64 percent in FY 1996, and 74 percent in FY 1997.

Other factors that will affect the DOD cleanup efforts include proposed new rules for the remediation of munitions at training ranges and the implementation of a new system for prioritizing sites for cleanup. Under this new system, DOD may assign varying levels of priority to different sites on a given installation. This policy may lead to the acceleration of some projects at a given installation while causing other projects at the same installation to be postponed.

1.4.5 Department of Energy Sites

DOE is responsible for cleaning up installations and other locations that have been used for nuclear weapons research, development, and production for over five decades. In addition to large, complex government-owned properties, DOE is responsible for cleaning up thousands of private residential and commercial properties that are contaminated because uranium mill tailings were used as fill for construction and landscaping or were carried by the wind to open areas. Environmental problems at DOE sites include unique radiation hazards, large volumes of soil and groundwater, and contaminated structures used to contain nuclear reactors and chemical plants for the extraction of nuclear materials.

Three key factors could affect the DOE market. First, the cleanup approaches used will directly determine both specific technologies to be applied and costs. DOE plans to place greater emphasis on containment than on treatment and other active remediation strategies. Second, the level of the DOE budget, which has been debated in Congress, could significantly alter the scheduling of site restoration and technology development projects. Third, the nature and magnitude of the contamination at many DOE sites is still only partially known; only about 46 percent of the more than 10,500 sites have been fully characterized. As sites are further investigated and new technologies to address the contamination problems become available, it may be necessary to alter budgets and the demand estimates for specific technologies.

The DOE cleanup market estimates relied on several critical assumptions, which makes them particularly sensitive to budget fluctuations, cleanup standards, and further site investigations.

1.4.6 Civilian Federal Agency Sites

"Civilian" federal agencies (CFAs) include all federal agencies except DOE and DOD. These agencies are responsible for the cleanup of contaminated waste at currently or formerly owned facilities. Under SARA, the federal government also may be liable for cleaning up contaminated waste at facilities acquired through foreclosure or other means and facilities purchased with federal loans. To meet these requirements, civilian federal agencies have established programs to assess potentially contaminated sites, and, if necessary, clean them up. Because detailed data on CFA site characteristics are limited, more site investigation is needed to fully identify cleanup needs. The programs are considerably smaller than those of DOD and DOE. The FY 1997 budget for 14 agencies combined is $288 million, about 14% of DOD's eenvironmental restoration budget.

In managing their environmental restoration programs, civilian federal agencies are subject to the same technical and political issues as are DOD and DOE. Future funding for site restoration at most civilian federal agencies is uncertain. To address this uncertainty, program managers have recognized the need to prioritize cleanup activities and to find better, faster, and less expensive cleanup approaches.

1.4.7 State and Private Party Sites

The financial and legal commitment to site restoration varies from state to state. Many states have programs to encourage voluntary cleanups and develop brownfield properties.

All sites not owned by federal agencies that require cleanup, but cannot be addressed under the federal Superfund, RCRA corrective action, or UST programs, are addressed by state cleanup programs. The cleanup of these sites must be financed by the states or private parties. To manage the cleanup of contaminated sites, many states have created their own programs patterned after the federal Superfund program. These programs generally include enforcement authority and state funds to finance the remediation of abandoned waste sites. Although enforcement activities vary from one state to another, most states have the legal authority to initiate or compel the cleanup of sites, recover costs from responsible parties, and seek criminal or civil penalties. The extent and pace of a state cleanup program is ultimately determined by its financial and legal commitment to environmental restoration.

Voluntary cleanups and “brownfield” sites represent another potential market for hazardous waste remediation services. Although the full extent of this market is unknown, 34 states have developed formal voluntary programs which are designed to promote the timely evaluation and remediation of waste sites with a minimum of state oversight and expenditure and to allow these properties to return to economically productive use. “Brownfields” are abandoned, idle, or under-used industrial and commercial facilities where real or perceived environmental contamination may be hampering expansion or redevelopment. The investigation and cleanup of these sites is a high priority among both environmental protection and economic development authorities at both the state and federal levels.

Using This Document

Chapter 2 describes the recent trends in the use of remedial technologies at Superfund sites. Because many contamination problems are similar across the seven market segments, the Superfund technology information is useful to help understand potential technology trends in the other markets. The remaining seven chapters address each of the market segments.

For each market segment, five areas are discussed: (1) the structure, operation, and regulatory requirements of the program; (2) the economic and political factors that may change the size or characteristics of the market segment; (3) the quantitative measures of the market in terms of the number of sites, occurrence of contaminants, and extent of remediation work needed; (4) remediation cost estimates; and (5) procurement and technology issues. Citations are referenced at the end of each chapter.

Appendices A through H contain supporting data, sources for additional information on the remediation market and technologies, and definitions of terms used in this report. The acronyms are on the last three pages of the document.

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CHAPTER 2
TRENDS IN THE USE OF REMEDIAL TECHNOLOGIES AT NATIONAL PRIORITIES LIST SITES

The Nation faces a significant technological challenge to clean up its contaminated waste sites efficiently and effectively. The most comprehensive information on technology use at waste sites is available for the Superfund program. Although Superfund sites represent a small percentage of all contaminated sites, experience with technology applications at these sites is likely to influence technology selection in other market segments. The Superfund program has made great progress in selecting and applying new treatment technologies that are less costly and more effective. Nearly half of the remedial treatment decisions for source control (primarily soils) in recent years involve technologies that were not even available when the law was reauthorized in 1986. The development of new technologies has been driven by a preference for treatment in the reauthorized law and the resulting quest for more cost-effective processes. This chapter describes the historical trends in the selection of technologies at Superfund sites. For new or innovative technologies, it describes the status of their implementation, and the types and quantities of wastes being addressed.

2.1 The Superfund Program

Superfund is the federal program to clean up releases of hazardous substances at abandoned or uncontrolled hazardous waste sites. The program is administered by EPA under the authority of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA). In addition to establishing enforcement authorities, CERCLA created a trust fund to be used for site identification and cleanup. The Superfund Amendments and Reauthorization Act of 1986 (SARA) made three important changes to the Superfund program that are of particular importance to technology vendors: (1) it stressed the importance of permanent remedies; (2) it supported the use of new, unproven treatment technologies; and (3) it expanded research and demonstrations to promote the development of innovative treatment technologies.

Superfund reauthorization is again being discussed in Congress, and some of the proposed provisions would affect the types of remedies selected. Some of the proposals are discussed in Chapter 3.

2.1.1 The National Contingency Plan

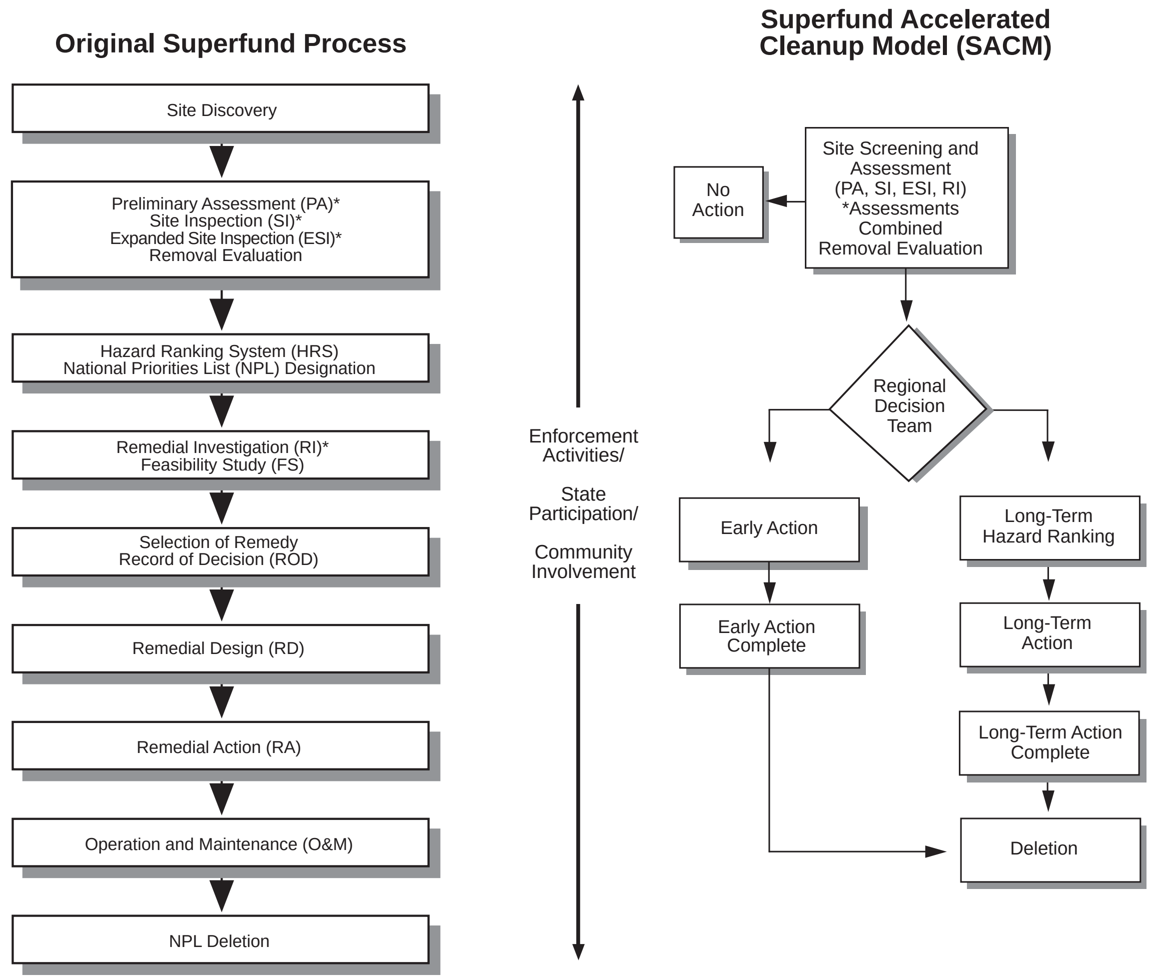
The procedures for implementing CERCLA are spelled out in the National Oil and Hazardous Substances Pollution Contingency Plan, commonly referred to as the National Contingency Plan (NCP). This plan outlines the steps that EPA and other federal agencies must follow in responding to releases of hazardous substances or oil into the environment. The goal described in the NCP is to select remedies that protect human health and the environment, maintain protection over time, and minimize untreated waste. The NCP specifies several treatment expectations to achieve this goal including:

- Use of treatment for principal threats wherever practical;
- Combination of treatment with containment, as necessary; and
- Consideration of innovative treatment technologies to the maximum extent practicable.

2.1.2 The Superfund Process

The site characterization and cleanup process established by the NCP is depicted in Exhibit 2-1. If more than one cleanup action is needed at a site, several steps in this process are repeated for each action. The process begins with the discovery of a potential hazardous waste site, and includes the following general steps:

Exhibit 2-1: Superfund Process Overview



* Indicates assessment phase of pipeline.

Source: U.S. EPA, Office of Emergency and Remedial Response.

1) A "preliminary assessment" (PA) is conducted to determine the existence of potential threats to human health or the environment that require a "removal action" or further study. If the PA indicates an emergency requiring immediate or short-term action to reduce the risk to the public, a removal action is conducted to stabilize or clean up the site.

2) If a hazard is identified or remains after a removal action is performed, a "site inspection" (SI) is conducted to determine whether a site warrants scoring under the Hazard Ranking System (HRS). EPA uses the HRS to score sites on the basis of potential human health and environmental effects from contamination and determine a site's eligibility for the National Priorities List (NPL). Sites with an HRS score of 28.5 or higher are proposed for the NPL, which is EPA's national list of sites with the worst contamination problems. Inclusion on the NPL means that the cleanup of the site can be accomplished using the Superfund Trust Fund.

3) When a site is added to the NPL, an in-depth planning and investigation phase begins, during which the nature and extent of contamination and site risks are determined, and treatment alternatives are evaluated. This phase is known as the "remedial investigation/feasibility study" (RI/FS). EPA requires the results of the RI/FS, including the rationale for selecting a remedy, to be presented to the public, and documented in a "Record of Decision" (ROD). Some sites require a series of RI/FSs and RODs to address different "operable units," which are portions of a site reflecting pathways of exposure (*e.g.*, soil, water) that require separate cleanup actions.

   RODs provide useful information for technology vendors interested in gaining access to the hazardous waste cleanup market. First, RODs specify the technology type determined to be the appropriate remedy for a site. Second, technology vendors can use RODs to determine why EPA selected or rejected a specific remedy. EPA must consider nine criteria for remedy selection: overall protectiveness; compliance with other environmental laws and regulations; long-term effectiveness and permanence; short-term effectiveness; implementability; cost; and reduction of toxicity, mobility, or volume of wastes. State and community acceptance also are considered.

4) Following the ROD, detailed engineering specifications for the selected cleanup approach are developed. This phase is called "remedial design" (RD). The designs are used to solicit competitive bids to perform the "remedial action" (RA). In the RD phase, waste is actually treated, disposed, or contained. If necessary, "operation and maintenance" (O&M) begins at the conclusion of the RA. This phase can include such actions as groundwater monitoring and periodic site inspections to ensure continued effectiveness of the RAs. The final step in the process is to delete the site from the NPL. This step is initiated when all necessary cleanup responses under CERCLA are completed.

At any point in this process, an emergency requiring a removal action can occur at a site. In addition, community involvement activities take place throughout the process to ensure that all interested parties participate in the decision-making process. Enforcement actions that compel those responsible for the contamination to clean up the site also occur throughout the cleanup process to ensure optimal use of Trust Fund resources.

EPA is now implementing the Superfund Accelerated Cleanup Model (SACM). The purpose of SACM is to make hazardous waste cleanups more timely and efficient by integrating Superfund's administrative components. The process is illustrated in Exhibit 2-1. Under SACM, EPA has adopted a continuous process for assessing site-specific conditions and the need for action. Risks will be reduced quickly through early action (removal or remedial). SACM operates within the existing statutory and regulatory structure. Superfund priorities will remain the same: deal with the worst problems first; aggressively pursue enforcement; and involve the public at every stage of the work.

As part of its responsibility for implementing the Superfund program, EPA is responsible for determining the best way to clean up each site. Other federal agencies such as the Department of Defense (DOD) and Department of Energy (DOE) are responsible for cleaning up NPL sites at their facilities in accordance with the requirements of the NCP and with EPA concurrence and oversight. Under the Superfund program, states also may take the lead to determine remedial alternatives and contract for the design and remediation of a site.

2.1.3 Program Status

Since its beginning in 1980, efforts under Superfund have included the identification and ranking of sites, detailed site investigation, mitigation of immediate threats, and selection and implementation of remedies to clean up the worst sites (those listed on the NPL). As of September 30, 1996, EPA had conducted preliminary assessments at 88 percent of the 12,657 potentially hazardous sites listed on the

Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS), EPA's Superfund site tracking system.[a] EPA had listed 1,387 sites on the NPL, and proposed another 52 sites. Of these, 118 sites were deleted from the NPL, and six were referred to another authority leaving a total of 1,263 final NPL sites. As additional sites are studied and ranked, they may be added to the NPL.

In the past four years, the number of sites that have progressed from study and evaluation to actual cleanup has grown. By September 30, 1996, remedial construction activity was complete at 410 sites and construction was underway at 491 sites. Another 140 sites were in the RD phase and the remainder were in various stages of site investigation or remedy selection. In addition, EPA had conducted removal actions at 3,450 sites, over 80 percent of which are not currently NPL sites.[1]

The analyses of technology trends presented in this chapter are based on data from RODs signed between fiscal years (FYs) 1982 and 1995, which ended on September 30, 1995. During this period, EPA made cleanup decisions in 1,669 RODs for 1,070 NPL sites. The analyses described in this chapter are based primarily on these sites. Fiscal year 1995 is the latest year for which detailed ROD and site data are available.

2.2 History of Technology Use in Superfund

The types of remedial approaches selected have changed over time, partly in response to changes in regulatory authority and EPA policy and also as a result of the availability of specific technologies. This section reviews the broad trends in the use of hazardous waste remediation technologies at NPL sites.

2.2.1 Containment and Disposal Technologies

Since Superfund was established, the approach to cleaning up contaminated sites has evolved from emphasizing containment of waste to promoting waste treatment. Prior to 1987, the most common methods for remediating hazardous waste were to excavate the contaminated material and dispose of it in an off-site landfill, or to contain the waste on site by means of containment systems (*e.g.*, caps or slurry walls). Because SARA provided a preference for the use of permanent remedies for site cleanup, known as "alternative treatment technologies," the number of remedies that included treatment began to increase.

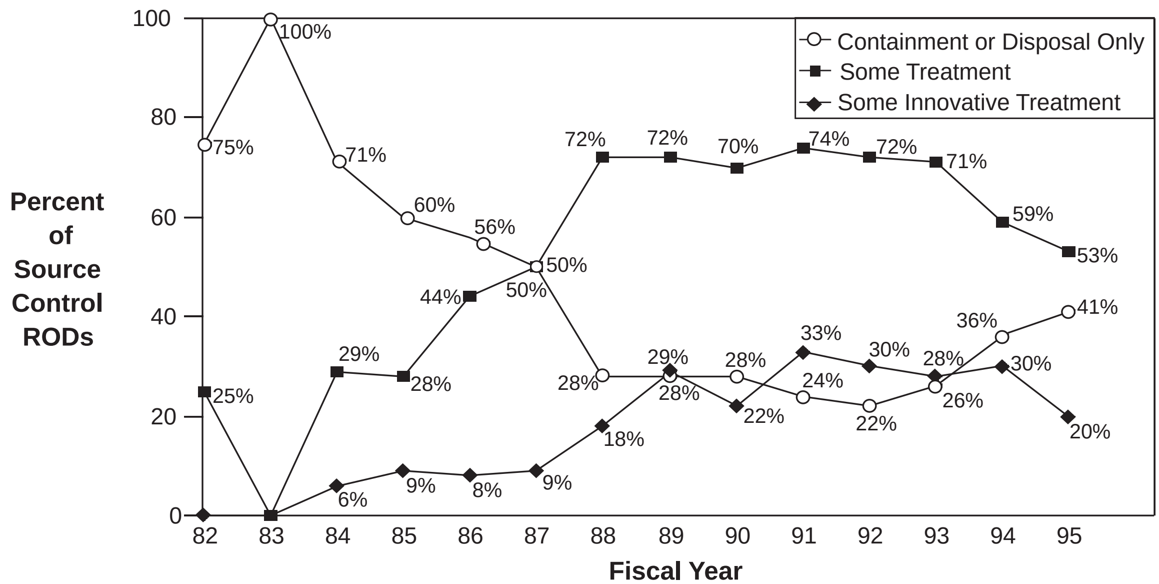
Of the 1,669 RODs signed between FY 1982 and FY 1995, 1,126 (67 percent) address the source of contamination: typically soil, sludge, sediment, or solid waste. Prior to 1987, more than half of these "source control" RODs specified the containment or disposal of the waste from the sites. From 1988 through 1993, almost three-quarters of all source control remedies involved some treatment to reduce the toxicity, mobility, or volume of waste (Exhibit 2-2). In the past two years, remedies have shifted toward containment used alone. This decline can be explained in part by an increase in the number of RODs for landfill sites and other difficult-to-treat wastes. Overall, more than 60 percent of all source control RODs signed between FY 1982 and FY 1995 included the treatment of some portion of the waste at the sites. In the future, the relative use of containment compared to treatment will greatly depend on the provisions of a forthcoming Superfund reauthorization.

2.2.2 Innovative and Established Technologies for Treatment

EPA's *Innovative Treatment Technologies: Annual Status Report (8th Edition)* contains information on each planned, ongoing, and completed treatment technology project selected for use in the Superfund program through FY 1995.[2] It also contains data on a limited number of non-Superfund federal facility sites (*i.e.*, DOD and DOE sites). Most of the discussion on the selection and use of innovative and established technologies presented in the remainder of this chapter is derived from this report.

[a] As of September 30, 1996, EPA removed and archived 28,008 sites from CERCLIS, in order to promote economic redevelopment at these sites by removing the stigma that may be associated with the presence of a site in CERCLIS. EPA, states, or tribes have completed evaluations at these sites, and no further work under the federal Superfund program is required.[1]

Exhibit 2-2: Treatment and Disposal Decisions for Source Control at NPL Sites



Notes: Data for innovative technologies are derived from Records of Decision (RODs) for fiscal years 1982-1995 and anticipated design and construction activities as of August 1996. A site may use more than one technology. Appendix Exhibit A-2 contains supporting data. Data for fiscal year 1995 are preliminary.

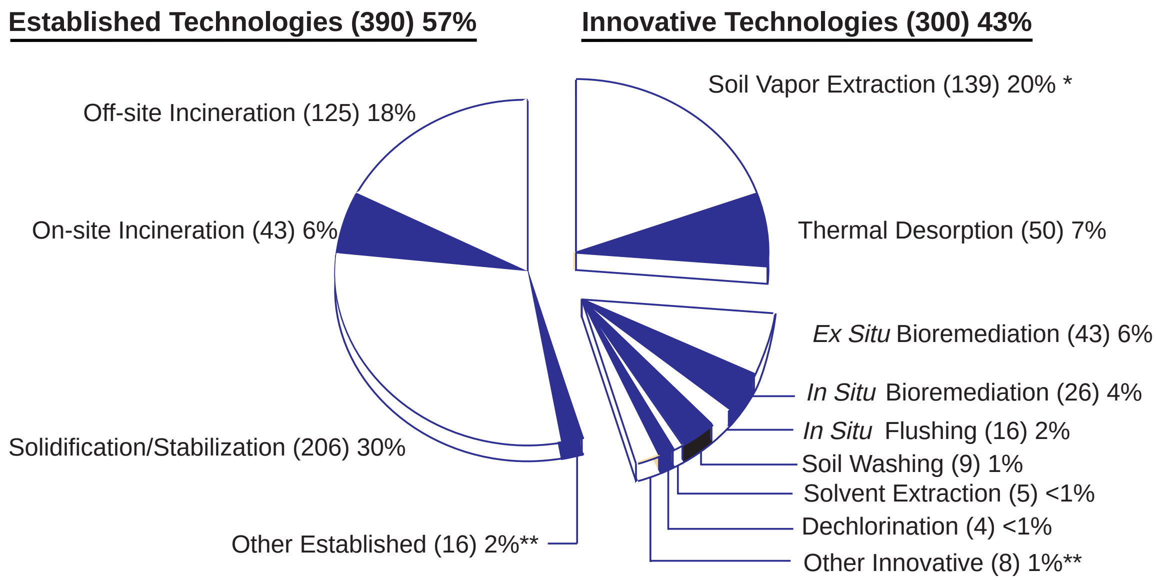
Source: U.S. EPA, Office of Solid Waste and Emergency Response, Technology Innovation Office, *Innovative Treatment Technologies: Annual Status Report (Eighth Edition)*, EPA 542-R-96-010, November 1996.

The frequency of use of established and innovative source control treatment technologies at NPL sites is shown in Exhibit 2-3. The technologies are grouped into 20 technology types, including 11 selected most frequently and nine “others.” Fifty-seven percent of the 690 treatment technologies selected for source control are considered “established.” Established remediation technologies are those that have sufficient published cost and performance data to support their regular use for site cleanup. The most frequently used established technologies are solidification / stabilization and incineration. “Innovative” remediation technologies are those for which sufficient published cost and performance data to support their regular use for site cleanup are not readily available.[b] In practice, the use of a number of remedial technologies that are considered innovative has increased at Superfund and other contaminated sites. In particular, a number of soil vapor extraction (SVE) and thermal desorption projects have been completed, and these technologies have become more accepted. However, because the results of most of the projects are not widely known, these two technologies are considered innovative for this report.

Solidification / stabilization (also called “fixation” and “immobilization”) has been the most common technology to treat soil and other wastes. It accounts for 30 percent of all technology applications for source control at NPL sites between FY 1982 and FY 1995. However the use of this technology has declined since 1992 (Exhibit 2-4). Solidification / stabilization usually is selected to remediate metal containing waste and continues to be the favored technology to treat metals,

[b] Brief definitions of innovative technologies selected at Superfund sites, such as soil vapor extraction, soil washing, and dechlorination, are provided in Appendix G. Additional information on innovative technologies is provided in a technical screening guide published by several federal agencies.[3] Many other publications on both innovative and established remedial technologies are listed in a bibliography compiled by EPA,[4] and another compiled jointly by EPA and other federal agencies.[5]

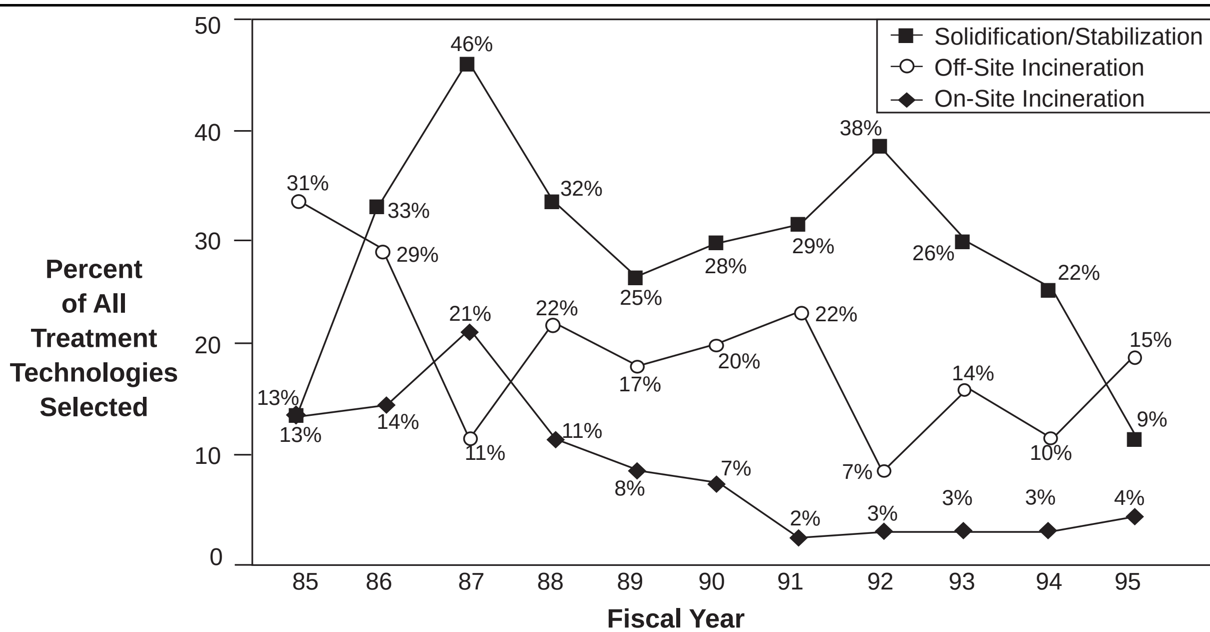
Exhibit 2-3: Source Control Technologies Selected for Superfund Sites Through Fiscal Year 1995



Notes: * Includes two dual-phase extraction projects also listed as *in situ* groundwater technologies.
** "Other" established technologies: soil aeration, open detonation, and chemical neutralization.
"Other" innovative technologies: physical separation, contained recovery of oily wastes (CROW™), cyanide oxidation, vitrification, hot air injection, and plasma high-temperature metals recovery.

Source: U.S. EPA, Office of Solid Waste and Emergency Response, Technology Innovation Office, *Innovative Treatment Technologies: Annual Status Report (Eighth Edition)*, EPA 542-R-96-010, November 1996.

Exhibit 2-4: Trends for the Most Frequently Selected Established Technologies for Source Control at NPL Sites



Note: Few treatment technologies were selected in the earlier years of the Superfund Program: one in 1982, none in 1983, four in 1984, and 12 in 1985.

Source: Adapted from U.S. EPA, Office of Solid Waste and Emergency Response, Technology Innovation Office, *Innovative Treatment Technologies: Annual Status Report (Eighth Edition),* EPA 542-R-96-010, November 1996.

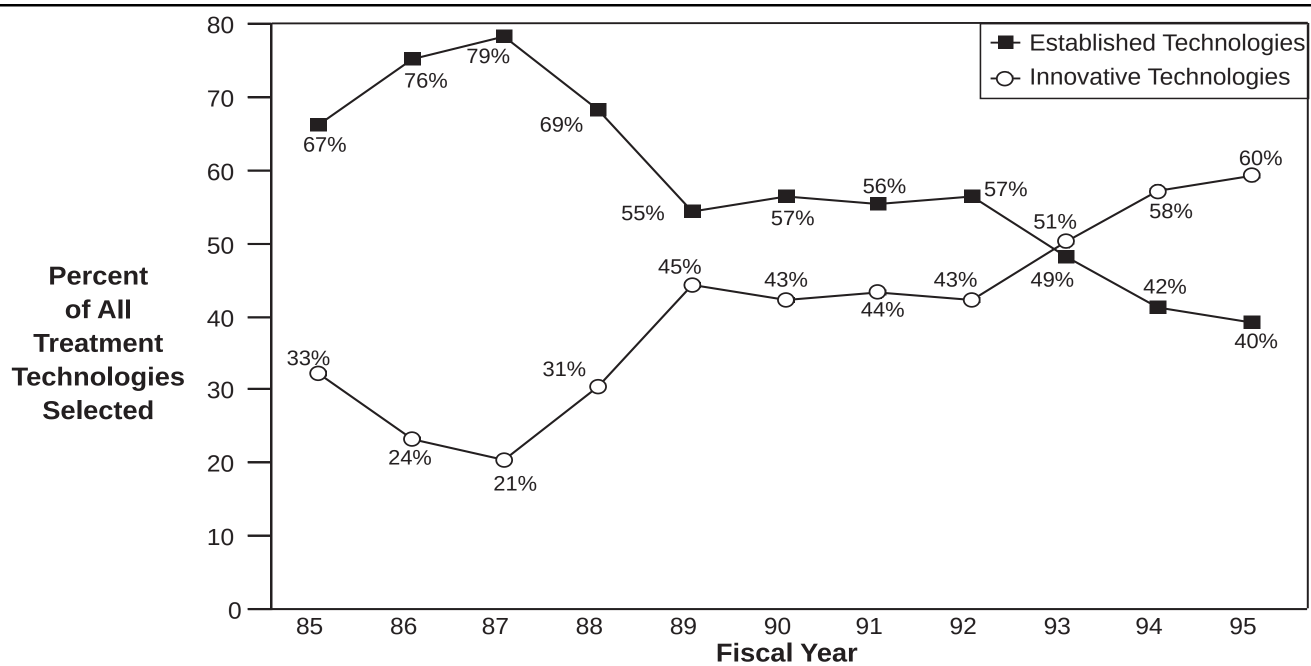
although some compounds are not easily solidified. In some cases, it is selected to treat organic contaminants, primarily semivolatile organic compounds (SVOCs). Although solidification/stabilization has several advantages, including low cost, questions remain concerning its effectiveness over time. Consequently, it may require long-term monitoring.

Incineration has been the second most frequently selected technology for treating soil, sludge, and sediment in Superfund and was the first technology available for treating organic contaminants in these matrices. The major advantage of incineration is its ability to achieve stringent cleanup standards for highly concentrated mixtures. On-site and off-site incineration together accounted for 24 percent of all treatments selected for source control through FY 1995. However, based on recent project data, on-site incineration is seldom being used (Exhibit 2-4). Off-site incineration is more applicable to smaller quantities (typically less than about 5,000 cubic yards) of highly contaminated material and for residuals of pre- or post-treatment technologies that separate and concentrate contaminants.

While solidification/stabilization and incineration (both established technologies) have accounted for a decreasing share of all technologies selected for source control for Superfund sites, the share accounted for by innovative treatments has grown (Exhibit 2-5). In FY 1993, for the first time, over half of the treatment technologies selected for source control were innovative; and about 20 percent of all sites with RODs are using at least one innovative technology. The most widely selected innovative technology, SVE, was selected for 20 percent of source control technologies selected through FY 1995 (Exhibit 2-3). The other most common innovative technologies are bioremediation, thermal desorption, *in situ* flushing, and soil washing. Trends in selection of the three most commonly used innovative technologies are shown in Exhibit 2-6.

Seventy-six percent of Superfund sites with RODs require some sort of groundwater remediation. In most cases groundwater is being addressed by pump-and-treat technology, in which groundwater is pumped to the surface to be treated by physical/chemical methods (Exhibit 2-7). For this

Exhibit 2-5: Relative Use of Established and Innovative Technologies for Source Control at NPL Sites



Note: A site may use more than one technology.

Source: Adapted from U.S. EPA, Office of Solid Waste and Emergency Response, Technology Innovation Office, *Innovative Treatment Technologies: Annual Status Report (Eighth Edition),* EPA 542-R-96-010, November 1996.

report, all above-ground treatment of groundwater is considered established, although some innovative approaches are being developed for aqueous treatment. All *in situ* treatment technologies for groundwater are considered innovative. *In situ* groundwater remedies have been selected for fewer than six percent of groundwater sites. Of 603 sites for which groundwater remedies have been selected, pump-and-treat technology alone is being implemented at 93 percent and is combined with *in situ* treatment at 5 percent of the sites. *In situ* treatment alone has been selected for only nine sites.

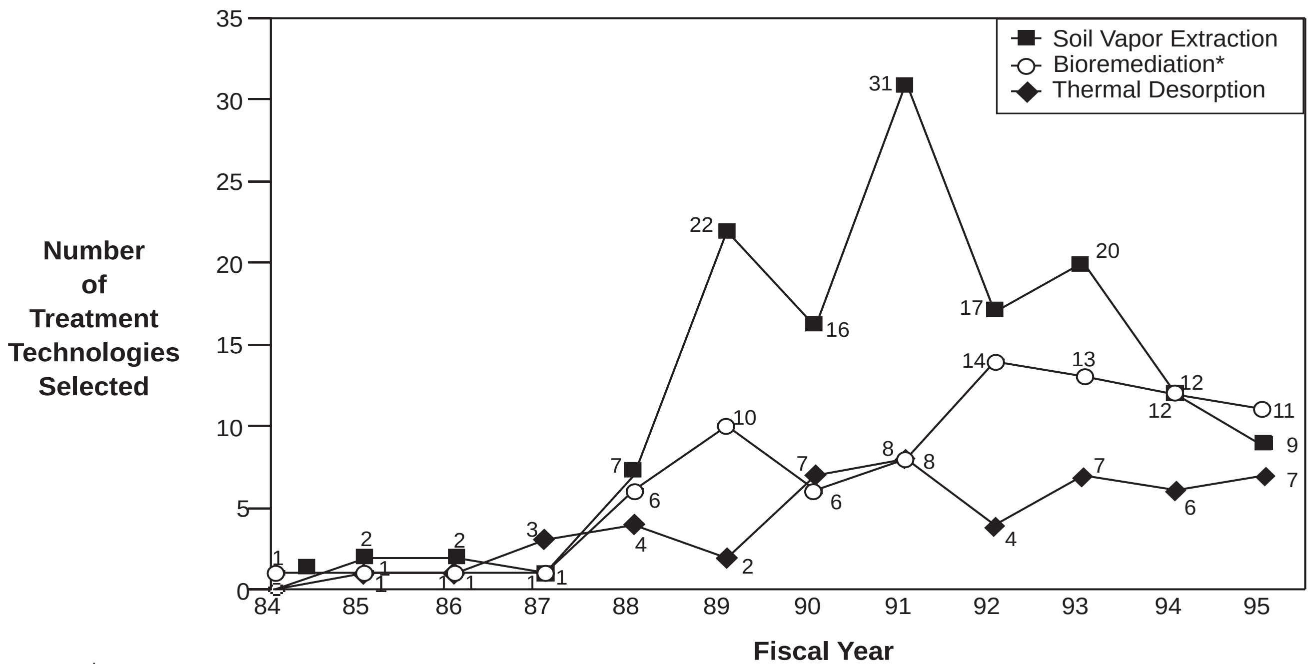
2.3 Innovative Remedies for Source Control

EPA closely tracks the status of innovative technology projects at NPL sites. Exhibit 2-8 provides the implementation status of innovative treatment technologies selected for Superfund sites. Fifty-six projects using innovative technologies have been completed as of August 1996. Consequently, operating experience is limited but growing for innovative technologies chosen at Superfund sites.

The innovative treatment projects now in design will be implemented within the next several years. As of August 1996, innovative treatment technologies for source control and groundwater were designed, or being installed for 174 projects, and operational for 99 projects. Another 114 projects were at the predesign or design stages. As these projects are implemented and completed, EPA will make available more complete information on full-scale cost and performance for many sites.

Exhibit 2-9 presents a cumulative account of how often the seven most commonly used types of innovative remedies for source control have been selected to treat each of the three major contaminant groups: VOCs, SVOCs, and metals. Although not reflected here, the presence of other contaminant groups or specific site conditions also may affect the technology selection. Since technologies may target more than one constituent, these numbers are not additive. The following subsections address each of the three contaminant groups.

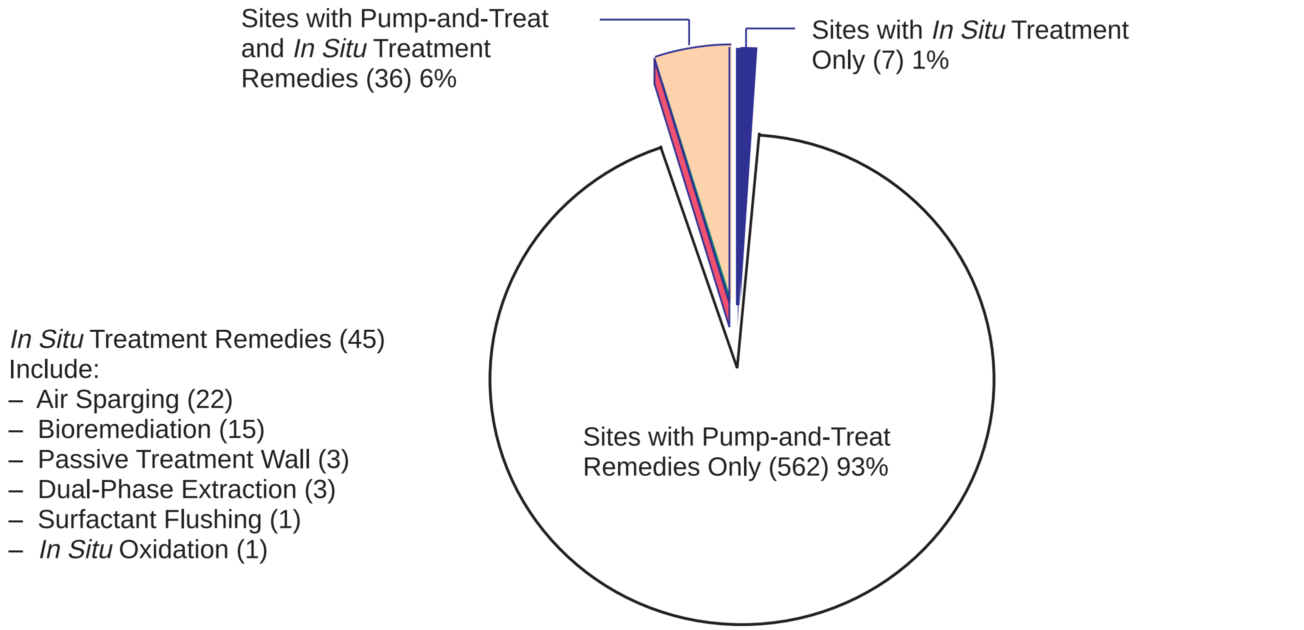
Exhibit 2-6: Trends for the Three Most Frequently Selected Treatment Technologies at NPL Sites



Notes: * Also includes *in situ* groundwater treatment.

Source: U.S. EPA, Office of Solid Waste and Emergency Response, Technology Innovation Office, *Innovative Treatment Technologies: Annual Status Report (Eighth Edition),* EPA 542-R-96-010, November 1996.

Exhibit 2-7: Groundwater Treatment Remedies at NPL Sites Through Fiscal Year 1995



Notes: Does not include groundwater sites with nontreatment remedies (*i.e.*, monitoring, institutional controls, alternate water supply, well-head treatment, closing wells, containment, or natural attenuation).

Source: U.S. EPA, Office of Solid Waste and Emergency Response, Technology Innovation Office.

2.3.1 Treatment of Volatile Organic Compounds

Of the three major contaminant groups, NPL sites with VOCs are the most frequently treated with innovative technologies (Exhibit 2-9). SVE has become the preferred technology for both chlorinated and nonchlorinated VOCs in soil. Despite its frequent selection, SVE is still considered innovative in this report because its effectiveness has not been confirmed for many types of sites, and because the results of many projects are not yet widely known. The selection of SVE for Superfund sites has decreased recently (Exhibit 2-6).

The overall popularity of this technology is due to its low cost and the frequent occurrence of VOCs at Superfund sites. Although performance varies from one application to another, SVE usually is the most cost-effective means of reducing VOC concentrations. SVE has been selected in some cases to pretreat soils prior to excavation or subsequent treatment. At some sites, SVE may be modified to enhance *in situ* bioremediation (called "bioventing"). Bioventing optimizes SVE performance by maximizing the biodegradation of certain organics by controlling the air flow. Bioventing also may lead to increased use of SVE when VOCs and SVOCs are present. Other means of expanding the range of application of SVE include integrating with groundwater treatment technologies such as dual-phase extraction and air sparging, improved well placement, and improved recovery through hydraulic or pneumatic fracturing and thermal processes. Further developments that may expand the application of SVE include radio frequency heating, horizontal well techniques, and other methods to increase soil permeability. Overall, 18 SVE projects have been completed at NPL sites and 52 are operational.

Thermal desorption and bioremediation also are commonly used to treat VOCs. Bioremediation is usually applied to non-halogenated VOCs, such as benzene (Exhibit 2-9).

2.3.2 Treatment of Semivolatile Organic Compounds (SVOCs)

Bioremediation and thermal desorption are the most frequently selected innovative technologies for NPL sites with SVOCs. In addition, soil vapor extraction has been selected for some of the more

Exhibit 2-8: Status of Innovative Technology Projects at NPL Sites as of August 1995

Technology	Predesign/ In Design	Design Complete/ Being Installed	Operational	Completed	Total
Source Control Technologies					
Soil Vapor Extraction	36	33	52	18	139
Thermal Desorption	14	8	4	24	50
Ex Situ Bioremediation	16	8	14	5	43
In Situ Bioremediation	9	5	10	2	26
In Situ Flushing	7	2	6	1	16
Soil Washing	6	2	0	1	9
Solvent Extraction	2	2	0	1	5
Dechlorination	1	1	0	2	4
Vitrification	2	0	0	1	3
Cyanide Oxidation	1	0	0	0	1
Hot Air Injection	1	0	0	0	1
Contained Recovery of Oily Wastes (CROW™)	0	0	0	1	1
Physical Separation	0	0	0	1	1
Plasma High Temperature Metals Recovery	1	0	0	0	1
Total	**96 (32%)**	**61 (20%)**	**86 (29%)**	**57 (19%)**	**300**
Groundwater Technologies					
Air Sparging	6	8	8	0	22
In Situ Bioremediation	7	5	3	0	15
Passive Treatment Wall	3	0	0	0	3
Dual-Phase Extraction	1	2	0	0	3
In Situ Well Aeration	1	0	0	0	1
In Situ Oxidation	0	1	0	0	1
Total	**18 (40%)**	**16 (36%)**	**11 (24%)**	**0**	**45**

Notes: Data are derived from Records of Decision for fiscal years 1982-1995 and anticipated design and construction activities as of August 1996.

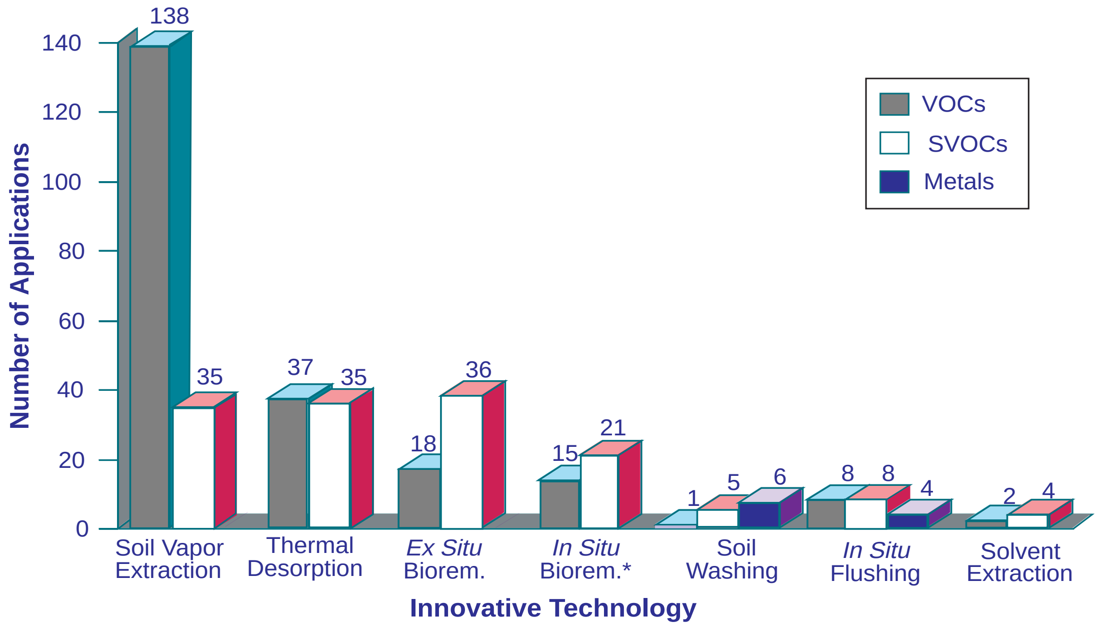
Source: U.S. EPA, Office of Solid Waste and Emergency Response, Technology Innovation Office, *Innovative Treatment Technologies: Annual Status Report (Eighth Edition)*, EPA-542-R-96-010, November 1996.

volatile SVOCs (*e.g.*, phenols and naphthalenes).[6] Other technologies used to treat SVOCs are dechlorination, vitrification, and contained recovery of oily waste (CROW™).[6]

Bioremediation methods selected include land treatment, *in situ* treatment, and slurry-phase treatment. Bioremediation has been selected for 47 projects to treat polyaromatic hydrocarbons (PAHs) and 10 projects to treat other SVOCs.[6] Overall, seven bioremediation projects for source control have been completed and 24 are operational. From 1992 to 1995, bioremediation for source control was chosen 10 times per year, on average.[2]

Since bioremediation destroys organic contaminants, it has a major advantage over other innovative technologies that rely on separation techniques. Nevertheless, bioremediation has not been selected more often at Superfund sites, probably because, in its current state of development, it addresses a limited number of biodegradable compounds; and many site conditions (such as the presence of metals and clayey soil) inhibit performance. Bioremediation also may have difficulty meeting stringent cleanup levels or may require long periods of time to achieve the required reductions. Current research efforts are focused on biodegradation of chlorinated aliphatic hydrocarbons, such as

Exhibit 2-9: Applications of Innovative Treatment Technologies for Source Control at NPL Sites



Notes: Includes technologies selected in Records of Decision for fiscal years 1982-1995.
* Does not include *in situ* groundwater bioremediation.

Source: U.S. EPA, Office of Solid Waste and Emergency Response, Technology Innovation Office, *Innovative Treatment Technologies: Annual Status Report (Eighth Edition),* EPA 542-R-96-010, November 1996.

trichloroethylene (TCE) and vinyl chloride, which occur at many sites.

Thermal desorption treats a broad spectrum of SVOCs, most frequently PAHs and PCBs. In all, 24 thermal desorption projects have been completed and four are operational (Exhibit 2-8). Thermal desorption may be particularly well-suited for pretreating organics prior to metals treatment. Soil washing has been selected five times to treat SVOCs, such as PAHs, phenols and pesticides, and one soil washing project has been completed. Dechlorination, a form of chemical treatment, also has been selected to treat PCBs for four projects, two of which have been completed.[5],[6]

2.3.3 Treatment of Metals

The most frequently selected technology for metal waste is solidification / stabilization, which has been selected for 206 projects (Exhibit 2-3). In the past two years, its selection has decreased substantially. Of the innovative technologies, soil washing is being used to remediate metals at six sites, three of which also contain organics. *In situ* flushing has been selected for three projects to treat metallic wastes, two of which also contain organics, and at one site to treat arsenic. The application of *in situ* flushing is largely dependent on site hydrogeology, which must carefully be considered to reduce the possible spread of contamination. In this process, contaminants may leach into underlying groundwater, from which they are typically recovered by pump-and-treat methods. Some new methods under development to remediate metals include phytoremediation and electrokinetics.

No treatment technologies have yet been selected at NPL sites with low-level radioactive metals combined with other hazardous constituents (known as "mixed wastes"). In the past, the selected remedy has been excavation and on-site storage, or disposal in an on- or off-site landfill permitted to accept such waste. DOE is testing and implementing several technologies, such as vitrification, to address radioactive contaminants.

Often, "treatment trains" are use to address media and wastes containing both metals and organics. A "treatment train" is the combined use of several treatment technologies in a series in order to: reduce the volume of material requiring subsequent treatment; prevent emission of volatile contaminants during excavation and mixing; or address multiple contaminants within the same medium. Treatment trains that use innovative technologies have been selected at 32 Superfund sites (Exhibit 2-10), 18 of which use established technologies as part of the treatment train.

2.3.4 Waste Matrices and Quantities

Of the 345 innovative technology projects selected at Superfund sites, 300 address source control and 45 are for the treatment of groundwater *in situ*. Of the innovative technology applications for source control, soil is addressed at 99 percent of the sites, sludge at six percent, sediments at five percent, and solids at less than one percent.[6] The total exceeds 100 percent because each technology may be used to treat more than one waste matrix at a site. As shown in Exhibit 2-11, the quantities of soil treated by the various innovative techniques vary widely from one site to another. In general, *in situ* technologies such as *in situ* flushing, SVE, and *in situ* bioremediation have been chosen to treat larger volumes of soil. These three technologies account for over 90 percent of the soil and other material to be treated by innovative technologies for those sites where data are available. Technologies that treat excavated wastes or require waste postprocessing (*e.g.*, soil washing, thermal desorption, and solvent extraction) generally are selected to treat smaller amounts of soil.

2.4 Innovative Remedies for Groundwater

Of the 45 applications of innovative technologies to groundwater at 44 sites, 36 address VOCs, 17 address SVOCs, and two address metals. The most frequently selected innovative groundwater technologies are air sparging, selected 22 times, and bioremediation, selected 15 times.

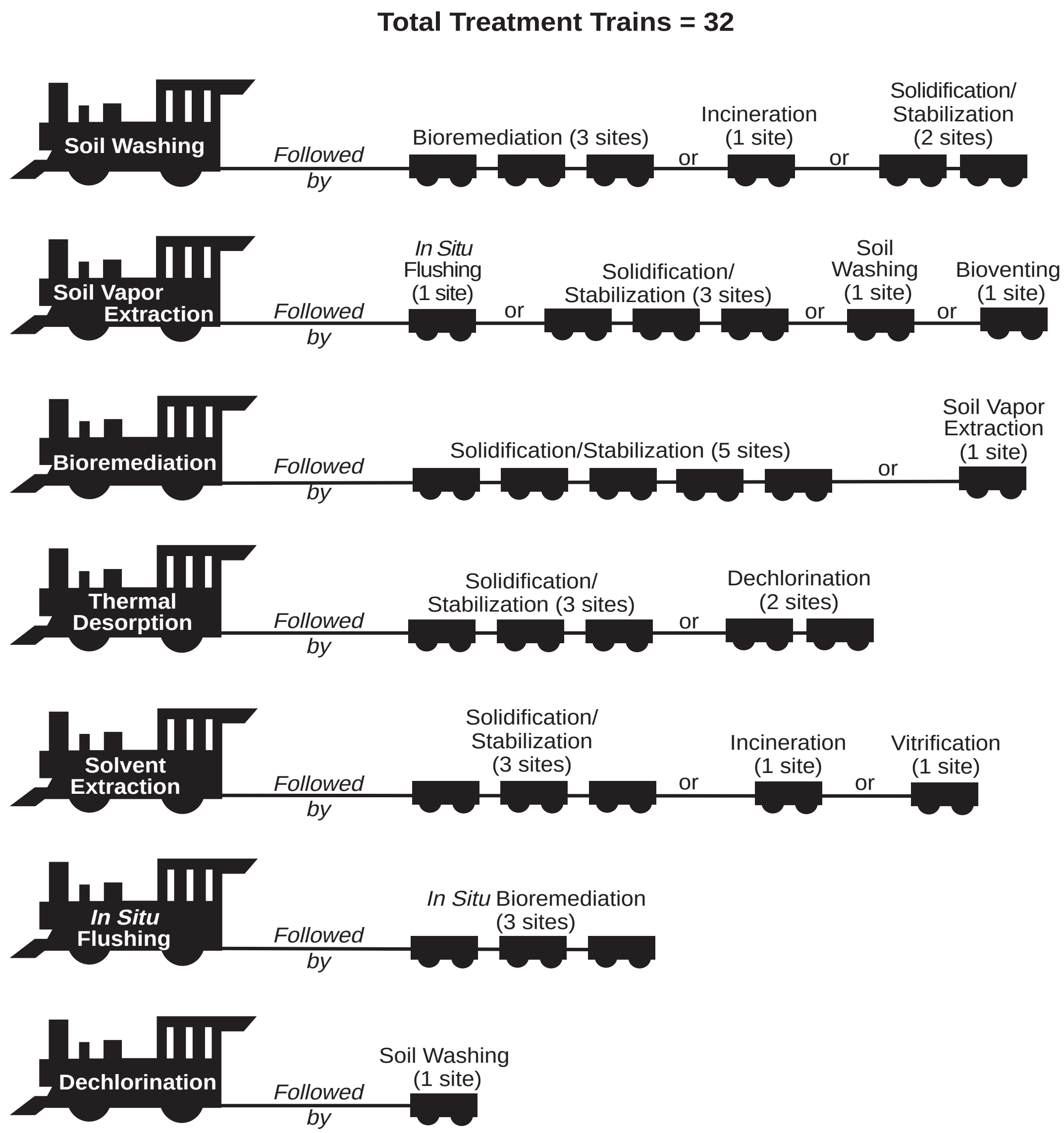
Previous EPA studies have shown that pump-and-treat technology alone is often insufficient to meet cleanup levels selected.[7] Until recently, contaminants in unsaturated soils were considered to be the most significant source of groundwater contamination. However, studies indicate that nonaqueous phase liquids (NAPLs) and contaminants captured or absorbed by soils in the aquifer are released slowly into the groundwater. Consequently, improved *in situ* groundwater remediation technologies are needed to treat this residual subsurface contamination.[8]

Three recent efforts have further expanded the information available on new technologies for groundwater and other media. The first is the establishment of the *Groundwater Remediation Technologies Analysis Center* (GWRTAC) at the National Environmental Technologies Applications Center (NETAC) in association with the University of Pittsburgh. This center develops and disseminates information on current *in situ* research, development, and demonstration efforts, and analyzes technology development trends. Section 3.5.4 describes how to contact the center. The second effort is the 1995 EPA publication of six technology status reports that describe existing research, demonstrations, and references for *in situ* abiotic groundwater technologies.[9] These efforts identified over 90 research and demonstration projects involving the six technologies: thermal enhancements (18 projects), surfactants (19 projects), treatment walls (23 projects), fracturing (12 projects), cosolvents (four projects), and electrokinetics (16 projects). Interest in these technologies, particularly treatment walls, is increasing rapidly. The third effort is the development of a database called the *Bioremediation in the Field System*, which was developed by the Bioremediation Field Initiative, an affiliation of government and industry representatives working jointly to document the use of bioremediation for soils and groundwater. This database includes data on more than 400 sites for which public information is available.[10]

2.5 Research and Development

Future technology use also will be influenced by technology development efforts, and the perceived needs of industry. EPA and other federal agencies currently are coordinating two technology development programs directed toward identifying and implementing research, development, and demonstration projects based on user needs. Under these programs, the Remediation Technologies Development Forum (RTDF) and the Clean Sites Public-Private Partnerships, 11 different technologies have been identified for further efforts (Exhibit 2-12).

Exhibit 2-10: Treatment Trains with Innovative Treatment Technologies Selected for Remedial Sites



Note: Includes technologies selected in FY 1982-1995 Records of Decision.

Source: U.S. EPA, Office of Solid Waste and Emergency Response, Technology Innovation Office, *Innovative Treatment Technologies: Annual Status Report (Eighth Edition),* EPA-542-R-96-010, November 1996.

All except one are technologies for *in situ* treatment of soil or groundwater, and five are bioremediation methods. The RTDF is a consortium of partners from industry, government, and academia who share the common goal to develop more effective, less costly hazardous waste characterization and treatment technologies.[11] RTDF achieves this goal by identifying high priority needs for technology development. For each priority need, the RTDF organizes an Action Team composed of organizations who share that interest, to plan and conduct collaborative laboratory and field research and development. Although federal agencies provide in-kind contributions and funding, the formation of teams is driven by the

Exhibit 2-11: Estimated Quantities of Soil to be Treated by Innovative Technologies at NPL Sites

Technology	Number of NPL Sites: Total Sites	Number of NPL Sites: Sites with Data	Quantity (Cubic Yards): Range	Quantity (Cubic Yards): Average	Quantity (Cubic Yards): Total
Soil Vapor Extraction	137	118	11 - 6,200,000	250,130	29,515,300
In Situ Bioremediation	26	12	5,000 - 484,000	106,108	1,273,300
In Situ Flushing	16	12	5,200 - 750,000	97,383	1,168,600
Soil Washing	9	8	5,500 - 62,000	23,263	186,100
Ex Situ Bioremediation	43	35	400 - 208,000	34,591	1,210,700
Dechlorination	4	4	700 - 48,000	27,700	110,800
Solvent Extraction	5	5	7,000 - 100,000	27,540	137,700
Thermal Desorption	50	43	250 - 180,000	26,813	1, 153,000
Cyanide Oxidation	1	1			3,000
Contained Recovery of Oily Wastes (CROW™)	1	1			200
Physical Separation	1	1			8,000
Plasma High Temperature Metals Recovery	1	1			65,000
Vitrification	3	1			4,600
Total	297	242			34,836,300

Notes: Does not include sites conducting *ex situ* SVE or treating sediments or sludge. Includes technologies selected in Fiscal Year 1992-1995 Records of Decision.

Source: U.S. EPA, Office of Solid Waste and Emergency Response, Technology Innovation Office, *Innovative Treatment Technologies: Annual Status Report (Eighth Edition)*, EPA-542-R-96-010, November 1996.

organizations responsible for site cleanups. Five Action Teams have been established to date. More information on the RTDF is available from EPA's Technology Innovation Office (703-603-9910).

Through the Clean Sites Public-Private Partnerships for technology acceptance, EPA and Clean Sites, Inc., a nonprofit firm, develop partnerships between federal agencies, such as DOD and DOE, and private industry site owners (responsible parties, owner/operators) for the joint evaluation of full-scale remediation technologies.[11] The purpose of this program is to create demand for new technologies by allowing the end users of the technologies to be involved throughout the demonstration process. Typically, Clean Sites, with the assistance of federal agencies, identifies and characterizes a candidate federal facility, solicits industry participation, and brings together the facility and private companies. Based on common problems identified by these partners, the host facility arranges for the procurement of technologies for demonstration. The partners develop evaluation plans and conduct the demonstrations. Currently, there are six evaluation projects under this program. More information is available from the Technology Innovation Office (703-603-9910).

Based on the technologies listed in Exhibit 2-12, prospective users of innovative technologies are interested in *in situ* processes that are generally viewed as being cheaper, more acceptable to the public, and posing lower risk to workers. There is considerable interest in the use of SVE in conjunction with several other technologies, including dual-phase extraction, air sparging, dynamic underground stripping, and rotary steam drilling. Several processes entail the

Exhibit 2-12: Examples of Technology Needs Identified by Users Participating in Two Federal Programs

Medium	Public/Private Partnerships	Remediation Technologies Development Forum
In Situ Management of Soils	• Lasagna™ (electroosmosis, hydrofracturing treatment zones)	• Lasagna™ • Co-metabolic bioventing • Phytoremediation of metals
In Situ Management of Groundwater	• Anaerobic bioremediation • Permeable treatment walls • Air sparging	• Accelerated anaerobic bioremediation • Permeable treatment walls • Intrinsic bioremediation
In Situ Management of Soil and Groundwater	• Rotary steam drilling • Dual-phase extraction	• Not applicable
Ex Situ Management of Soil	• Enhanced bioslurry reactors	• Not applicable
Ex Situ Management of Groundwater	• Membrane separation	• Not applicable

creation of treatment zones (permeable barriers, microbial filters, and the Lasagna™ process) and the use of electric fields to mobilize both organics and inorganics.

EPA and other federal agencies have other active research and demonstration programs for most types of innovative cleanup technologies. Through the Superfund Innovative Technology Evaluation (SITE) program, EPA has, for a decade, been evaluating field-ready and emerging innovative technologies offered by specific companies. Under SITE, the Agency develops reliable engineering, performance, and cost data on these technologies by field testing them on hazardous wastes at existing sites or in a test that duplicates site conditions. EPA selects participants by soliciting and evaluating proposals, and enters into cooperative agreements with technology developers. By September 1996, EPA had completed 86 field demonstrations and 53 bench-scale or early pilot-scale projects.[12] Section 3.5.4 describes how to access SITE reports and other information. The program has less funding than in the past, and future funding may depend on a new Superfund law. More information on this program is available from the National Risk Management Research Laboratory (513-569-7696).

Lastly, to encourage the acceptance and use of innovative cleanup technologies, the Federal Remediation Technologies Roundtable sponsors a coordinated effort by federal agencies to document the cost and performance of remediation technologies. Case studies of selected ongoing and completed remediation projects are available on the Internet (http://www.frtr.gov).

2.6 Conclusions on Technology Trends

After a significant increase in the selection of treatment technologies, especially innovative technologies, in the early 1990s, the selection of several technologies has levelled off or decreased in the past two years, and the selection of containment has become more common. Most of the applications of innovative technologies for Superfund cleanups have been to treat organic contamination in soil. Three innovative technologies account for over 75 percent of innovative technology applications:

- SVE, which is primarily used to treat VOCs, is the most commonly used innovative technology. The selection of SVE relative to other technologies grew rapidly from 1986 to 1989, fluctuated for the next few years, and declined in 1995. Enhancements, such as methods to increase soil permeability or contaminant volatility, may expand its applicability and improve performance.

- Bioremediation is the second most frequently selected innovative technology, and its selection has remained fairly constant over the past several years. This trend may reflect a limit in the number of sites with contaminants that can be treated by bioremediation in its current state of development. The contaminants most often treated by bioremediation are petroleum hydrocarbons and PAHs. Current bioremediation research could lead to improved performance and expand the types of contaminants amenable to biological degradation.

- Thermal desorption is the third most frequently selected innovative technology. The frequency of selection for this technology has remained relatively constant over the past five years. It is used primarily to treat VOCs, (particularly when SVE is not feasible), and SVOCs, primarily PAHs and PCBs. Soils containing both metals and organics present another major treatment opportunity, since organics will volatize at relatively low temperatures. Residuals containing metals then can be treated by another technology, such as solidification / stabilization.

Relatively few innovative treatment methods are being selected for metals-contaminated soils. The most widely used technology for the treatment of metals is solidification / stabilization, which has been selected for 30 percent of the source control projects at Superfund sites. The selection of this technology has declined during the past two years. Although solidification / stabilization has several advantages, including low cost, questions remain concerning its effectiveness over time. Consequently, the sites may require long-term monitoring. New separation technologies such as electrokinetics could provide alternative methods for remediating metals in the future. Additional field tests of these and other technologies are needed.

Despite recent advances, about 93 percent of remedies selected for groundwater continue to rely on conventional pump-and-treat technologies. Bioremediation and air sparging are the most widely used innovative *in situ* approaches. Usually, these technologies are applied in conjunction with pump-and-treat. Research and demonstration efforts to develop innovative methods for the treatment of groundwater, which are enumerated in Chapter 3, include both biological and abiotic *in situ* processes. Chapter 3 addresses additional factors that may affect the demand for innovative technologies for Superfund cleanups.

2.7 References

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CHAPTER 3
DEMAND FOR REMEDIATION OF NATIONAL PRIORITIES LIST SITES

This chapter presents estimates of the number, location, size, characteristics, and cleanup costs of hazardous waste sites placed on the Superfund National Priorities List (NPL) and describes the implications of these factors for the demand for specific cleanup technologies. Because many Superfund sites have undergone detailed site assessments, much information is available on their characteristics. In addition, to the extent that Superfund sites are similar to those in other cleanup programs, the remediation technologies demanded for the Superfund program are likely to reflect needs in other programs.

This chapter is closely related to the previous chapter, which describes historical trends in the selection of technologies and their implementation at Superfund sites, the statutes that authorize the Superfund program, the history of the program, and the process used to manage Superfund sites. While Chapter 2 addresses Superfund sites for which remedies have been selected and documented in Records of Decision (RODs), Chapter 3 focuses primarily on the characteristics and potential remediation technologies for sites for which remedies have *not* been selected.

3.1 Factors Affecting Demand for Cleanup

Many technical, economic, public policy, and legal factors have combined to determine the number of sites currently included in the Superfund program, the cleanup standards and technologies to be used, and work schedule. Because Superfund is facing reauthorization, it is likely that legislative, budgetary, and regulatory changes will occur during the next few years. Some factors that could alter the scope of the cleanup effort, as well as the technologies to be used, are described below.

- EPA has added few sites to the NPL in recent years, and currently does not plan to change this policy. In addition, EPA has been emphasizing the completion of remedial designs and cleanup actions at sites already listed, and is spending somewhat less effort on the conduct of remedial investigations and feasibility studies (RI/FSs). The rate of addition of new sites also may be influenced by Congress through the EPA budget process and the forthcoming reauthorization of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

- In planning and implementing its cleanup programs, EPA coordinates extensively with various EPA offices, potentially responsible parties (PRPs), state and planning authorities, and local communities. These requirements may influence the sequence of work and types of technologies selected for a site.

- Federal, state, and PRP funding for Superfund site cleanups may fluctuate in the future. For Superfund remedial actions, the states contribute 50 percent of the construction and operation costs where they own the site and 10 percent of operations and maintenance (O&M) costs for all Superfund actions in their state. Also, PRP contributions to site remediation may be affected by business conditions and EPA's enforcement program activities.

- Changes to the Superfund process proposed in Congress over the past several years, as well as EPA administrative reforms, could significantly impact the total amount and schedule of remediation work required, and the types of technologies to be used. Some of the proposals are listed below:

  — Change the federal and state cleanup standards that apply. For example, proposed legislative changes may reinforce existing EPA administrative reforms to consider future land use in setting cleanup goals.

— Emphasize the treatment and disposal of only the highly toxic or highly mobile contamination at a site. In this proposal, other waste could be contained and the current preference for permanent remedies would be removed or reduced. Changes to the mandate for permanent remedies could cause changes in the types of treatment technologies used.

— Change the liability aspect of CERCLA to reduce the cost and time needed to assign the liability for a cleanup project. This proposal would reinforce and build upon initiatives under EPA administrative reforms. If PRP liabilities are reduced, more funds may be needed from the Superfund or other federal programs, thereby creating additional competition for limited federal funds. Nevertheless, because of the expected reduction in litigation, site cleanup decisions may occur more quickly.

— Limit the addition of new sites to the NPL. This proposal may reduce the size of the future federal Superfund cleanup market and cause some sites to be transferred to other federal and state programs. Although some sites not listed on the NPL are addressed under other programs, others may be addressed only minimally. In addition, the emphasis placed on innovative technologies by state programs varies. As described in Chapters 6 through 9 of this report, state and other federal cleanup actions are significantly affected by current budget conditions.

3.2 Number of Sites

The market for cleanup at NPL sites includes those sites where remedial action (RA) is scheduled, but has not yet begun. Remedial action is the phase of cleanup that typically involves construction, and in some cases operation, of the remedial technology. As of September 30, 1996, 547 proposed and final NPL sites not owned by the federal government still required at least one further remedial action.[1] The location of these sites is shown in Exhibit 3-1. An additional 124 NPL sites located at federal facilities require one or more RAs. Federal facilities on the NPL are included in the market estimates provided in Chapters 6, 7, and 8.

For some of the 547 sites EPA has identified more than one operable unit (OU) or part of the site for which an RA is planned; the total number of OUs with planned RAs is 726. Over one-third of these OUs are undergoing remedial investigations and feasibility studies (RI/FSs), and still awaiting the selection of remedial technologies (Exhibit 3-2). For 53 percent, remedies have been selected, but not implemented (*i.e,*. RA has not begun). Although the specific technologies selected are not included in this report, Chapter 2 enumerates the treatment technologies selected through fiscal year (FY) 1995 and provides references for additional site-specific information. Appendix Exhibit A-5 lists the names of the sites, OU number, state, EPA identification number, and phase of the project.

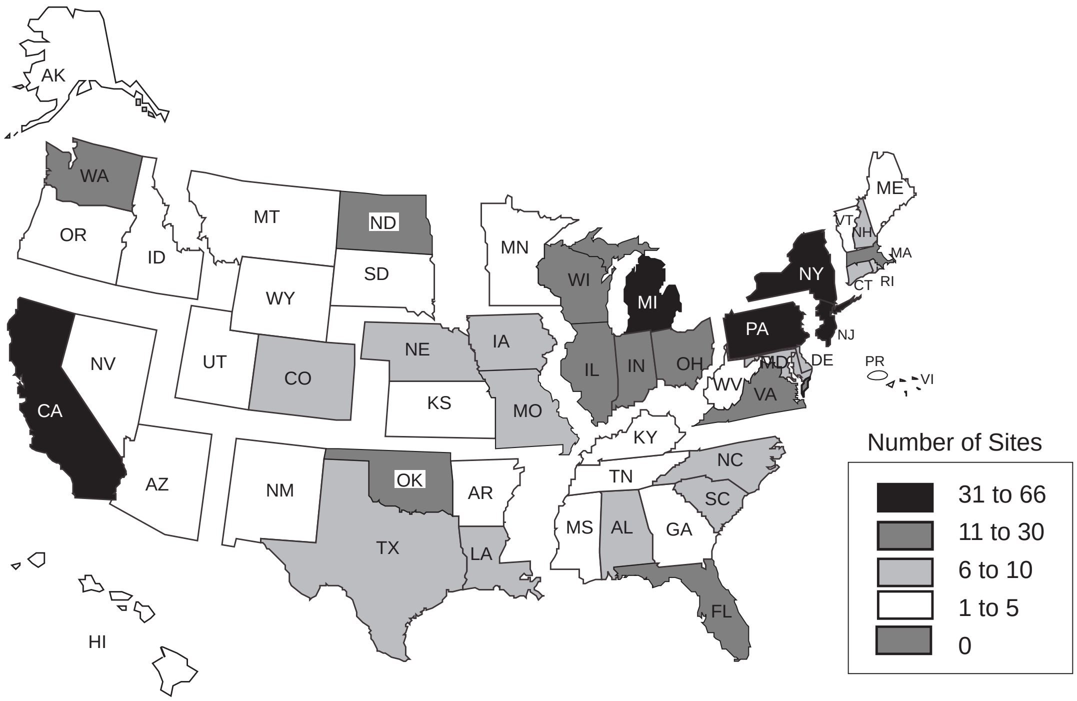
Cleanup contractors for EPA-lead sites typically are selected after the remedial design (RD) has been completed. For PRP-lead sites, some PRPs select a vendor to conduct both the RD and RA. EPA estimates that PRPs will conduct RDs and RAs at about 70 percent of the 547 sites.

This report does not estimate the smaller market for remediation technologies in the Superfund removal program. As of the end of FY 1996, the EPA had conducted removal actions at 3,450 sites, over 80 percent of which are not currently NPL sites.[2] It is difficult, however, to predict the number, type, and timing of the cleanup of these sites. Removals are usually limited to one year and $2 million, and historically have relied less on innovative technologies than have longer term remedial actions. The innovative technologies addressed in this report have been used 32 times in 27 removal actions.[3]

Future NPL Sites

The estimate of the future NPL market in this report does not include future listings on the NPL, which also represent a market for remediation technologies. The number of sites that eventually will be listed is uncertain and may depend upon forthcoming legislation to reauthorize CERCLA. Between 1993 and July 1996, the Agency listed a total of 120 sites, or an average of 30 per year. The characteristics of NPL

Exhibit 3-1: Location of NPL Sites with Planned Remedial Actions



Note: Includes 547 proposed and final National Priority List (NPL) sites not owned by the federal government.
Source: U.S. EPA, Office of Emergency and Remedial Response, CERCLA Information System, September 30, 1996.

sites vary with the basis for listing and when the listing occurs. The three basic mechanisms for adding sites to the NPL are the following:

- Each state may nominate a total of one site without regard to its Hazard Ranking System (HRS) score;
- The Agency may propose for listing sites recommended by the Agency for Toxic Substances and Disease Registry; and
- A site may be evaluated with the HRS, and if the score is above 28.5, that score could be used to support adding that site to the NPL.

This third mechanism is the primary tool used to add sites. Most of the sites currently listed on the NPL were ranked under the original HRS, which emphasized exposure to contaminated ground-water. The revised HRS also considers soil and sediment exposure and additional pathways.[4]

Exhibit 3-2: Phase of Remediation of Operable Units at Non-Federal NPL Sites with Planned Remedial Actions

Remedial Assessment Not Begun	Study Under Way	Remedy Selected	Design Under Way	Total Operable Units
76	263	87	300	726

Note: Total sites equals 547; each site may contain more than one operable unit.

Source: U.S. EPA, Office of Emergency and Remedial Response, CERCLA Information System, September 30, 1996.

Potential for Innovative Technology Use

Using trends from past years, EPA estimates that about 15 percent of remedial actions for which EPA has not selected remedies will incorporate at least one innovative technology. About 15 percent of all RODs signed between FY 1990 and FY 1995 included at least one innovative technology, primarily for source control (*e.g.*, treatment of soil). This percentage has varied widely from year-to-year, from six percent to 32 percent. This percentage is greater if only source control RODs are considered (Exhibit 2-4). In FY 1995, 22 percent of source control RODs included an innovative technology.

3.3 Site Characteristics

This section describes how frequently certain waste matrices and contaminants are being remediated at NPL sites. This information can be used to estimate the potential to use certain remedial technologies at NPL sites where RAs are planned.

The analysis is based on a study of sites with past RODs. Out of 994 NPL sites with RODs as of the end of FY 1994, data on contaminants and contaminated matrices are available for 944 sites.[5] Data are not available for the other 50 sites with RODs, many of which had "No Action" RODs which did not call for remediation. Because these 944 sites represent 70 percent of the 1,355 sites ever listed or proposed for listing on the NPL as of the end of FY 1994, EPA believes that their characteristics are representative of those of other NPL sites.

Exhibit 3-1 presents the geographical location of the 547 NPL sites for which future RAs are planned. The data reflect the industrialized nature of these regions and the number of abandoned industrial and commercial facilities. New Jersey, Pennsylvania, New York, California, and Michigan alone account for approximately 44 percent of these NPL sites.

3.3.1 Types of Contaminated Matrices

Exhibit 3-3 shows the percentage of NPL sites remediated for various contaminated matrices: 76 percent of sites require remediation of groundwater, 72 percent of soil, 22 percent of sediments, and 12 percent sludge. Because too few sites with RODs contain data on other types of wastes, such as waste piles, mine tailings, and liquid wastes, a meaningful analysis for those types of wastes could not be done.

3.3.2 Types of Contaminants

Sites with RODs were analyzed for the presence of three major contaminant groups: volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), and metals. These broad groups of contaminants were further divided into more specific treatability subgroups (discussed below) that better coincide with the application of certain technologies, such as bioremediation. The 12 most frequently occurring contaminants also are identified. Appendix Exhibit A-2 lists common chemicals in each group. With the exception of polychlorinated biphenyls (PCBs) and pesticides, which are grouped with SVOCs, chemicals and elements are grouped in accordance with EPA test methods for evaluating solid waste.[6]

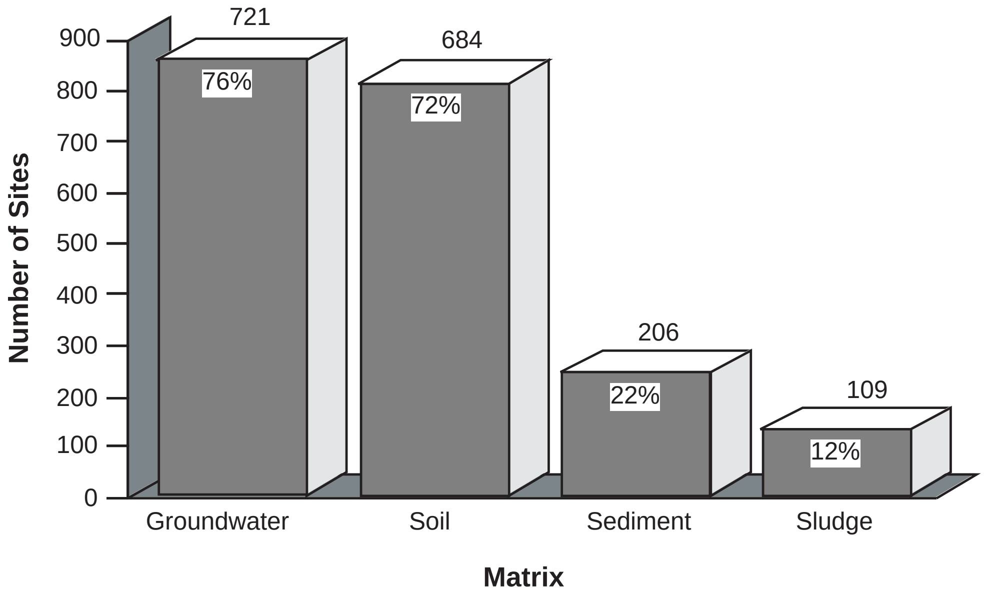
Major Contaminant Groups

Exhibit 3-4 presents the frequency of cleanup of the major contaminant groups. VOCs are to be remediated at 71 percent of sites, followed by metals (65 percent) and SVOCs (61 percent). For this analysis the occurrence of a contaminant group at a site is counted only once, whether or not it was found in more than one matrix. These data also indicate that the NPL sites tend to be complex: all three groups (VOCs, SVOCs, and metals) are to be remediated at 41 percent of the sites and two groups are to be remediated at 25 percent of the sites, but not necessarily in the same matrix. The sites listed as "others" only contain contaminants described as radioactive elements, non-metallic inorganics such as nitric oxides, explosives and asbestos, or unspecified organics or inorganics.

Subgroups of Volatile and Semivolatile Organics

Two of the major contaminant groups, VOCs and SVOCs, were subdivided into more specific treatability subgroups that better coincide with the application of certain technologies, such as bioremediation. Exhibit 3-5 shows the frequency

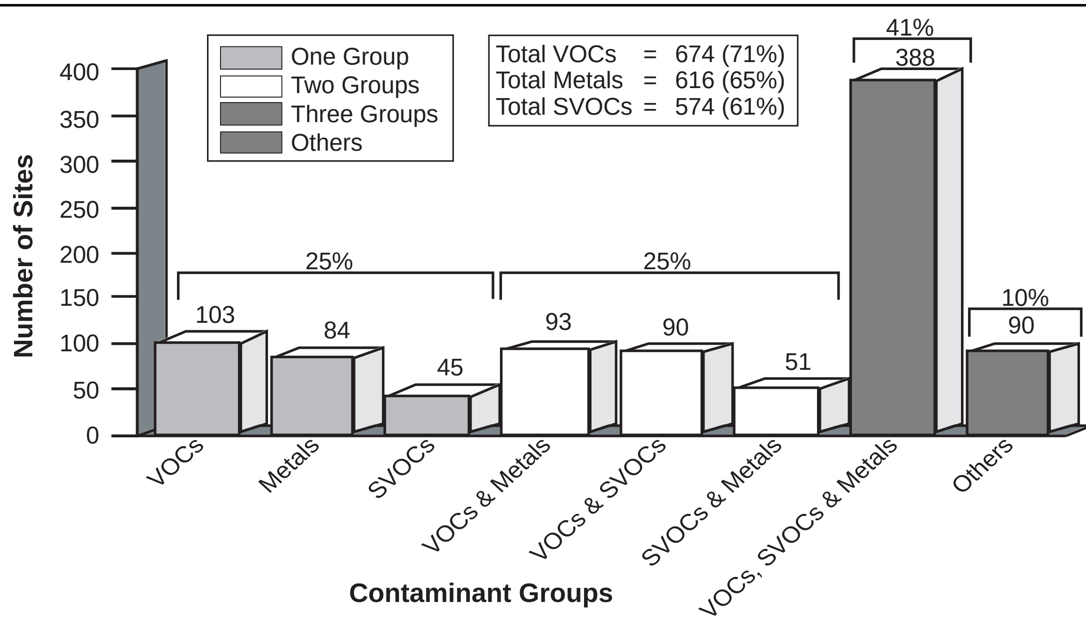
Exhibit 3-3: Frequencies of Contaminated Matrices at NPL Sites with RODs



Notes: Based on data available for 944 National Priorities List sites with fiscal year 1982-1994 Records of Decision (RODs). A site may contain more than one contaminated matrix.

Source: U.S. EPA, Office of Emergency and Remedial Response, ROD Information Directory, December 1995.

Exhibit 3-4: Frequencies of Major Contaminant Groups at NPL Sites with RODs

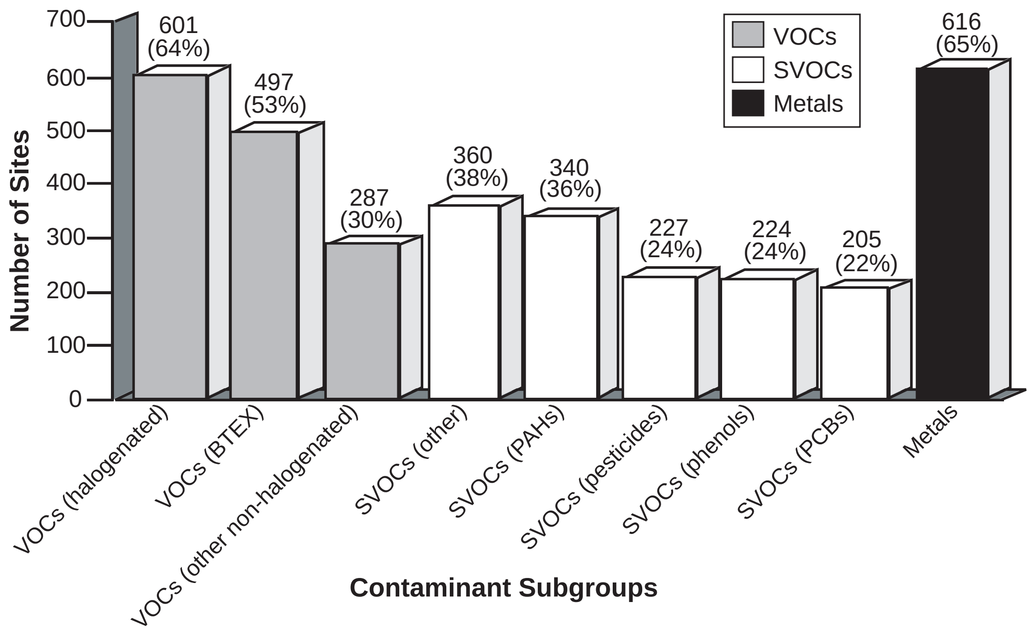


Notes: Based on data available for 944 National Priorities List sites with fiscal year 1982-1994 Records of Decision (RODs). Percentages do not total to 100 due to rounding.

The 90 sites listed as “others” contain only radioactive elements, non-metallic inorganics, or unspecified organics or inorganics.

Source: U.S. EPA, Office of Emergency and Remedial Response, ROD Information Directory, December 1995.

Exhibit 3-5: Frequencies of Major Contaminant Subgroups at NPL Sites with RODs



Notes: Based on data available for 944 National Priorities List sites with fiscal year 1982-1994 Records of Decision (RODs). Contaminant information for 90 of the sites with data does not fall into these subgroups. A site may contain one or more of the nine contaminant subgroups.

Source: U.S. EPA, Office of Emergency and Remedial Response, ROD Information Directory, December 1995.

of cleanup of these subgroups as well as the metals group. The subgroups are described below, grouped according to the three major contaminant groups:

- VOCs include: halogenated, BTEX (benzene, toluene, ethylbenzene, xylene), and other non-halogenated VOCs (ketones and alcohols). The most prevalent class of organics, halogenated VOCs, which are widely used as solvents, are being remediated at 601 (64 percent) of the sites. With regard to BTEX, although many of these compounds result from petroleum products, CERCLA prohibits listing sites on the NPL that are contaminated with petroleum products alone.

- SVOCs include: polychlorinated biphenyls (PCBs), polynuclear aromatic hydrocarbons (PAHs), pesticides, phenols (including pentachlorophenol), and other SVOCs, which include chlorobenzene and phthalates. The most common SVOCs are PAHs and pesticides, to be addressed at 36 percent and 24 percent of sites, respectively.

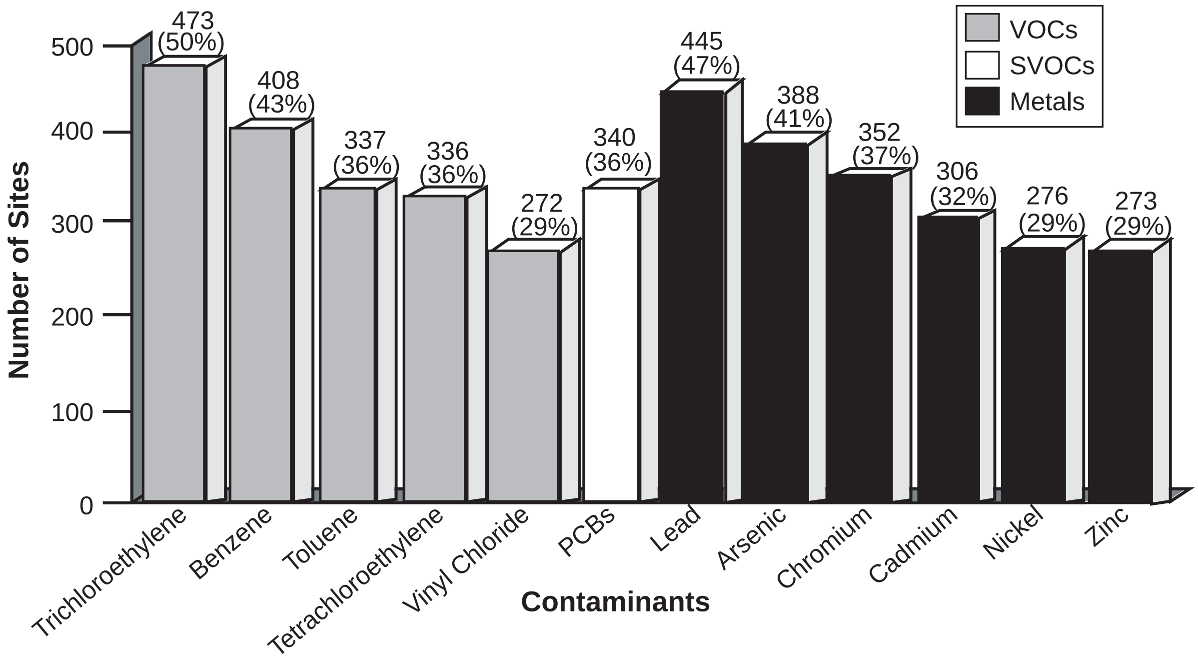
- Metals include: lead, arsenic, chromium, cadmium, zinc, nickel, and other less frequently found metals.

For this analysis, each subgroup was counted only once per site, regardless of whether it occurred alone, with other types of contaminants, or in more than one matrix. Because more than one contaminant subgroup can be present at a site, the total number of occurrences is greater than the total number of sites.

Most Common Individual Contaminants

Exhibit 3-6 shows the 12 contaminants most commonly found to need remediation at NPL sites. The list contains five VOCs, six metals, and one SVOC. Again, a contaminant is only counted once for each site, even if it occurs in more than one matrix; and more than one contaminant can occur per site.

Exhibit 3-6: Frequencies of the Most Common Contaminants at NPL Sites with RODs



Notes: Based on data available for 944 National Priorities List sites with fiscal year 1982-1994 Records of Decision (RODs). A site may contain one or more of these contaminants.

Source: U.S. EPA, Office of Emergency and Remedial Response, ROD Information Directory, December 1995.

3.3.3 Estimated Quantities of Contaminated Material

The market also can be described in terms of the quantity of contaminated material to be remediated. Fewer RODs contain quantity data than the number that contain contaminant and matrix information. The RODs for 42 percent of the 994 sites with RODs contain information on the quantities of soil, sludge, or sediment to be remediated using any method (*i.e.*, treatment, containment, or off-site disposal). The data from these sites are used to characterize the quantities of material requiring some type of remediation.

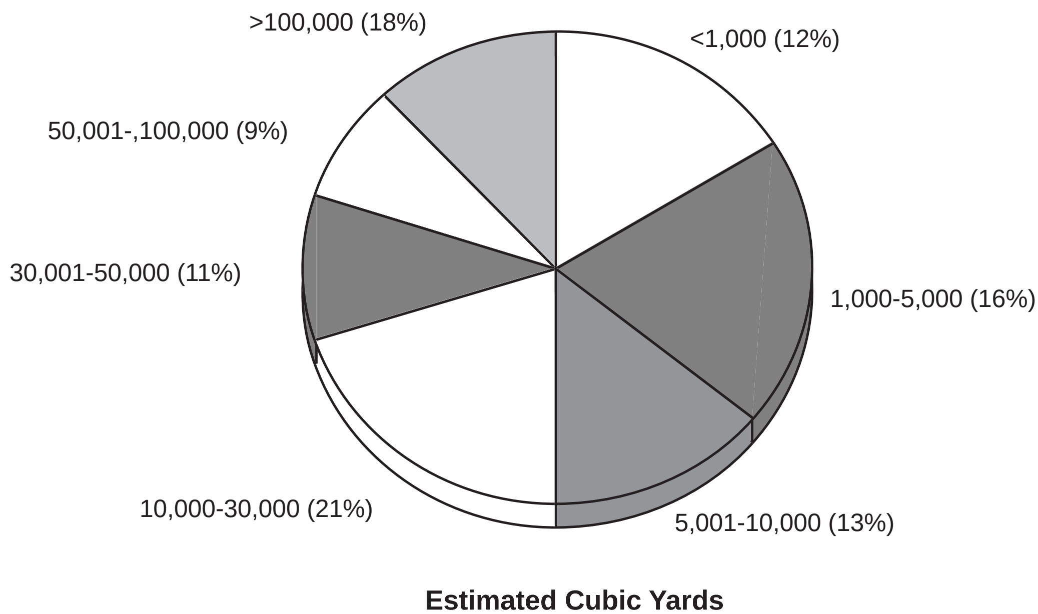
Distribution of Quantities

Exhibit 3-7 presents the distribution of the total quantities per site of contaminated soil, sediment, and sludge requiring remediation. Based on these estimates, approximately 40 percent of the sites are expected to contain 10,000 or fewer cubic yards, and only 18 percent of the sites are expected to contain 100,000 or more cubic yards of contaminated material. These data indicate an appreciable market for technologies that can effectively treat small quantities of contaminated media. These data include all available data on material to be treated, contained, or disposed. However, because reviews of RODs indicate that quantities of waste to be capped often are not documented in the ROD, the proportion of sites that contain large quantities of wastes may be greater than the data indicate. The quantity distributions for soil, sediment, and sludge, which are shown in Appendix Exhibit A-3, indicate that about 90 percent of the sites with data involve contaminated soil to be remediated.

Quantities by Major Contaminant Group

The quantities of contaminated material (soil, sediment, and sludge) at the 547 non-federal NPL sites with planned RAs were estimated for the three major contaminant groups (*i.e.*, VOCs, SVOCs, and metals) from estimates contained in the RODs for sites containing similar contaminants. The average quantity for each contaminant group at the sites with ROD data was multiplied by the estimated number of sites

Exhibit 3-7: Distribution of Total Quantities of Contaminated Soil, Sediment, and Sludge at Selected NPL Sites with RODs



Notes: Based on data available for 944 National Priorities List sites with fiscal year 1982-1994 Records of Decision (RODs). See Appendix Exhibit A-3 for supporting data.

Source: U.S. EPA, Office of Emergency and Remedial Response, ROD Information Directory, December 1995.

that contain the same contaminant groups based on the percentages in Exhibit 3-4. Statistical outliers were not included in the calculation.

Exhibit 3-8 indicates the estimated quantities of contaminated materials at NPL sites by contaminant group. An estimated 33 million cubic yards of soil, sludge, and sediment are to be remediated at the sites. Much of this material, 24 million cubic yards, is accounted for by materials contaminated by metals, alone and in combination with other contaminants. VOCs, alone and combined with other contaminants, total 23 million cubic yards; and SVOCs total 21 million cubic yards.

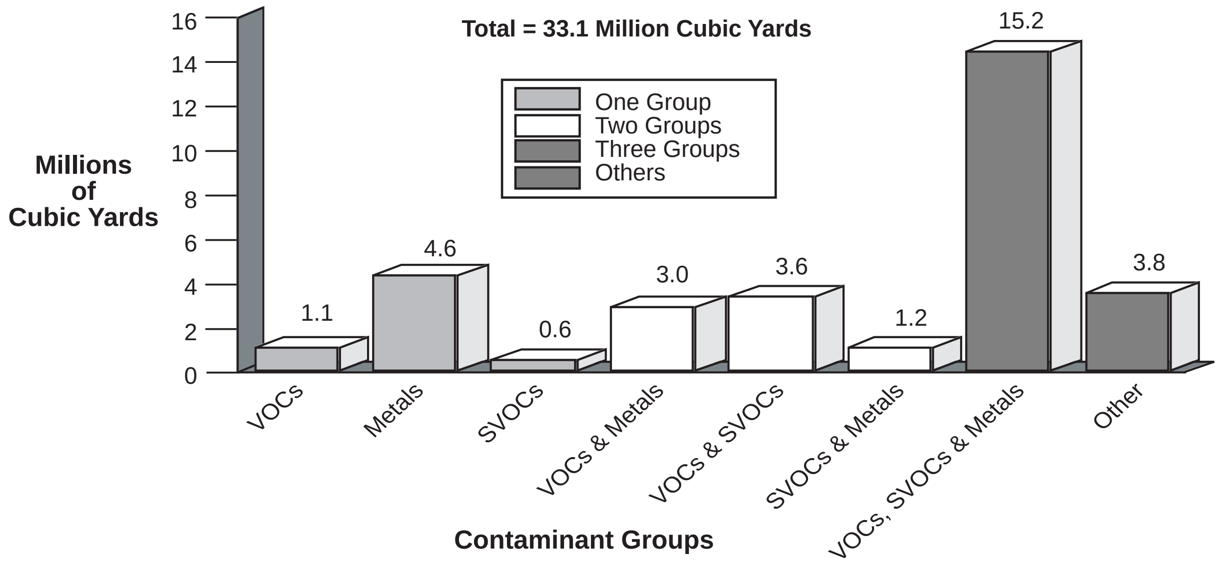
In developing these estimates, it was assumed that all of the contaminated material at a site contained the contaminant groups present. The average site quantities by contaminant group varied from a low of 19,000 cubic yards for VOCs alone to a high of 93,000 cubic yards for metals alone. The details of the calculations are shown in Appendix Exhibit A-4.

3.4 Estimated Cleanup Costs

EPA has estimated the value of the market for 746 OUs at the 547 non-federal facility NPL sites with planned RAs. The estimated total RA cost for non-federal Superfund sites that have not begun RA is $6.7 billion in 1996 dollars. This estimate does not include costs for federal facility NPL sites, which are described in Chapters 6 through 8. The NPL site cost estimate also does not include costs for site assessments and studies, designs, operation and maintenance, long-term response actions, removals, site management, administrative costs such as payrolls, other federal agency support, oversight of potentially responsible party (PRP)-lead cleanups, and enforcement activities. This estimate is based on the following assumptions:

- EPA assumes that PRPs will be responsible for at least 70 percent of future RA starts. Seventy percent of the 746 OUs yields 522 PRP-lead OUs: the remaining 224 OUs are fund- or state-lead.

Exhibit 3-8: Estimated Quantity of Contaminated Soil, Sediment, and Sludge by Major Contaminant Groups at NPL Sites with Planned Remedial Actions



Notes: These estimates are the quantities for 547 non-federal NPL sites that require remedial action. A site is counted only once. These values are derived from estimates in fiscal year 1982-1994 Records of Decision (RODs) for 420 sites containing similar contaminants. See Appendix Exhibit A-4 for supporting calculations.

"Other" includes 52 sites that contain only radioactive elements, non-metallic inorganics, or unspecified organics or inorganics.

Source: U.S. EPA, Office of Emergency and Remedial Response, ROD Information Directory, December 1995.

- Based on a study sponsored by DOE, the costs of cleaning up PRP-lead sites are about 15 percent less than those of fund-lead sites, on average.[7] These costs include site investigations, design, and construction.

- For fund-lead sites, the average RA cost is $10 million per OU.[8] Using the previous assumption, the RA cost for a PRP-lead OU will average $8.5 million ($10.0 million minus 15 percent). RA cost includes work conducted by the cleanup contractors, oversight by EPA, and initial operation and maintenance costs.

Multiplying the above figures (224 OUs X $10 million + 522 X $8.5 million) results in the $6.7 billion total costs for both Fund-lead and PRP-lead sites noted above.

Another indication of the amount of cleanup effort needed is the size of the EPA Superfund budget. Congress allocated $1.4 billion for FY 1997. These funds are allocated for direct and indirect site activities, oversight of PRP activities, research and development, and program support. The EPA budget does not include costs incurred by PRPs, states, or other federal agencies.

3.5 Market Entry Considerations

Technology decisions for Superfund sites are based on the specific information available for each site and the state-of-the-art of the available technologies. Information on new technologies is particularly critical at two points in the decision-making process: during remedy selection, and during remedy design and procurement. Technology vendors must be aware of the information sources used as well as how site managers consider their options during these two cleanup phases.

3.5.1 Market Considerations During Remedy Selection

The Superfund RI/FS process is an integrated, phased approach to characterizing the site risks and evaluating remedial alternatives. Early in the RI/FS stage, technologies are identified and screened with respect to technical implementability, effectiveness, and relative cost. To ensure that Superfund site managers and consulting engineers consider a given technology, it is important to make them aware of the technology at this early stage. During the final technology evaluation, later in the RI/FS, technologies are compared and evaluated using the nine evaluation criteria specified in the National Contingency Plan (NCP). Information on technology performance and cost is particularly important during this final evaluation. EPA and engineering consulting firms (who usually conduct the RI/FSs for EPA, states, and PRPs) use a variety of information sources, many of which are described in Section 3.5.4, to identify potential technologies. Since information for innovative technologies may be limited, treatability studies or on-site demonstrations may be used to assess cost and performance.

While Superfund policies encourage the selection and implementation of new technologies, the Superfund remedy selection process can present some hurdles for innovative technology vendors:

- Information on many innovative technologies is limited. Superfund site managers and consulting engineers may not have as much information on the performance and cost of an innovative technology as for an established technology. The Agency and others have developed reports and databases to disseminate information about remedial technologies. Nonetheless, Superfund site managers may have difficulty comparing the merits of an innovative and a conventional technology if they do not have information on a technology's cost, implementability, short- and long-term effectiveness, and ability to reduce the toxicity, volume, or mobility of the contaminants.

- Treatability studies and on-site demonstrations may be impractical. The NCP and EPA policy encourage the use of bench- or pilot-scale treatability studies, when appropriate and practical.[4] Furthermore, EPA policy stipulates that: *promising new technologies should not be eliminated from consideration solely because of uncertainties in their performance and cost, particularly when timely treatability study could resolve those uncertainties*.[9] In reality, the funding and schedule for site cleanup, as well as contracting and regulatory impediments, may preclude the use of studies and demonstrations.

- The RI/FS contractor may be prohibited from bidding on the RA. Also, for EPA- and state-lead sites, the remedial design contractor at a site usually does not conduct the remedial action. A technology vendor that also provides RI/FS services should determine the relative value of the two opportunities before deciding which service to provide.

To make their capabilities more widely known, technology vendors should consider participating in the programs cited in Section 3.5.4, and contacting remedial project managers (RPMs) and consulting engineers. A vendor who is interested in a particular NPL site, may contact the assigned EPA RPM for more information. The appropriate EPA regional office, listed in Appendix E, can provide the identity of the RPM for a specific site. Also, information on specific technologies may be provided to consulting engineers for their consideration in the analysis of cleanup options. Consulting engineers include firms under the Alternative Remedial Contracting Strategy (ARCS) or Remedial Action Contracting Strategy (RACS) to conduct RI/FSs. A current list of regional service contracts also is provided in Appendix E. The Agency expects to award additional RAC contracts in the future.

3.5.2 Market Considerations During Design and Procurement

Once a remedy has been selected and documented in a ROD, the project enters the design process, where the details of the cleanup, such as waste quantities and performance standards, are more clearly defined. At this stage, federal and state agencies can make use of technology information for preparing requests for proposals and evaluating bids.

All Superfund sites requiring cleanup for which EPA has the lead currently are funded by one of the following mechanisms:

- Remedial Action Contracting Strategy (RACS) and Alternative Remedial Contracting

Strategy (ARCS): EPA contracts with architecture/engineering (A/E) firms for the remedial program.

- Emergency Remedial Contracting Strategy (ERCS): EPA contracts with A/E firms for the removal program.

- Interagency Agreements (IAGs): EPA enters into agreements with the U.S. Army Corps of Engineers, Bureau of Reclamation, or other federal agencies.

- Cooperative Agreements (CAs): EPA enters into agreements with states, political subdivisions, or Native American Tribes.

As previously stated, a list of regional service contracts is included in Appendix E.

The three most definitive sources of information on selected remedies for sites entering RD and RA are the ROD, the *ROD Annual Report*,[10] the ROD CD-ROM, [11] and the *Innovative Technologies: Annual Status Report Database (ITT Database)*.[12] The ROD and the *ROD Annual Report* provide detailed information on the site contaminants and risks posed, the selected remedy, estimated costs, and associated cleanup levels. The latest publication of the *ROD Annual Report* is for FY 1992. The RODs on disk and paper copies are available through the Superfund automated phone request line (800-775-5037 or 202-260-8321) For innovative treatment and selected established technologies, the *ITT Database* provides more current summary information on the contaminants and media to be remediated, anticipated or actual cleanup schedule, and expected site lead (EPA, state, PRP).

A vendor may use these publications to identify opportunities. Vendors also may provide cost, performance, and availability information to the EPA RPM or state site manager and the site remedial design firm or agency. Vendors can enhance their responsiveness to requests for proposals (RFPs) for site remedial actions by keeping abreast of site activities. Once an RFP has been issued, the award of a contract may take weeks or months.

3.5.3 Research and Development

Recent cuts in funding have reduced the number and scope of research, development, and demonstration programs conducted by federal agencies, particularly those at EPA. Some opportunities still exist for vendors who want to work cooperatively with EPA, and the Departments of Defense (DOD) and Energy (DOE). In many cases the programs involve other industry partners as well. Some of the more important efforts include the Superfund Innovative Technology Evaluation (SITE) program, the Remediation Technologies Development Forum (RTDF), and the Clean Sites Public-Private Partnerships project. These programs involve on-site demonstration projects. The three are discussed in Section 2.5. Section 3.5.4 describes how to access SITE program reports and other published information. In addition, there is a coordinated effort by federal agencies to document the cost and performance results of completed remediation projects.

3.5.4 Disseminating Innovative Technology Information

Several sources of information on innovative and established treatment technologies have been developed to help potential technology users identify and evaluate cleanup alternatives and technology vendors. Some of the primary resources of importance to both technology users and suppliers are listed below. Most of these resources are available for downloading from the Clean-Up Information System (CLU-IN) via internet (http://www.clu-in.com) or modem (301-589-8366). Voice help is available at 301-589-8368. The sources listed below also may be available from EPA’s National Center for Environmental Publications and Information (NCEPI) voice (800-490-9198 or 513-489-8190), or fax (513-489-8695).

- *Bioremediation in the Field Search System (BFSS)*.[13] BFSS is a computer database of information on over 400 waste sites across the U.S. where bioremediation is being tested or implemented, or has been completed. It is available for downloading from CLU-IN. To provide data for input into the next system update, vendors may call 617-674-7329, or fax: 617-674-2851.

- *Vendor Information System on Innovative Treatment Technologies (VISITT)*.[14] This computer database allows users to quickly screen innovative technologies for particular applications. The EPA's Technology Innovation Office (TIO) released the latest version in August 1996, and updates the system annually. Version 5.0 contains current vendor-supplied information on 346 innovative treatment technologies to treat soil, both above ground and in place, groundwater *in situ*, and off-gas generated by innovative treatment systems. The information provided on each method includes contaminants and matrices treated, performance data, and project experience. VISITT is available from CLU-IN and NCEPI. Information on how to be included in VISITT is available from the VISITT/VendorFACTS Hotline at 800-245-4505 or 703-883-8448, or on the internet at http://www.prcemi.com/visitt.

- *Vendor Field Analytical and Characterization Technologies System (VendorFACTS).*[15] VendorFACTS is a computer database that provides information on innovative technologies used to measure or monitor hazardous contaminants at contaminated sites. The 128 technologies in the system address air, water, and soil. VendorFACTS is available from CLU-IN and NCEPI. Information on how to be included in VendorFACTS is available from the VISITT/VendorFACTS Hotline (see above). TIO released the second version of the database in March 1997.

- *Groundwater Remediation Technologies Analysis Center (GWRTAC).* In 1995, EPA established GWRTAC at the National Environmental Technologies Applications Center (NETAC) in association with the University of Pittsburgh. This center develops and disseminates information on current research development and demonstration efforts related to *in situ* groundwater technologies. The Center also analyzes trends in technology development. GWRTAC operates a homepage at http://www.gwrtac.org.

- *Superfund Innovative Technology Evaluation (SITE) Program*. Under this program, which is described in Section 3.5.3, EPA provides reports on completed SITE evaluations. The *SITE Profiles* describes each project and lists available reports.[16] The document may be ordered from the ORD publications office (513-569-7562) or viewed on the internet at http://www.epa.gov/ORD/SITE. Information on how to participate in the program is available from EPA's National Risk Management Research Laboratory at 513-569-7696.

- Technical Guidance. EPA, often jointly with other organizations, develops guidance on specific types of innovative technologies. A list of selected references on innovative technologies is found in *Bibliography for Innovative Site Cleanup Technologies,* available from CLU-IN or NCEPI.[17]

Since these sources are often used in the preparation of lists of cleanup alternatives or bid documents, it is important that technology vendors and developers ensure that information on their products and services are represented. In addition, joining and participating in activities of various professional societies and trade groups may help a vendor promote specific capabilities.

3.6 References

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3. U.S. Environmental protection Agency, Office of Solid Waste and Emergency Response, Technology Innovation Office, *Innovative Treatment Technologies: Annual Status Report (Eighth Edition)*, EPA-542-R-96-010, November 1996.

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8. U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, *The Facts Speak for Themselves: A Fundamentally Different Superfund Program*, November 1996.

9. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, *Initiatives to Promote Innovative Technology in Waste Management*, OSWER Directive 9380.0-25, April 29, 1996.

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17. U.S. Environmental Protection Agency, Office Solid Waste and Emergency Response, Technology Innovation Office, *Bibliography for Innovative Site Clean-Up Technologies*, EPA-542-B-96-003, August 1996.

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CHAPTER 4
DEMAND FOR REMEDIATION OF RCRA CORRECTIVE ACTION SITES

EPA estimates that over 6,000 facilities currently operate or have operated as treatment, storage, or disposal facilities (TSDFs) regulated under the Resource Conservation and Recovery Act (RCRA) (42 U.S.C. UU6901-6922k). Prior to the creation of RCRA, facilities that treated, stored, or disposed of hazardous wastes often experienced releases of wastes into the environment. Much of that waste, which is similar to the hazardous wastes found at Superfund sites, was disposed of intentionally or unintentionally on the land. While not all RCRA facilities will require remediation, this program represents a substantial market for environmental site characterization and remediation services. EPA is authorized under RCRA and fully committed to oversee the correction of past contamination.

RCRA assigns the responsibility of corrective action to facility owners and operators and authorizes EPA to oversee corrective action. Unlike Superfund, RCRA responsibility is delegated to states. EPA and authorized states have completed initial assessments of potential environmental contamination at over 70 percent of RCRA facilities required by statute to address corrective action, but are still examining the extent of that contamination and the scope of remediation needed. Environmental contamination at many RCRA facilities is expected to be less severe than that at Superfund sites, but a number of RCRA facilities have corrective action problems that could equal or exceed those of many Superfund sites. EPA and states authorized by EPA to provide corrective action oversight expect remediation of existing contamination at RCRA facilities to extend into the next century.

4.1 Program Description

RCRA mandates several regulatory programs, but the largest is the waste management program, known as Subtitle C, which sets forth the comprehensive national requirements for managing the treatment, storage, disposal, and recycling of solid and hazardous waste. Among other provisions, Subtitle C establishes a management system to control new hazardous waste from the time of its generation to its ultimate disposal (“cradle-to-grave”). Although its primary purpose is to prevent releases of wastes into the environment by minimizing waste generation and by creating reuse and recycling incentives, Subtitle C contains important requirements to address releases of contaminants from RCRA facilities that will influence the nature and amount of nationwide remediation activities.

Releases of contamination at RCRA facilities are addressed under the RCRA corrective action program, which is the primary focus of this chapter. Congress initially authorized EPA to promulgate requirements for monitoring and remediating only on-site releases to groundwater from hazardous waste management units, such as landfills. Later, with enactment of the 1984 Hazardous and Solid Waste Amendments (HSWA) of RCRA, Congress greatly expanded EPA’s corrective action authority to include releases to all environmental media from regulated solid waste management units (SWMUs) at TSDFs seeking a permit under Subtitle C. A solid waste management unit is a discernible unit in which solid wastes have been placed at any time, irrespective of whether the unit was intended for the management of solid or hazardous wastes. This definition includes any area of a facility at which solid wastes have been routinely and systematically released. A release may include intentional or accidental spillage, leakage, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposal of hazardous waste into the environment. It also includes the abandonment or discarding of barrels, containers, and other closed receptacles containing hazardous wastes or hazardous constituents. Both the RCRA corrective action program for cleaning up past contamination and the hazardous waste management program for preventing contamination are administered by EPA's Office of Solid Waste (OSW) and by states EPA has authorized to implement one or both programs.

In 1990 EPA prepared an overall strategy known as the RCRA Implementation Study (RIS). The strategy, which was designed to encourage corrective actions that produce the greatest near-term environmental benefits, contains two key components: to increase the use of interim actions that reduce imminent threats and prevent further spread of contamination, and to set national priorities for directing resources to the highest priority facilities.[1]

EPA established procedures for implementing near-term corrective actions in the 1992 RCRA Stabilization Strategy.[2] This strategy provides guidelines for eliminating or controlling sources of contamination and stabilizing contaminated media at RCRA facilities to prevent the further spread of contamination before long-term cleanups can be undertaken. These actions are similar to those undertaken in Superfund emergency response actions but place greater emphasis on substantial action to prevent the migration of contamination within and outside the facility boundary.

Because of the anticipated magnitude of remedial needs at RCRA facilities, EPA developed a computer-based system known as the RCRA National Corrective Action Prioritization System (NCAPS) to help establish priorities for corrective action activities.[3] Among the factors considered in NCAPS are the history of hazardous waste release, likelihood of human and environmental exposure, and type and quantity of waste handled at the facility. NCAPS rankings are used by EPA and the states in conjunction with other considerations, such as enforcement history, to assign relative priorities among facilities subject to RCRA corrective action and allocate limited oversight resources. RCRA facilities are ranked high, medium, or low priority. Exhibit 4-1 presents the number of high-, mid-, and low-priority facilities that EPA and the states have ranked in each state and territory. In October 1995, there were approximately 1,540 high-priority facilities, 1,116 mid-priority facilities, and 1,175 low-priority facilities that had been ranked across the nation. High-priority facilities are the main focus of EPA's program to stabilize contaminated media because of their perceived threat to human health and the environment.

4.1.1 Corrective Action Process

EPA first set forth the procedural and technical corrective action requirements in a 1990 proposed rule (Subpart S in the RCRA Part 264 regulations, July 27, 1990).[4] In scope and level of detail, this 1990 proposed rule was analogous to the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). The 1990 proposed rule includes provisions for the consideration of cleanup standards, action levels, remedy selection, points of compliance, permitting and reporting procedures, and other technical and procedural issues. Although EPA has finalized only a few sections of the 1990 proposal, the bulk of the proposal has routinely been used as guidance during corrective actions. EPA published an Advanced Notice of Public Rulemaking (ANPRM) in May 1996.[5] It stresses flexibility of the corrective action process by including less detailed oversight, more emphasis on results, and greater reliance on state programs. The ANPRM is functioning as guidance for the program until a final rule is promulgated.

The corrective action process, which is consistent with other Agency cleanup programs, generally includes the following events:

1) EPA or an EPA-authorized state conducts an initial assessment, termed a "RCRA Facility Assessment" (RFA) of the TSDF. The RFA involves identification and examination of a facility's SWMUs to determine if a release has occurred or if the potential for a release exists.

2) If the RFA reveals a release, the owner or operator of the facility may be required to conduct a "RCRA Facility Investigation" (RFI), which involves sampling and other efforts to determine the nature and extent of contamination and to fully characterize the site's geological and hydrological conditions. Concurrent with the RFI, the owner or operator may take near-term action (such as stabilization) to contain or remediate the contamination. Near-term corrective actions under the 1992 RCRA Stabilization Strategy may take place at any time.

Exhibit 4-1: Priority Ranking of RCRA Facilities in Corrective Action Workload Universe

STATE OR TERRITORY	RANKING				TOTAL FACILITIES
	High	Mid	Low	Unranked	
Alabama	37	12	9	10	68
Alaska	10	8	3	1	22
Arizona	9	11	40	24	84
Arkansas	14	13	7	19	53
California	102	106	212	134	554
Colorado	28	32	48	51	159
Connecticut	76	18	11	1	106
Delaware	10	0	3	2	15
DC	0	1	0	0	1
Florida	44	30	9	11	94
Georgia	45	24	21	32	122
Guam	1	2	0	2	5
Hawaii	4	9	6	4	23
Idaho	4	5	6	2	17
Illinois	61	49	87	5	202
Indiana	52	65	63	7	187
Iowa	14	65	16	1	96
Kansas	13	22	8	1	44
Kentucky	30	23	11	8	72
Louisiana	37	15	11	11	74
Maine	10	7	0	4	21
Maryland	23	7	8	3	41
Massachusetts	21	13	6	1	41
Michigan	61	59	54	5	179
Minnesota	17	13	46	3	79
Mississippi	16	10	6	7	39
Missouri	29	45	18	2	94
Montana	2	5	1	0	8
Nebraska	10	18	6	3	37
Nevada	2	5	7	6	20
New Jersey	63	52	50	61	226
New Mexico	11	5	4	4	24
New Hampshire	3	1	0	0	4
New York	88	32	31	30	181
North Dakota	3	1	3	1	8
North Carolina	30	25	17	18	90
Ohio	89	69	78	16	252
Oklahoma	18	16	5	4	43
Oregon	18	10	10	5	43
Pennsylvania	106	28	22	18	174
Puerto Rico	9	14	19	11	53
Rhode Island	5	1	5	0	11
South Carolina	35	13	9	11	68
South Dakota	2	1	0	0	3
Tennessee	28	9	12	21	70
Texas	87	84	95	112	378
Trust Territories	1	0	0	1	2
Utah	12	5	10	7	34
Vermont	3	2	1	3	9
Virgin Islands	1	0	0	0	1
Virginia	48	9	12	23	92
Washington	33	25	28	14	100
West Virginia	31	5	3	2	41
Wisconsin	24	17	35	1	77
Wyoming	10	0	3	5	18
TOTALS	**1,540**	**1,116**	**1,175**	**728**	**4,559**

Source: U.S. EPA, Office of Solid Waste, RCRIS National Oversight Database, October 17, 1995.

3) The TSDF owner or operator is responsible for performing a "Corrective Measures Study" (CMS) to identify alternative measures for remediating contaminated areas when needed. Sometimes the CMS can be truncated or eliminated if the remedial alternative is obvious. The CMS also can be conducted concurrently with the RFI or after the investigation has been completed.

4) Upon approval of a remedy by the regulatory agency, the owner or operator may begin "Corrective Measures Implementation" (CMI), which includes designing, constructing, maintaining, and monitoring the remedial measures.

4.1.2 Corrective Action Implementation

Permitting and Enforcement

Corrective action may be implemented through the RCRA permit process, state or federal enforcement orders, or voluntarily. RCRA permits are required for all facilities that treat, store, or dispose of hazardous waste. Section 3004(u) of HSWA, which is directed specifically toward controlling releases from SWMUs, is the primary authority requiring corrective action at permitted TSDFs. It compels a facility owner or operator to address SWMU releases resulting from past disposal or recent contamination whenever seeking a RCRA permit. Additional authority is available under §3004(v) of HSWA to require a permitted TSDF to clean up contamination beyond the facility boundary. Thus, HSWA requires all hazardous waste facilities that obtain a RCRA permit after November 8, 1984, to take corrective action for any releases from past disposal or recent contamination from the facility, including all SWMU and off-site releases. For a TSDF operating under interim status rather than a RCRA permit, EPA can invoke HSWA §3008(h), which provides for enforcement orders, or state orders in an authorized state, to address any release of hazardous waste. The corrective action process for both permitting and enforcement orders is similar.

For actual or potential releases not originating from a SWMU, such as a one-time spill from a vehicle traveling across a facility, or for releases at TSDFs with permits that pre-date HSWA, EPA may use its omnibus permitting authority pursuant to HSWA §3005(c)(3). This provision allows EPA to modify the facility's permit as necessary, requiring corrective action for any potential threat to human health or the environment. Also, HSWA §7003 gives EPA broad authority to seek injunctive relief in the appropriate U.S. District Court or to issue administrative corrective action orders for any waste from any source, including SWMUs, where the handling, storage, treatment, transportation, or disposal of solid or hazardous wastes may pose an imminent and substantial danger to public health or the environment.

To minimize the regulatory burden of RCRA corrective action without endangering public health or the environment, EPA has created exemptions and special permits. For example, EPA conditionally exempts from the Subtitle C hazardous waste regulations any waste samples collected solely for the purpose of monitoring or testing the characteristics or composition of RCRA facility contamination. Referred to as the Treatability Studies Sample Exemption Rule, which became final on February 18, 1994, the exemption places limits on the quantity of contaminated media that can be shipped, stored at a laboratory or testing facility, and treated there.[6] The exemption rule also limits the amount of time the contaminated media may be retained for analysis or treatment.

Special permits and modifications are available to facilitate the development and application of innovative treatment technologies. For example, facility owners or operators may obtain RCRA research, development and demonstration (RD&D) permits for pilot-scale evaluations of treatment technologies. For on-site technology demonstrations at corrective action sites, EPA, in collaboration with the state, has the authority to modify a permit or enforcement order by granting a site-specific treatability variance for contaminated soils and debris when the facility cannot achieve the stringent technology-based treatment standards in the Land Disposal Restrictions (LDRs). Other permitting options are available through the Subpart X rule of RCRA, titled "Miscellaneous Units," which addresses hazardous waste management units that do not fit the current RCRA definition of container, tank, surface impoundment, pile, land treatment unit, landfill, incinerator, boiler, industrial furnace, or underground injection well.[7] For example, EPA and the Department of Defense (DOD) have worked together to dispose of munitions using the permitting options available for pilot-scale RD&D and the Subpart X rule.

State Authorization

States are the primary implementors of the RCRA program, including RCRA corrective action. As of December 1995, EPA has authorized 47 states, some territories, and the District of Columbia to manage their own base programs for waste management and prevention. Thirty-two of these states and territories also were authorized to implement RCRA corrective action. In addition, many other states have for some time been operating similar corrective action programs under their own authorities. Prior to granting a state full authorization for corrective action, EPA regional offices may develop grants and cooperative agreements under RCRA §3011 giving the state the lead for corrective action oversight at specific facilities. Although authorized state programs must meet the minimum federal requirements, a state may adopt regulations that are more stringent than the federal requirements.

4.2 Factors Affecting Demand for Cleanup

The factors that are likely to impact the extent of RCRA corrective actions relate to efforts to build more flexibility into the application of national standards to specific facilities.

Flexibility is needed primarily to facilitate the application of the Subtitle C hazardous waste management requirements to contaminated media that are the result of corrective action, and to expedite the time consuming and expensive permitting process.

Media containing hazardous waste from RCRA corrective actions are subject to the same Subtitle C regulations that apply to the management of newly-generated hazardous wastes. This requirement can, however, be counterproductive when applied to the cleanup of individual facilities because it can impose unnecessary costs and delays and limit cleanup options. For example, application of Subtitle C LDRs can, in some situations, cause selection of corrective action remedies that are environmentally less desirable (*e.g.*, containment) and sometimes more expensive than alternative remedies that otherwise would have been considered.

EPA and the states have sought to address contaminated media and permitting problems through several regulatory and policy directives, such as the LDR treatability variances for contaminated soils and the regulations for corrective action management units (CAMUs) and temporary units. However, the establishment and implementation of the CAMU rule have been difficult. Three rulemaking efforts will ultimately influence the extent and nature of corrective actions needed. These are described below:

- The final CAMU and temporary unit rule, published in 1993, was intended to result in more on-site treatment of greater volumes of remedial wastes at less cost and more expeditiously by providing EPA or authorized states with the authority to designate a site-specific area at a RCRA facility, called a CAMU, for the placement of remediation wastes without triggering LDR requirements.[8] The rule also promoted innovative technologies that are appropriate for specific wastes and site characteristics.

  Although the CAMU rule has received broad support from many affected organizations, it is not clear how much impact it is having. The Environmental Defense Fund is concerned that the rule may result in unacceptably lenient treatment requirements and has challenged the legal and policy basis for the rule. The litigation, which has been stayed pending publication of the final Hazardous Waste Identification Rule - Media (HWIR-Media), has slowed application of the rule. EPA expects that the HWIR-Media rule will largely obviate the need for the CAMU rule, and is planning to propose withdrawal of the CAMU regulations as part of the HWIR-Media proposal (which is discussed below). In the meantime, CAMUs may be used to support efficient and protective cleanups.

- EPA and the states, through a unique co-regulator effort, are developing a new rulemaking called the *Hazardous Waste Identification Rule for Contaminated Media* (HWIR-Media). This proposed rule would modify the RCRA Subtitle C management requirements that apply to hazardous remediation wastes generated as a part of government-overseen cleanups (such as those under RCRA corrective action, Superfund, and other state programs). HWIR-Media was proposed on April 29, 1996.[9] The proposal addressed a number of issues such as: exempting remediation wastes from certain Subtitle C management requirements; modifying land disposal restrictions; streamlining cleanup permit requirements (including exempting cleanup-only permits from the requirement for facility-wide corrective action); and streamlining state authorization. The rule would not address cleanup standards, remedy selection, or other "how clean is clean" issues. EPA expects that the final HWIR-Media rule will be an essential complement to the final RCRA Subpart S corrective action regulations. EPA and authorized states are committed to issuing regulations that reduce cleanup delays, achieve regulatory relief, and protect human health and the environment.

- As described in Section 4.1.1, EPA published an Advanced Notice of Public Rulemaking (ANPRM) in May 1996 which modifies technical and procedural corrective action requirements. The ANPRM is functioning as guidance for the program until a final rule is promulgated.

- As part of the President's initiative for reinventing environmental regulations, the Administration has, with input from interested parties, identified potential legislative amendments to provide appropriate relief for high-cost, low-benefit RCRA provisions. The administration believes any reforms to RCRA should proceed separate from CERCLA reauthorization.

  A key area identified for potential legislative reform is the application of the RCRA Subtitle C hazardous waste management requirements to remediation wastes managed during cleanups overseen by regulatory agencies. EPA believes that an alternative framework for remediation waste management could be developed that would protect human health and the environment while streamlining existing cleanups at RCRA, Superfund and Brownfield sites. This approach may stimulate a significant number of new cleanups, and significantly reduce costs for managing remediation wastes.

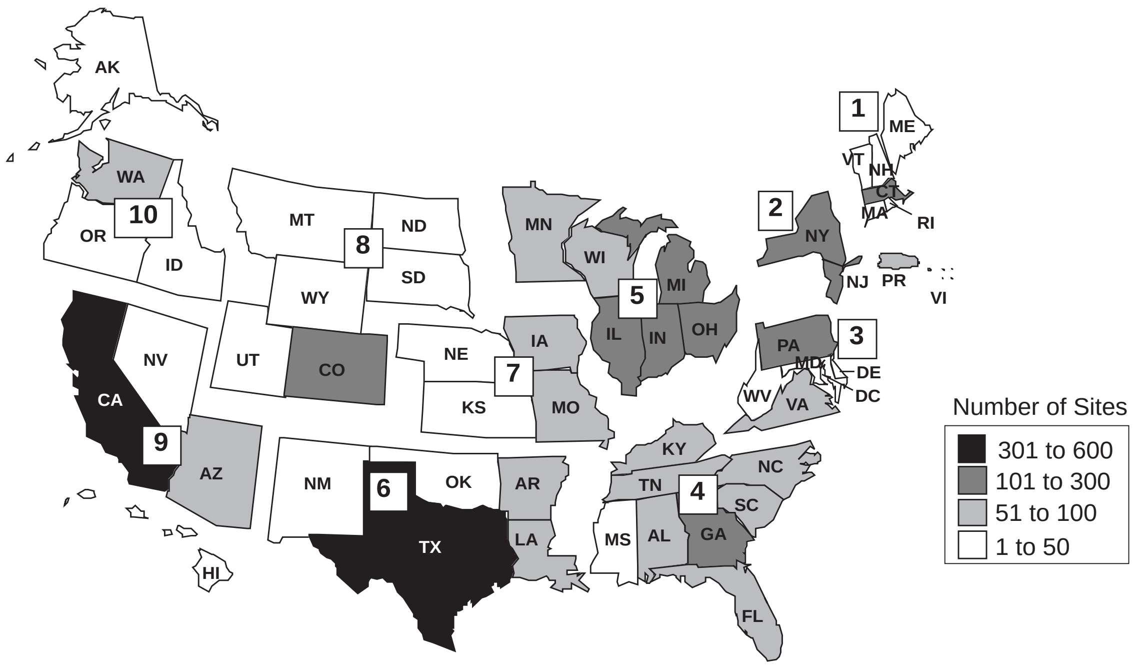
4.3 Number and Characteristics of Facilities

All facilities that are required to have RCRA permits and those where the Agency has discretionary authority to impose remediation are subject to corrective action requirements. However, not all of these facilities will actually require remediation, and until further study is conducted, the number of RCRA facilities that will require cleanup can only be estimated. Nevertheless, EPA's database, which includes the universe of potential corrective action facilities, called the corrective action workload universe, as well as two previous EPA studies, can be used to estimate the potential extent of corrective action in the future.

4.3.1 Number and Types of Facilities

As of October 17, 1995 EPA's Resource Conservation and Recovery Information System (RCRIS), a national program management and inventory system on hazardous waste handlers, contained information on 6,190 RCRA facilities where EPA has discretionary or statutory authority to impose corrective action when necessary.[10] Of these, the corrective action workload universe contains 4,559 facilities that are required to address corrective action because of permitting requirements or because they already are involved in some phase of corrective action. Approximately seven percent of them are federal facilities. Facilities excluded from this universe are clean-closed facilities, facilities that have not notified EPA or are late in notifying EPA that they are handling hazardous wastes, and facilities that have converted to less than 90-day storage of hazardous waste. Technically, however, all of these facilities are subject to RCRA permit requirements and corrective action. Exhibit 4-2 shows the distribution of RCRA facilities in the corrective action workload universe among the states, and Exhibit 4-1 (above) contains the current numbers of facilities in this universe in

Exhibit 4-2: Location of RCRA Corrective Action Facilities in EPA's 10 Regions



Notes: Includes 4,559 facilities in the Corrective Action Workload Universe (facilities with statutory requirements for corrective action due to permitting requirements and facilities where corrective action has been imposed).

Source: U.S. EPA, Office of Solid Waste, RCRIS National Oversight Database, October 17, 1995.

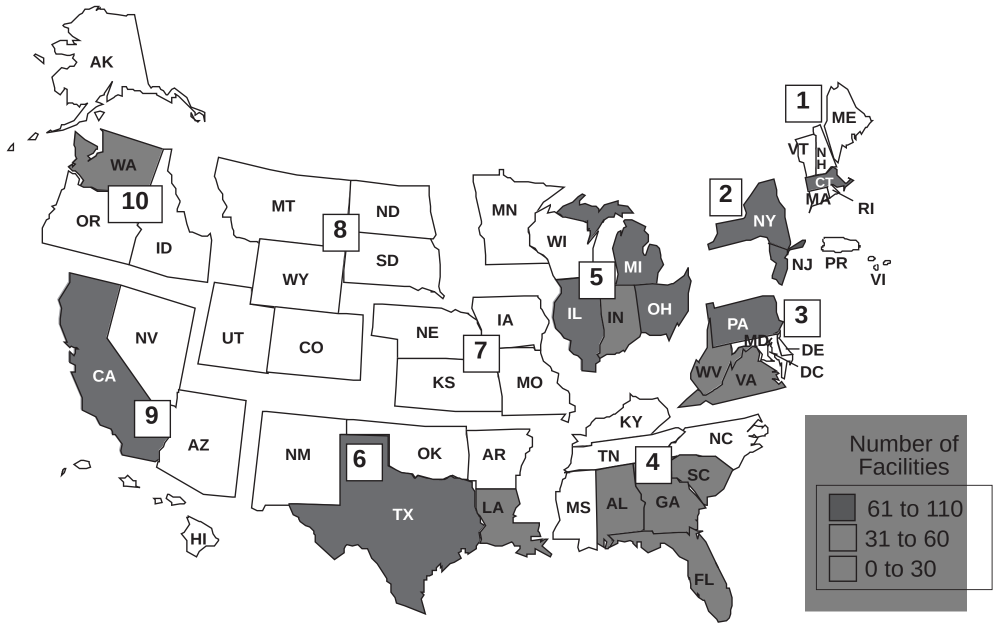
each state or territory. Approximately 1,540 of the facilities in the workload universe have been ranked as high-priority sites under the RCRA National Corrective Action Prioritization System. Exhibit 4-3 shows the states in which high-priority sites are located. Most states have under 31 high-priority facilities, nine states have over 60, and only Pennsylvania and California each have over 100.

A RCRA facility may operate one or more types of hazardous waste management processes, which may lend insight into the nature of the cleanup needed. RCRA facility processes include land disposal such as landfills, land treatment units, surface impoundments, waste piles, and underground injection wells; treatment or storage in tanks or containers; and incineration. A waste pile is any non-containerized accumulation of solid, nonflowing hazardous waste that is used for treatment or storage. The definitions of other processes, including container, tank, surface impoundment, landfill, incinerator, and injection well, may be found in 40 CFR §260.10.[11] Exhibit 4-4 presents the major processes operated now or in the past by permitted, closing, or closed facilities. Because each facility may be performing more than one process, the total number of processes exceeds the number of facilities. Storage and treatment in tanks or containers account for 71 percent of the processes reported, followed by land disposal at 26 percent, and incineration at three percent.

The Agency has developed two separate estimates of the number of facilities likely to require corrective action. These estimates, which were developed for different purposes, range from 2,600 to 3,700 facilities that are expected to eventually require investigation and remediation under the RCRA corrective action program.

The 1990 RCRA Implementation Study contained an estimate of 3,700 RCRA facilities that would likely require corrective action. In preparing this estimate, EPA projected that of approximately 4,700 RCRA land disposal, incinerator, and treatment and storage facilities in the United States at that time, about 80 percent, or 3,700 facilities, with about 64,000 SWMUs may need

Exhibit 4-3: Location of 1,540 High-Priority RCRA Corrective Action Facilities in EPA's 10 Regions



Notes: Based on 4,559 facilities in the Corrective Action Workload Universe (facilities with statutory requirements for corrective action due to permitting requirements and facilities where corrective action has been imposed).

Source: U.S. EPA, Office of Solid Waste, RCRIS National Oversight Database, October 17, 1995.

Exhibit 4-4: Major Processes for Managing Waste at RCRA Facilities

RCRA Facilities*

Land Disposal Processes** (2,953)

- Underground Injection (67)
- Landfill (536)
- Surface Impoundment (1,723)
  - Treatment (474)
  - Storage (880)
  - Disposal (369)
- Waste Pile (462)
- Land Application (165)

Incinerator Processes** (421)

Storage and Treatment Processes** (8,980)

- Tank (3,835)
  - Treatment (1,334)
  - Storage (2,501)
- Container (4,175)
- Other (970)

Notes: *Includes all 6,190 permitting, closing, and closed facilities in the Progress Universe of RCRIS.
**More than one type of process may apply at a single facility.

Source: U.S. EPA, Office of Solid Waste, RCRIS National Oversight Database, October 17, 1995.

additional investigation or corrective action.[1] About 3,000 facilities still needed a RFA to determine whether there were releases.

A 1993 corrective action regulatory impact analysis estimated that 2,600 facilities with 15,000 SWMUs would require corrective action for past, current, or future environmental releases under the 1990 proposed Subpart S rule.[12] The 15,000 SWMUs estimated to require corrective action include about half of the facilities with landfills, 45 percent of facilities with surface impoundments, and 10 percent of facilities with tanks. EPA developed these estimates by analyzing random samples of federal and nonfederal facilities and selecting a final sample of 79, comprised of nine federal and 70 non-federal facilities.

4.3.2 Characteristics and Quantities of Hazardous Waste

Information on the types of contaminants and contaminated media found at corrective action sites can indicate what kinds of cleanup technologies will be needed. Although the aforementioned EPA databases contain preliminary information, data are not available to thoroughly characterize the constituents and waste volumes that will require cleanup at all sites. Most facilities subject to corrective action have not undergone a RFI, which would characterize the extent of on- and off-site environmental contamination.

Two separate studies provide an indication of the nature of contaminants at RCRA corrective action sites. In one study, EPA's Technology Innovation Office obtained information on a total of 275 TSDFs from EPA's regional offices in 1992 and 1993 for the purpose of identifying relationships between site characteristics and the use of innovative technologies at RCRA corrective action sites.[13] At the 214 TSDFs where contamination data were available, halogenated volatile organic compounds (VOCs), the most prevalent of all contaminant groups reported, were present at 60 percent of the TSDFs, followed by heavy metals at 46 percent, and nonhalogenated VOCs at 32 percent. Exhibit 4-5 presents the frequency of the most common contaminant groups. Groundwater (82 percent) and soil (61 percent) were the most commonly reported contaminated media at the 256 TSDFs for which media data were available (Exhibit 4-6). Many of the study facilities had both soil and groundwater contamination.

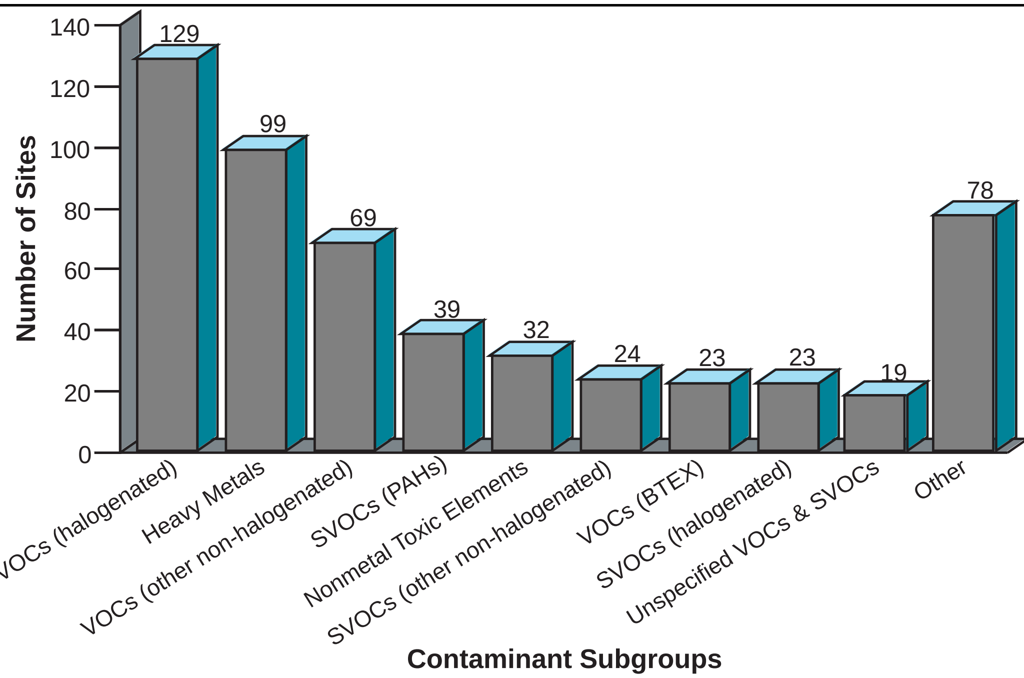
The second study is the regulatory impact analysis (RIA) developed to support the 1993 corrective action rule. This study utilized information on a sample of 79 TSDFs to estimate contamination that is likely to be present in soil or groundwater at concentration levels that would require action.[12] For some facilities, EPA used a fate and transport model to predict the extent of current and future contamination. EPA used a long-term modeling approach to simulate contaminant concentrations over 128 years, from 1992 to 2119. EPA attempted to capture some of the uncertainty associated with potential human exposures and risk assessment in these long-term projections.

Of the 2,600 TSDFs estimated to require corrective action in the RIA, about 2,100 (80 percent) might have significant releases to on-site groundwater, and at about half of these facilities the size of these releases will be one acre or less. Also, about 780 (30 percent) of the 2,600 TSDFs probably will have significant off-site groundwater contamination. Exhibit 4-7 displays the projected extent of on-site groundwater contamination over the modeling period for the 2,600 facilities.

The predominant contaminants expected in groundwater are presented, along with their concentration ranges, in Exhibit 4-8. The concentration range for each constituent in the table is expressed relative to EPA's action levels, which are concentrations that are high enough to trigger concern. The action levels referenced in Exhibits 4-8 and 4-9 are directly or indirectly derived from those used by the Agency in the 1990 proposed corrective action rule by applying assumptions given in that rule.[4] In the proposed rule, the Agency borrowed action levels from existing programs, such as the Safe Drinking Water Act's maximum contaminant levels.

For the RIA, EPA also estimated releases of contaminants to soil at TSDFs that may require corrective action. EPA used soil sampling data, information on SWMU size, and expert judgment to develop the estimates. Exhibit 4-10 presents the percent of facilities projected to have varying

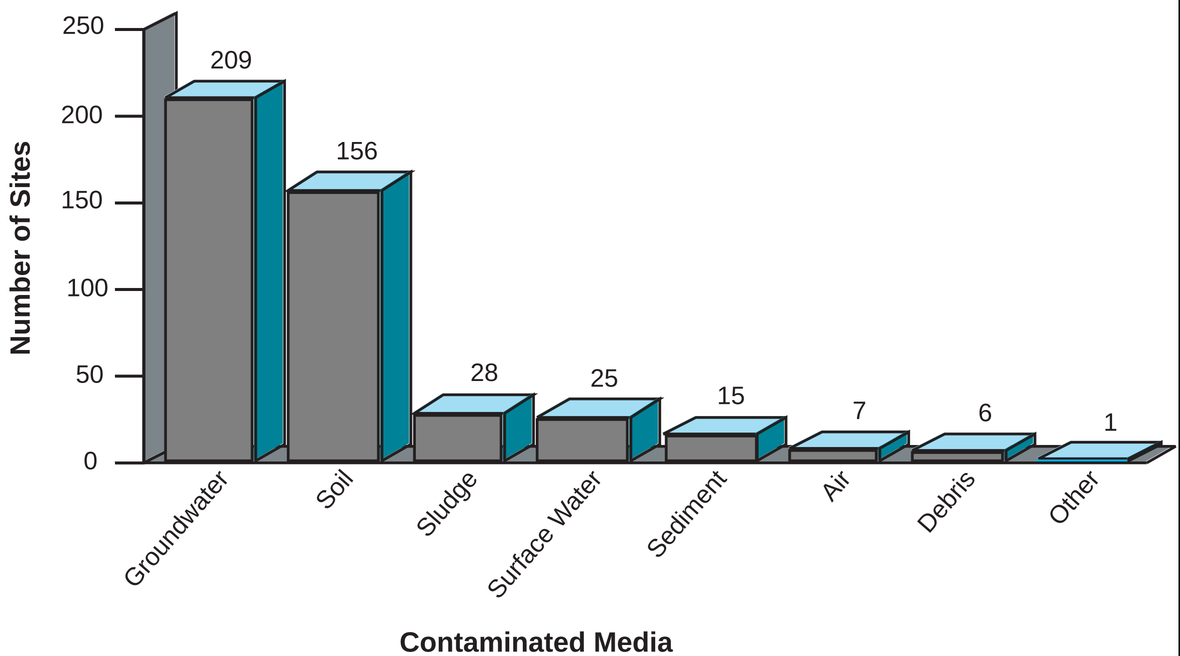
Exhibit 4-5: Frequency of Most Common Contaminant Groups at a Sample of RCRA Corrective Action Sites



Notes: Total sites = 214
PAH = Polynuclear aromatic hydrocarbons; BTEX = Benzene, toluene, ethylbenzene, and xylene

Source: U.S. EPA, Office of Solid Waste and Emergency Response, Technology Innovation Office, *Analysis of Facility Corrective Action Data*, January 1994.

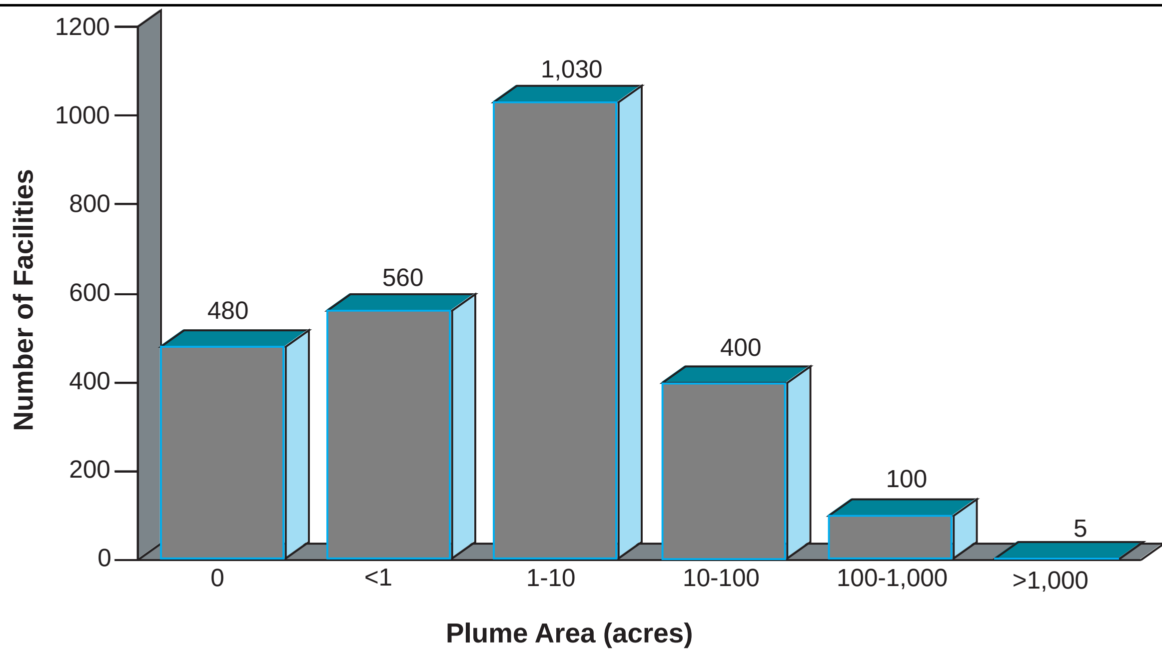
Exhibit 4-6: Frequency of Contaminated Media at a Sample Corrective Action Sites



Note: Total sites = 256

Source: U.S. EPA, Office of Solid Waste and Emergency Response, Technology Innovation Office, *Analysis of Facility Corrective Action Data*, January 1994.

Exhibit 4-7: Projected Extent of Baseline On-Site Groundwater Contamination at 2,600 RCRA Corrective Action Facilities



Note: Numbers do not add to 2,600 due to rounding.

Source: U.S. EPA, Office of Solid Waste and Emergency Response, Office of Solid Waste, *Draft Regulatory Impact Analysis for the Final Rulemaking on Corrective Action for Solid Waste Management Units Proposed Methodology for Analysis*, March 1993.

quantities of contaminated soil on-site, above EPA action levels. On-site soil contaminant concentrations above EPA action levels are expected to occur at about 1,700 (68 percent) of the 2,600 TSDFs estimated to require corrective action. About 500 of the facilities (19 percent) are estimated to have between 60,000 and 10 million cubic feet of contaminated soil per facility, and 1,240 (48 percent) of the facilities are expected to have under 60,000 cubic feet. 830 (32 percent) of the facilities have no soil contamination. The predominant constituents above action levels in on-site soil are presented in Exhibit 4-9 along with their concentration ranges relative to EPA's action levels.

Using a fate and transport model, EPA projected off-site soil contamination in excess of action levels at about 200 (8 percent) of the 2,600 facilities likely to require corrective action. Other media expected to be contaminated above action levels include off-site surface waters at about 140 (5 percent) sites and air at less than one percent of the 2,600 facilities.

4.4 Estimated Cleanup Costs

According to estimates derived from the 1993 corrective action RIA,[12] it will cost $38.8 billion (undiscounted in 1996 dollars), or $14.9 million per facility, to implement the 1990 proposed Subpart S corrective action program. Approximately 89 percent of this amount will be incurred by privately-owned facilities and the remaining 11 percent by federal facilities. The estimated corrective action costs included in the RIA do not include those of the very large DOD and DOE facilities, although it includes some smaller ones. Roughly half of the total cost of corrective action would be incurred by slightly more than 10 percent of the facilities expected to incur costs.

(The cost estimate published in the RIA, $18.7 billion, is the present value of the above figure, calculated using a seven percent discount rate and in 1992 dollars. The adjustment from 1992 to 1996 dollars is based on the Department of Labor's Consumer Price Index for all commodities). These estimates may not include some long-term monitoring and administrative

Exhibit 4-8: Predominant Constituents Projected Above Action Levels in Groundwater at 2,100 RCRA Corrective Action Facilities

Constituent	Percent of Facilities with Constituent	Ratio of Concentration Levels to Action Levels (mg/l)	
		Minimum Ratio Estimated	Maximum Ratio Estimated
Chromium	47	1	8,330
Benzene	30	1	488,680
Methylene Chloride	23	1	10,830
Arsenic	20	1	7,760
Lead	20	3	3,550
Tetrachloroethylene	18	1	108,210
Trichloroethylene	17	3	730
Naphthalene	14	20	349,640
1,1,2-Trichloroethane	11	2	11,000
1,1-Dichloroethylene	10	30	640
Methyl Chloroform	10	15	190
1,1-Dichloroethane	10	2	20
1,2-Dichloroethylene	10	1	6
Toluene	10	2	2,440
Cadmium	7	3	91,240
Nickel	7	3	1,570
Aniline	3	160	900
Selenium	3	6	2,060
Xylenes	3	1	4

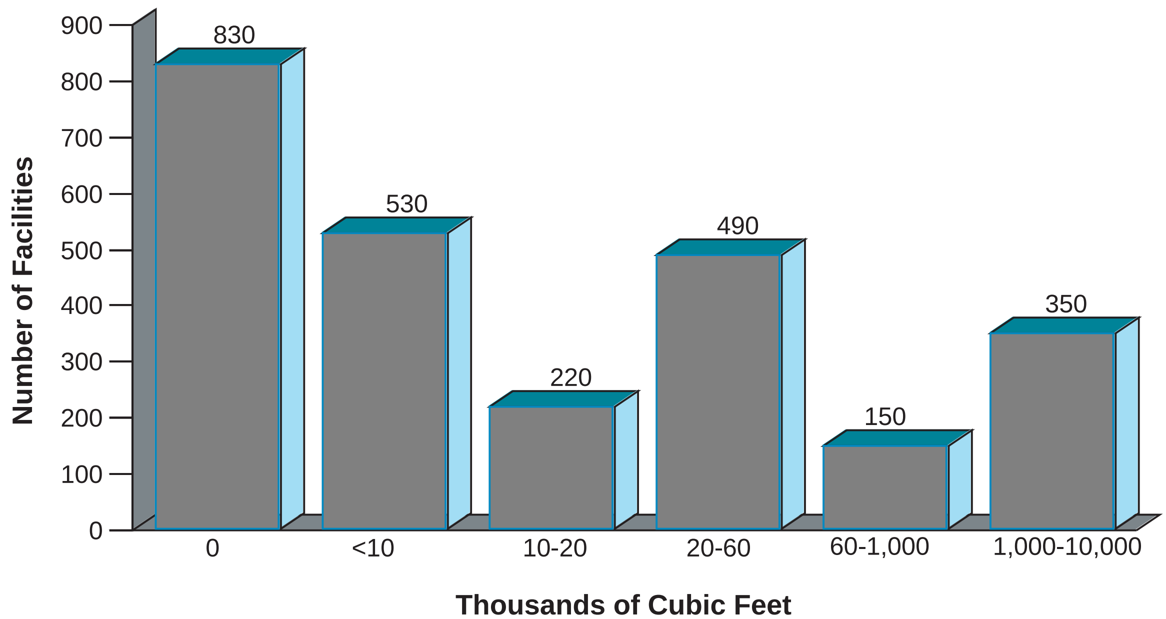
Source: Adapted from *Draft Regulatory Impact Analysis for the Final Rulemaking on Corrective Action for Solid Waste Management Units Proposed Methodology for Analysis*, March 1993.

Exhibit 4-9: Predominant Constituents Projected to be Above Action Levels in Soil at 1,700 RCRA Corrective Action Facilities

Constituent	Percent of Facilities with Constituent	Ratio of Concentration Levels to Action Levels (mg/l)	
		Minimum Ratio Estimated	Maximum Ratio Estimated
Tetrachloroethylene	26	1	100
Trichloroethylene	16	1	10
Chromium	13	0.01	10
Arsenic	13	0.1	100

Source: Adapted from *Draft Regulatory Impact Analysis for the Final Rulemaking on Corrective Action for Solid Waste Management Units Proposed Methodology for Analysis*, March 1993.

Exhibit 4-10: Projected Extent of Baseline On-Site Soil Contamination at 2,600 RCRA Corrective Action Facilities



Note: Numbers do not add to 2,600 due to rounding.

Source: U.S. EPA, Office of Solid Waste and Emergency Response, Office of Solid Waste, *Draft Regulatory Impact Analysis for the Final Rulemaking on Corrective Action for Solid Waste Management Units Proposed Methodology for Analysis*, March 1993.

costs, which together would be less than ten percent of total costs.

EPA projects that both overall and near-term program costs are likely to be much lower than those estimated in the RIA. Over the past few years, implementation of the corrective action program has shifted toward more risk-based cleanups, largely as a result of the development and publication of the May 1, 1996 Advanced Notice of Proposed Rulemaking (ANPRM) for Subpart S.[5] This shift represents a different approach to remediation than that which was modeled in the 1993 RIA. In addition, the near-term costs of the program are likely to be reduced due to the ANPRM's emphasis on stabilization remedies rather than permanent remedies in the short-term.

4.5 Market Entry Considerations

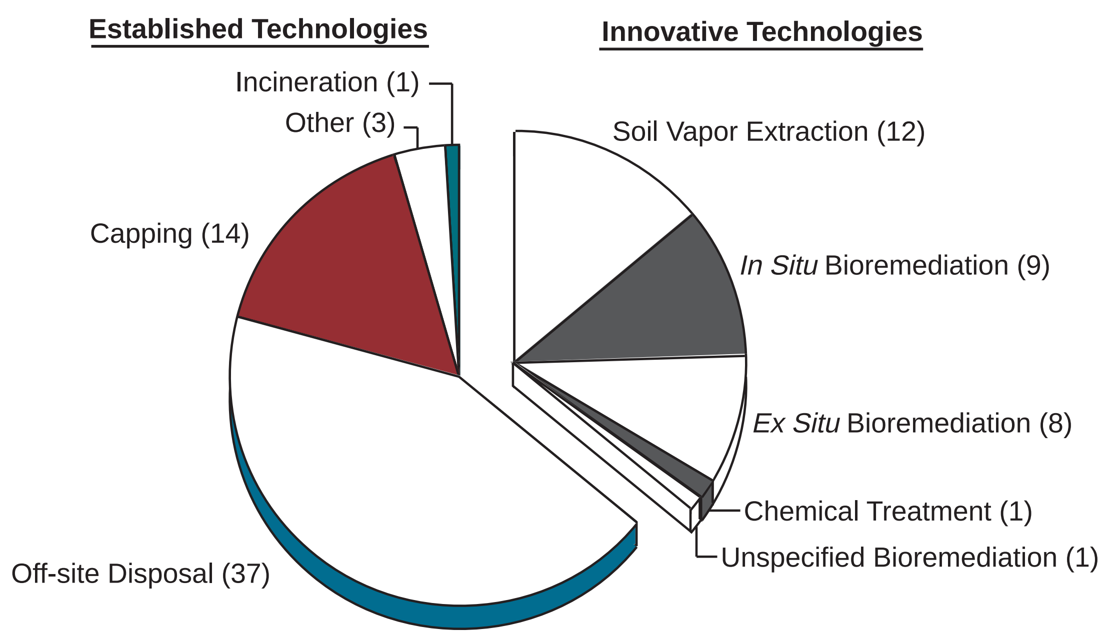
The responsibility for RCRA corrective action at individual facilities lies with the owners and operators who contract directly with commercial vendors for services. RCRA requires that owners and operators be aware of technologies that may be used and those that are subject to restrictions or are banned. Because there is no centralized source of RCRA facility information, vendors interested in the corrective action market will have to contact specific owners or operators to obtain information on an individual facility's corrective action requirements, waste characteristics, and cleanup needs. Many state hazardous waste agencies, and to a lesser degree EPA regional offices, have additional information about the corrective action needs of facilities in their areas.

4.6 Remedial Technologies

Data on technology applications for 186 TSDFs are available from an EPA study completed in 1994.[13] Of 133 facilities treating groundwater, pumping and treating was selected for 116 sites (87 percent) and innovative technologies were selected for nine sites (7 percent). The innovative technologies include *in situ* bioremediation for four sites, *ex situ* bioremediation for two sites, and unspecified bioremediation, thermal desorption, and chemical treatment for one site each. Of 86 sites requiring soil treatment, established technologies were selected for 55 sites (64 percent) including capping and off-site disposal for 51 sites, incineration for one site, and others for three sites. Innovative technologies, such as soil vapor extraction (SVE), bioremediation, and chemical treatment were selected for 31 (39 percent) of the sites requiring soil treatment. Of the innovative technologies selected for soil, most are likely to be used to remediate halogenated and nonhalogenated VOCs in soil. Exhibit 4-11 summarizes specific innovative and established technologies applied or likely to be applied to soil contamination at the 86 sites requiring soil treatment.

Information on technology applications also was found in the Statements of Basis for 50 sites collected by EPA. Based on these unpublished documents, innovative source control technologies (SVE and thermal desorption) were chosen seven times to treat VOCs in soil. Pump-and-treat was the most frequently selected remedy to treat groundwater.

Exhibit 4-11: Remedies Selected for Soil at 86 RCRA Corrective Action Facilities



Note: More than one technology may be used at a single site.

Source: U.S. EPA, Office of Solid Waste and Emergency Response, Technology Innovation Office, *Analysis of Facility Corrective Action Data*, January 1994.

4.7 References

1. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, *The Nation's Hazardous Waste Management Program at a Crossroads: The RCRA Implementation Study,* EPA/530-SW-90-069, 1990.

2. U.S. Environmental Protection Agency, Office of Solid Waste, *RCRA Stabilization Strategy*, October 25, 1991.

3. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, *RCRA National Corrective Action Prioritization System Guidelines (Revised),* August 1992.

4. U.S. Environmental Protection Agency, Office of Solid Waste, *Corrective Action for Solid Waste Management Units (SWMUs) at Hazardous Waste Management Facilities; Proposed Rule* (40 CFR Parts 264, 265, 270, and 217), 55 *Federal Register*, No. 145, pp. 30798-30884, July 27, 1990.

5. U.S. Environmental Protection Agency, *Corrective Action for Releases From Solid Waste Management Units at Hazardous Waste Management Facilities; Proposed Rule*, ANPRM, 40 CFR, 61 *Federal Register* Number 85, pp 19431-19464, May 1, 1996.

6. U.S. Environmental Protection Agency, Office of Solid Waste, *Hazardous Waste Management System: Identification and Listing of Hazardous Waste; Treatability Studies Sample Exclusion; Final Rule* (59 *Federal Register*, p. 8362), February 18, 1994.

7. U.S. Environmental Protection Agency, *Hazardous Waste Miscellaneous Units, Applicable to Owners and Operators; Final Rule* (52 *Federal Register*, p. 46946), December 10, 1987.

8. U.S. Environmental Protection Agency, Office of Solid Waste, *Corrective Action Management Units and Temporary Units; Corrective Action Provisions Under Subtitle C; Final Rule* (58 *Federal Register*, p. 8658), February 16, 1993.

9. U.S. Environmental Protection Agency, *Hazardous Waste Identification Rule; Proposed Rule*, 61 *Federal Register*, p. 18780, April 29, 1996.

10. U.S. Environmental Protection Agency, Office of Solid Waste, *Resource Conservation and Recovery Information System (RCRIS) National Oversight Database*, October 17, 1995.

11. U.S. Environmental Protection Agency, 40 CFR Part 260.10, 45 *Federal Register*, p. 33066, May 19, 1980.

12. U.S. Environmental Protection Agency, Office of Solid Waste, *Draft Regulatory Impact Analysis for the Final Rulemaking on Corrective Action for Solid Waste Management Units Proposed Methodology for Analysis*, March 1993.

13. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Technology Innovation Office, *Draft Analysis of Facility Corrective Action Data*, January 1994.

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CHAPTER 5
DEMAND FOR REMEDIATION OF UNDERGROUND STORAGE TANK SITES

Millions of underground storage tanks (USTs) containing petroleum products or hazardous chemicals are located throughout the United States. USTs are used by a wide variety of industries, such as petroleum and chemical manufacturing and distribution, transportation, agriculture, and government. About 1.1 million active tanks are currently subject to federal regulations, and about 96 percent of these contain petroleum products, including used oil. Less than 1 percent contain hazardous materials and 2 percent are empty. In addition, about one million federally regulated USTs have been closed.

Releases of petroleum or hazardous substances can result from a spill during tank filling operations, leaks in the tank or pipes attached to the tank due to corrosion, structural failure, or faulty installation. As of September 1996 almost 318,000 releases at federally regulated USTs had been confirmed, and more are expected. These releases can contaminate soil and groundwater and cause fires or explosions.

Subtitle I of the Hazardous and Solid Waste Amendments to the Resource Conservation and Recovery Act (RCRA), was enacted in 1984 to control and prevent leaks and spills from USTs. Subtitle I governs USTs storing regulated substances, including gasoline, aviation fuel, diesel fuel, other petroleum products, and hazardous substances defined under the Superfund program. Pursuant to Subtitle I, EPA has promulgated regulations requiring, among other things, that leaks and spills be detected and reported, contamination caused by leaks and spills be remediated, future releases be prevented, and each state has a regulatory program for USTs that is at least as stringent as that under the federal regulations. These regulations have compelled cleanup activities at many UST sites, providing opportunities for the application of a variety of remedial technologies.

5.1 Program Description

The federal regulatory program is implemented by EPA's Office of Underground Storage Tanks (OUST). The federal UST technical requirements and state program approval regulations were promulgated in September 1988, and became effective on December 22, 1988.[1] These regulations, to a large extent, determine the size of the market for cleanup services.

The regulations apply to any UST, except those specifically exempted, used to store petroleum products or substances defined as hazardous under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The regulations do not apply to tanks storing hazardous wastes regulated under Subtitle C of RCRA. An UST is defined as any tank that has at least 10 percent of its volume buried below ground, including piping connected to the tank. Generally, the requirements for tanks containing chemicals are somewhat more stringent than those containing petroleum products.

The basic federal requirements include:

- A tank owner must register his or her tank(s) with the state authority by completing a notification form about the characteristics and contents of the UST.

- A tank owner must institute a periodic leak detection program to actively seek out releases. For tanks installed after December 1988, leak detection requirements become effective at the time of installation. For older tanks, the requirements were phased in over time with a final completion date in December 1993.

- A tank owner must maintain records of leak detection activities, corrosion protection system inspections, repair and maintenance activities, and post-closure site assessments.

- A tank owner must notify the appropriate regulatory authority of all suspected or confirmed releases as well as follow-up actions taken or planned. Suspected leaks must be investigated immediately to determine if they are real. If evidence of environmental damage is the cause for suspicion, it must be reported immediately to the regulatory authority.

- If a leak or spill is confirmed, tank owners must: (a) take immediate action to stop and contain the leak or spill; (b) notify the regulatory authority within 24 hours or other reasonable time periods specified by the implementing agency; and (c) take action to mitigate further damage to people and the environment.

- By December 1998, all USTs must have corrosion protection and devices that prevent spills and overfills.

- A tank owner also has the option of closing USTs, but must notify the regulatory authority 30 days before permanent closure.

In addition to providing performance standards, the regulations establish requirements that a state must meet to receive EPA approval for its program. State or local authorities may have requirements that are somewhat different or more stringent. All states and territories have passed legislation for UST cleanups, and 45 states have state trust funds. The following kinds of tanks are currently *exempt* from the regulations:

- Farm and residential tanks holding 1,100 gallons or less of motor fuel used for non-commercial purposes;
- Tanks storing heating oil used on the premises where it is stored;
- Storage tanks on or above the floor of areas such as basements or tunnels;
- Septic tanks and systems for collecting storm water and wastewater;
- Flow-through process tanks;
- Tanks holding 110 gallons or less; and
- Emergency spill and overfill tanks.

Changes in the types of tanks covered by the regulations could significantly impact the potential size of the market. However, EPA is not contemplating any such changes at this time.

5.2 Factors Affecting Demand for Cleanup

The demand for remediation services at contaminated UST sites primarily will be influenced by federal regulations, state requirements, and the number of releases occurring at old and new tanks. Specifically, the following factors affect this market:

- The implementation of leak detection requirements (which became effective in 1993), in combination with the reporting requirements, have led to a large number of confirmed releases.

- The implementation of tank upgrading requirements, which become effective in 1998, is expected to cause an increase in the reporting of releases.

- Over a longer period of time, after 1998, it is anticipated that the rate of occurrence of confirmed releases will decline, because the failure rate of tanks will eventually decrease as a result of improved tank systems.

- Some states have promulgated requirements that are more stringent than the federal standards, such as a requirement for double-lined tanks, more stringent monitoring procedures, or earlier upgrading compliance dates.

- The pace of the cleanups will be affected by the adequacy of the reimbursement funds used by 45 states to help pay for needed cleanups. Most of the cost of UST cleanups by responsible parties (RPs) in these states are now paid out of these funds, and some of them often do not have sufficient money to clean up all of the eligible sites in a given year. The Federal Trust Fund accounts for a smaller portion of expenditures on UST cleanups than the state funds. These funds may be used for the oversight of RP cleanups and direct state cleanups where the RPs are insolvent, recalcitrant, or cannot be identified or located.

- The failure rate of tank systems is determined by such factors as tank age, material of construction, corrosion protection systems in place, and other design and site-specific factors such as soil type and weather. Because information on these factors is limited, estimates of market size are subject to some uncertainty. The estimates in the following section are based on the current RCRA requirements and available data.

- The availability of credit to UST owners, especially the many small businesses that operate USTs, is necessary to assist them in meeting their obligations to upgrade, maintain, and otherwise comply with RCRA Subtitle I and related environmental requirements. In September 1995, EPA promulgated regulations to encourage the extension of credit to credit-worthy UST owners. These regulations exempt from the definition of UST "owner" for purposes of corrective action persons who maintain an indicia of ownership in an UST or UST system primarily to protect a security interest, but are not otherwise engaged in petroleum production, refining, and marketing. Thus, any person or lending institution that guarantees loans secured by real estate containing an UST or UST system may not be liable for the required corrective action.[2]

5.3 Number and Characteristics of Sites

The data on the number and status of currently registered USTs are derived from data that EPA compiled from reports it periodically receives from 56 states and territories. States compile their data from information received from tank owners. The information in this chapter on the size, contents, construction materials, and other characteristics of USTs are derived from a survey EPA conducted in 1991.[3] Although this source is the most complete nationwide compilation of tank characteristics, the types and characteristics of the tank population has probably changed since it was conducted. Since then, over 600,000 tanks have been closed and newer tanks tend to be larger than older tanks. Thus, these data should be considered as an approximation of the distribution of the tank population.

Reporting quality varies among the states and has resulted in some under-reporting of the number of tanks subject to the regulations. Estimates of the extent of under-counting range from 15 percent to 80 percent.[a] However, since conditions probably have changed in the six years since these estimates were compiled, these factors are not included in the estimates provided here.

EPA reports most of these data in terms of the numbers of tanks. However, for purposes of this study, the data also are converted to "number of UST sites." EPA estimates that there is an average of 2.7 tanks per UST site, although the number actually varies widely among the sites.

5.3.1 Number of USTs

The number of potential corrective actions are related to the population of active and closed tanks subject to the federal regulations. EPA reports that as of September 30, 1996, 1,064,478 active tanks and 1,074,022 closed tanks have been registered in the U.S.[4] Using EPA's estimated average of the 2.7 tanks per site, approximately 792,037 sites with USTs are subject to the UST corrective action regulations. Estimates of the percentage of sites that are likely to leak and require cleanup of contaminated soils or groundwater are presented later in this section.

In 1988, EPA estimated that there were between 5 and 7 million USTs.[1] Taking the midpoint of this range implies a total UST population of 6.0 million, of which 2.1 million active and closed USTs are currently subject to the regulations. The remaining 3.9 million tanks are exempt from the federal regulations and not included as part of the market for remediation services in this report. Section 5.1 identifies the seven exempt categories of tanks. Although the exempt tanks are not considered part of the market in this report, they,

[a] Bueckman, Donna S., S. Kumar, and M. Russell, *Underground Storage Tanks: Resource Requirements For Corrective Action,* pages 17-19 and 31, Waste Management Research and Education Institute, University of Tennessee, December 1991 reports this range based on a review of several surveys. Based on this review, the authors estimated the average under-counting for the country to be 35%.

nevertheless, represent a potential for cleanup work in selected states where state regulations include some exempt tanks.

The following sections describe some basic characteristics of the federally regulated sites, such as their contents, ownership, size, and age. These descriptions are based on data collected by EPA in 1991, which is the most comprehensive source for this type of data identified. Although some characteristics of the tank population, such as average tank size, probably have changed since 1991, these data are the only national source available.

5.3.2 Types of Contaminants Found at UST Sites

The substances stored in RCRA-regulated tanks in 1991 are depicted in Exhibit 5-1. Most USTs contain petroleum products, which are mixtures of four types of hydrocarbons: paraffins, olefins, napthalenes, and aromatics. The literature contains data on the concentrations of benzene, toluene, ethylbenzene, and xylene (BTEX) in gasoline and diesel fuel, but information on the concentration of these constituents in other petroleum products is more limited. BTEX compounds also have been detected in soil and other media at UST sites where gasoline is stored.[5]

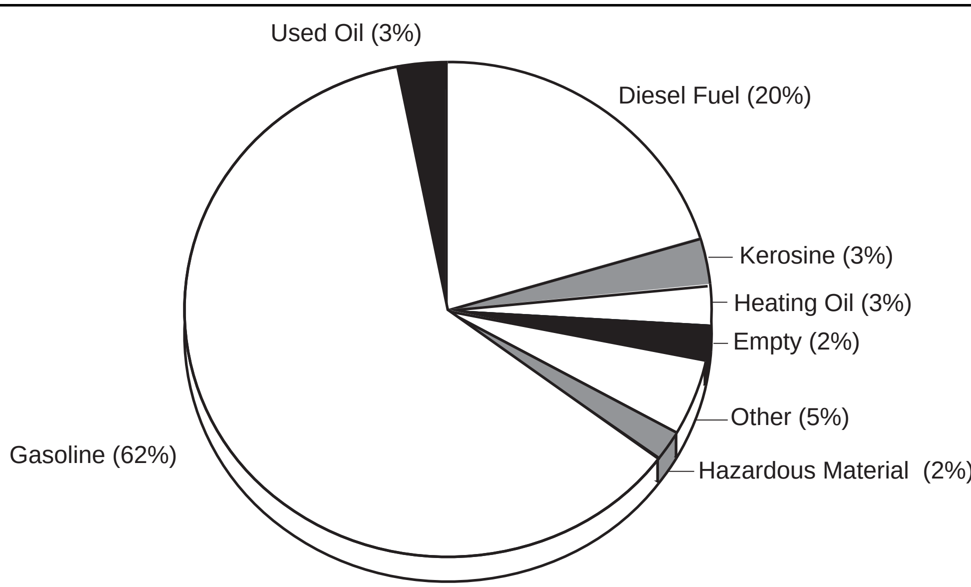
5.3.3 Ownership of Tanks

In 1991, private companies and individuals owned 69 percent of the tanks, state and local governments owned 8.4 percent, and the federal government and Indian tribes owned 2.2 percent. The ownership of the remaining 20.4 percent has not been identified.

5.3.4 Size and Age of Tanks

The size and age of a tank may contribute to the extent of the contamination and to the type of work needed at a site. Exhibit 5-2 shows the number of tanks of different sizes reported in the EPA survey, as of Spring 1991. Almost two-thirds of the tanks were between 2,000 and 30,000 gallons, and 28 percent were between 100 and 2,000 gallons. However, the size distribution may have changed somewhat over the past five years because newer facilities tend to have larger tanks, on average, than older facilities, and the tanks that have closed are primarily older.

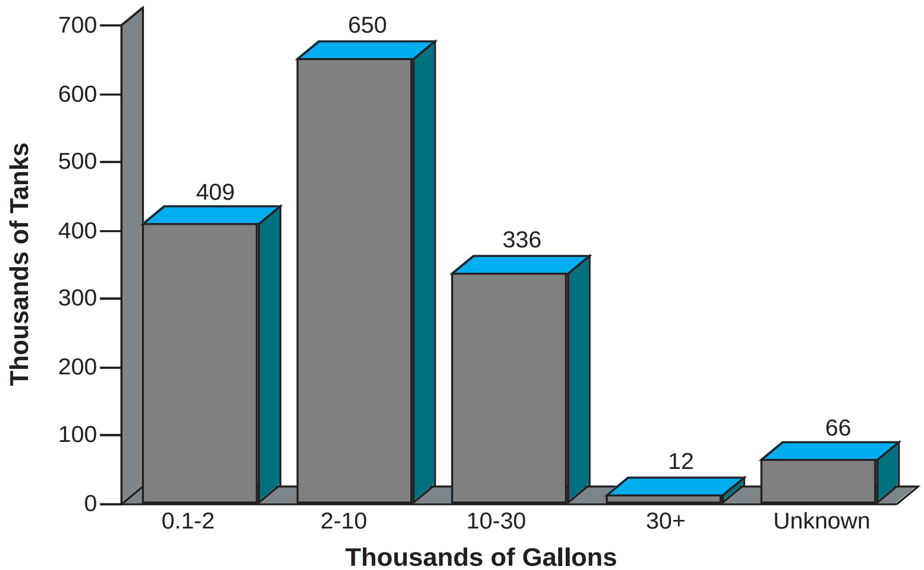
Exhibit 5-1: Contents of Federally Regulated Active and Closed Tanks as of Spring 1991



Notes: Based on a survey involving 1.6 million active and closed tanks in the spring of 1991. The distribution of USTs probably has changed somewhat, since approximately 600,000 tanks have closed since 1991.

Source: U.S. EPA, Office of Underground Storage Tanks, *National Survey of Underground Storage Tanks*, Spring 1991.

Exhibit 5-2: Size of Federally Regulated Tanks as of Spring 1991



Note: Based on data on 1.5 million active and closed tanks in Spring 1991. The size distribution of USTs probably has changed because approximately 600,000 tanks have closed since 1991 and the newer facilities tend to have larger tanks.

Source: U.S. EPA, Office of Underground Storage Tanks, *National Survey of Underground Storage Tanks*, Spring 1991.

Exhibit 5-3 shows the age of federally regulated tanks, including closed tanks. The probability of a leak is directly related to tank age. In 1991, 28 percent of the regulated tanks were over 25 years old. Data are not available on the current distribution of tank age.

5.3.5 Location of Regulated Tanks

Appendix B lists the number of regulated tank sites by state, as reported in September 1996. California, Texas, New York, Florida, North Carolina, Michigan, and Pennsylvania contain almost 40 percent of all active and closed tanks. The location data should be used with caution because the number of tanks in a state may not be correlated with the number of releases, and reporting quality varies among the states.

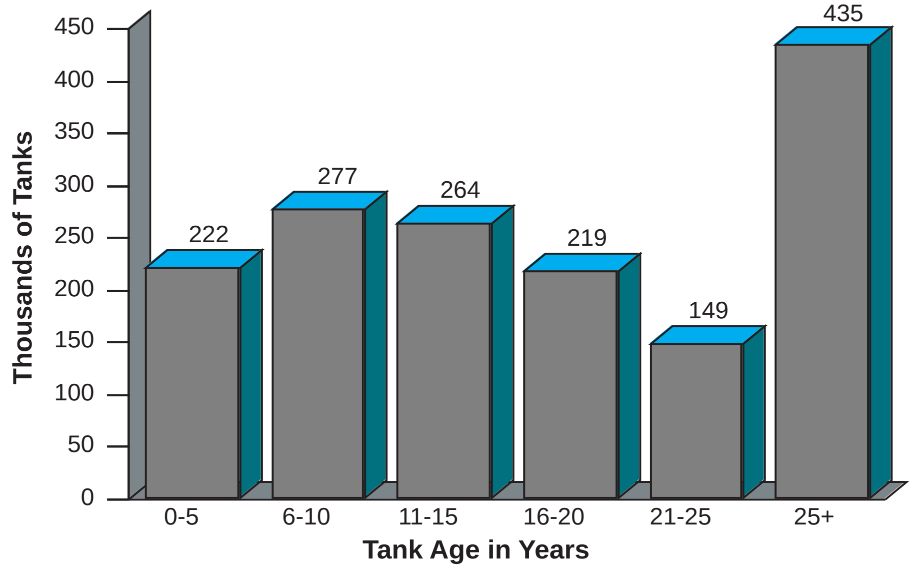
5.3.6 Potential Number of Sites to be Cleaned Up

EPA has estimated that the number of confirmed releases ultimately will total at least 418,000.[b] By September 1996, almost 318,000 of these releases had already been reported to EPA, and remedial design or remedial action had been initiated at almost 253,000 of these sites. Thus, it is estimated that 165,000 UST sites will ultimately need remediation (Exhibit 5-4).

Although the size of the entire market has been estimated, the year-to-year fluctuations in cleanup efforts are difficult to predict. EPA estimates that the RCRA UST requirements probably will cause an increase in the number of releases reported, followed by a decrease. The increase will result from the phase-in of tank upgrading requirements in 1998. The decline in confirmed releases will result from improvements in the types of tank systems and leak detection and monitoring practices required by RCRA. Exhibit 5-5 shows the corrective action activity for the past six years. The difference between confirmed releases and cleanups initiated has averaged over 64,000 for the past four years.

[b] Although the number of confirmed releases may not precisely equal the number of sites with releases, EPA estimates that the difference is small. Therefore, for the purpose of this analysis it is assumed that the number of confirmed releases equals the number of sites with releases.

Exhibit 5-3: Age of Federally Regulated Tanks as of Spring 1991



Note: Based on a survey of 1.6 million active and closed tanks in Spring 1991. The 600,000 tanks that have closed since 1991 tend to be older tanks. The age distribution probably has changed somewhat.

Source: U.S. EPA, Office of Underground Storage Tanks, *National Survey of Underground Storage Tanks*, Spring 1991.

5.3.7 Quantities of Contaminated Material

The volume of soil to be cleaned up varies widely from one site to another. A 1990 EPA survey provided data from 16 states on the average volume of soil and debris excavated at UST sites. The median volume for the 16 states ranged from 9 to 800 cubic yards, with a weighted average of 190. Multiplying this average by the number of sites expected to need remediation (165,000) results in an estimated 31.4 million cubic yards of material needing remediation. No information is available on the quantities of groundwater and surface water needing remediation.

5.4 Estimated Cleanup Costs

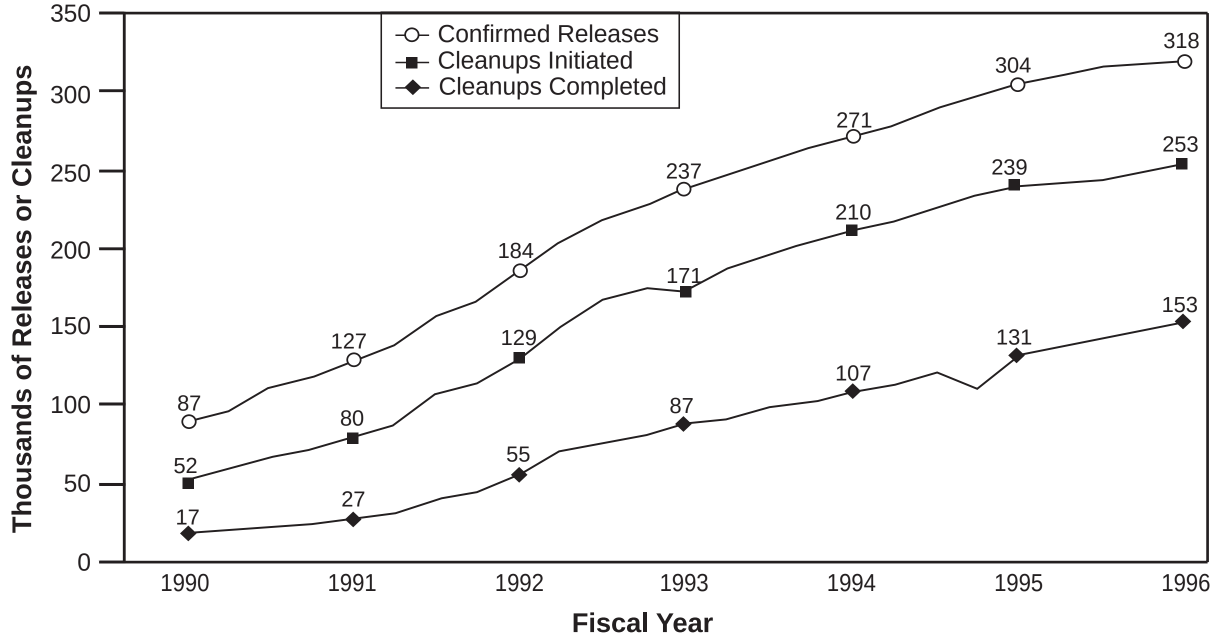
Based on a review of literature and data, the University of Tennessee reported that the cost of remediating UST sites had varied widely, generally between $2,000 to over $400,000. Costs at individual sites can exceed a million dollars.[6] Based on experience with a limited number of projects, EPA estimates that the average remediation cost per site is $125,000. This cost estimate includes treatment or disposal of soil and groundwater, site investigations, and feasibility studies. It does not include costs related to excavating, disposing of, or repairing tanks and related

Exhibit 5-4: Estimated Number of UST Sites Requiring Cleanup

	Reported to EPA	Sites with Future Releases	Total
Confirmed Releases	318,000	100,000	418,000
Cleanups Initiated[a]	253,000	0	253,000
Future Cleanups Required[b]	65,000	100,000	165,000

Notes:
[a] Some of these sites may not yet have designated cleanup contractors, but how many is not known.
[b] "Future Cleanups Required" is derived by subtracting "Cleanups Initiated" from "Confirmed Releases."

Exhibit 5-5: Status of UST Corrective Actions (Cumulative)



Source: U.S. EPA, Office of Underground Storage Tanks, Quarterly Reports, September 1990-September 1996; and Semiannual Reports, March 1996 and September 1996.

equipment such as piping. Multiplying this average by the number of sites expected to need remediation, the projected total remediation cost is $20.6 billion.

As discussed previously, EPA anticipates that cleanup activities will increase as the December 1998 deadline for upgrading tanks for corrosion protection and spill and overfill prevention approaches, and then decrease.

5.5 Market Entry Considerations

The following factors will be important to the success of vendors operating in the UST remediation market.

- Site work is primarily the responsibility of tank owners, especially of establishments such as retail gasoline stations, petroleum and chemical marketers, and fleet maintenance, auto repair, manufacturing, or transportation facilities.
- The level of enforcement activity varies from one state to another. In addition, some states regulate tanks that are not regulated under RCRA. Information on these activities generally are available through state authorities.
- As tank testing and other requirements are implemented, the extent of cleanup activities and costs per site probably will decrease. Thus, economical ways to remediate smaller releases may be needed.

5.6 Remedial Technologies

Data on the kinds of innovative technologies used to remediate contaminated UST sites have not been centralized. A study conducted in 1995 by EPA and the University of Massachusetts provided information on trends in the frequency of selection of alternative technologies as well as the kinds of technologies being used for cleanups.[7] The study was based on information collected from 49 state LUST program offices who responded to a written survey. Respondents were asked to provide reasonable estimates to survey questions, not to conduct file searches or research before responding. Thus, the results, which were based on the responses received, should be considered approximations.

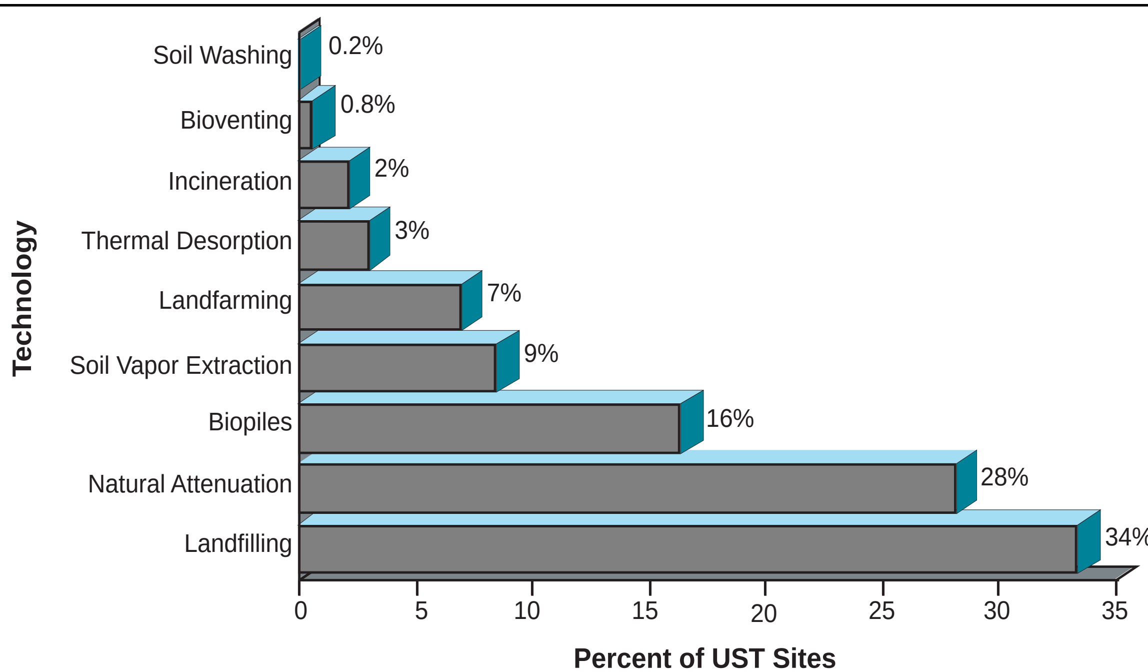
Based on the responses of the 49 states in 1995, approximately 96,000 sites were undergoing remediation in these states, or an average of almost 2,000 sites per state. Exhibit 5-6 shows the percentage of sites at which soil remediation technologies were being used. Landfilling was the most frequently selected option for soil remediation, followed by natural attenuation, biopiles, and soil vapor extraction.

Exhibit 5-7 shows the percentage of sites in 1995 at which groundwater technologies were being used. Natural attenuation and pump-and-treat were the most frequently selected groundwater technologies, at 47 percent and 29 percent of the sites, respectively.

Although most of these percentages appear low, they represent substantial increases in the relative use of these technologies. According to state and federal regulators, the use of air sparging has grown from only a handful of sites four years prior to the study to about 13 percent of the 35,000 sites undergoing groundwater remediation in 1995. According to thermal desorption industry representatives, thermal desorption was used on a limited basis four years prior to the study, and in 1995 was used at numerous sites in almost every state.[7] The 1995 EPA study indicated that thermal desorption was selected for about 3.1 percent of the sites undergoing soil remediation in 1995. The study also indicated that the use of all alternative technologies has increased during the two years before the study. Exhibit 5-8 shows the percentage of state LUST program offices that had noted increases in technologies between 1993 and 1995.

The use of on-site technologies had increased and the use of off-site technologies had decreased from 1993 to 1995 (Exhibit 5-9). Most of the increases were accounted for by the use of natural attenuation, soil vapor extraction, bioventing, air sparging, *in situ* bioremediation, and dual-phase extraction. For the study, off-site technologies included landfilling, incineration, thermal desorption, biopiles, and landfarming. All other technologies were considered on-site. (Since the study, some of the traditional off-site

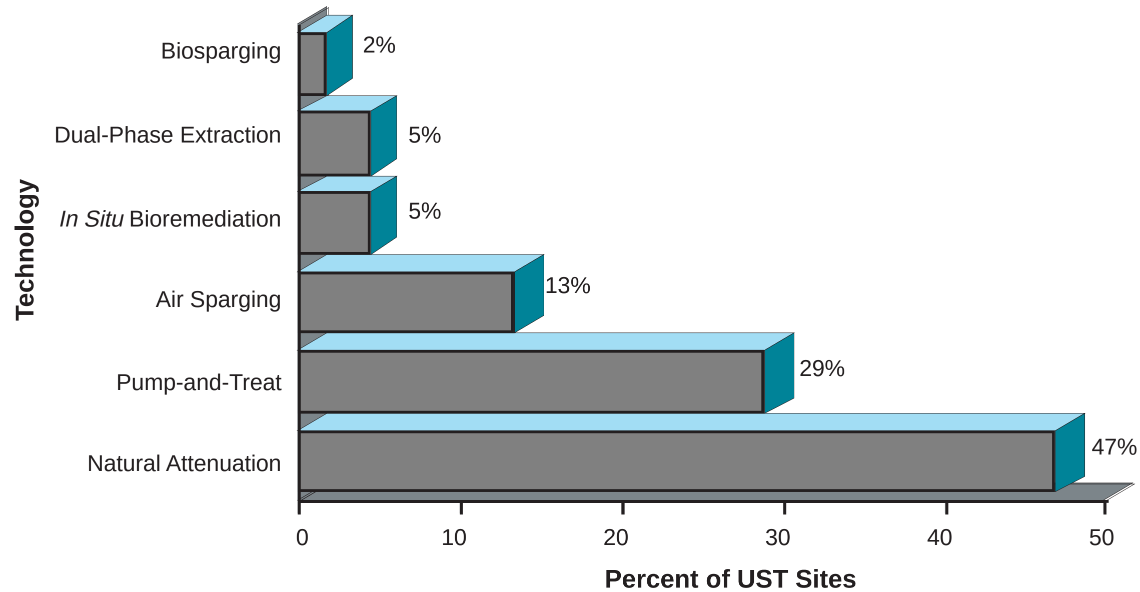
Exhibit 5-6: Percentage of UST Sites Using Specific Soil Remediation Technologies



Note: Based on information covering 103,000 sites.

Source: Tremblay, Deborah, L., D. S. Tulis, P. Kostecki, and Ewald, "Innovation Skyrockets at 50,000 LUST Sites,'' *Soil and Groundwater Cleanup*, December 1995.

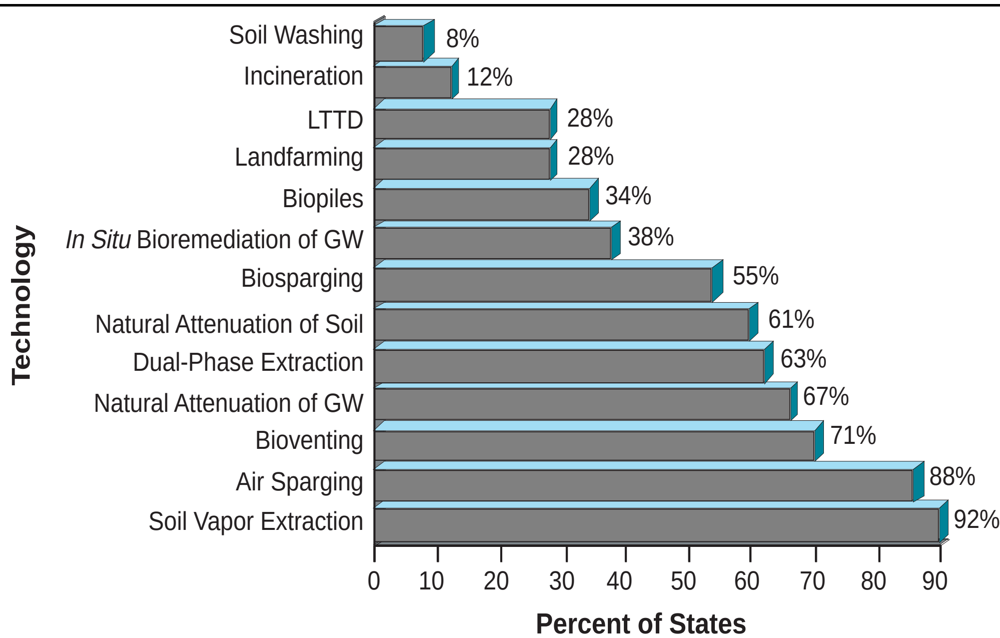
Exhibit 5-7: Percentage of UST Sites Using Specific Groundwater Remediation Technologies



Note: Based on information covering 36,000 sites. Percentages do not add to 100% due to rounding.

Source: Tremblay, Deborah, L., D. S. Tulis, P. Kostecki, and Ewald, "Innovation Skyrockets at 50,000 LUST Sites," *Soil and Groundwater Cleanup*, December 1995.

Exhibit 5-8: Percentage of States Reporting Increased Use of Alternative Technologies



Note: GW = groundwater; LTTD = low temperature thermal desorption.

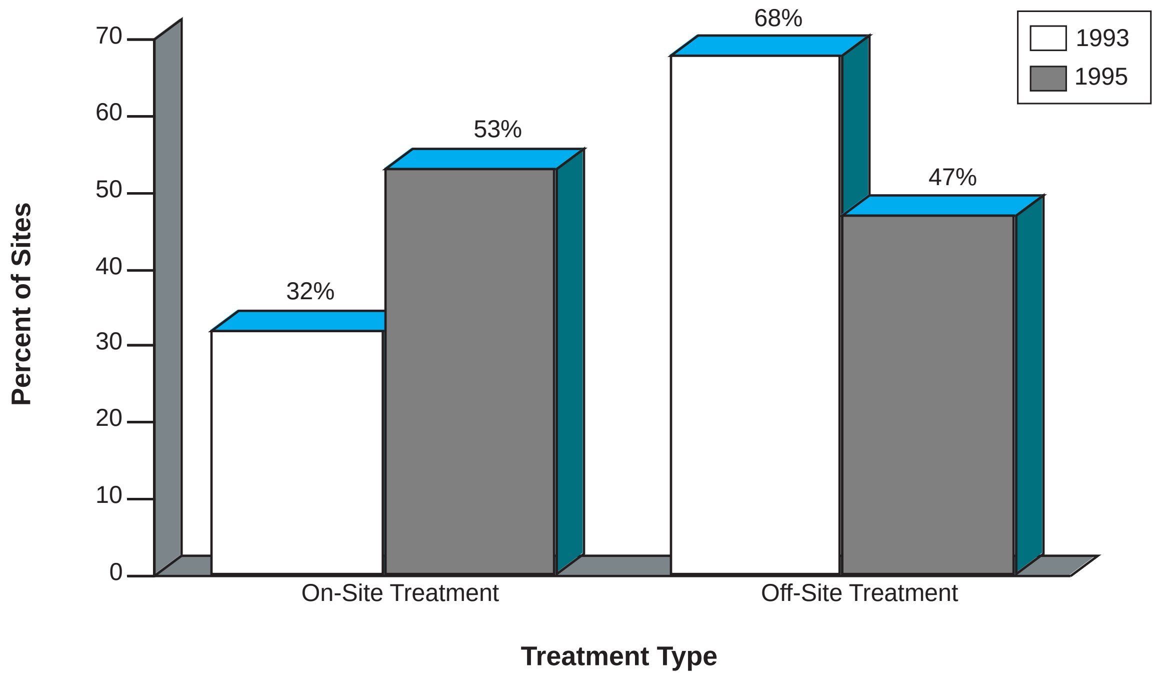
Source: Tremblay, Deborah, L., D. S. Tulis, P. Kostecki, and Ewald, "Innovation Skyrockets at 50,000 LUST Sites," *Soil and Groundwater Cleanup*, December 1995.

technologies are now being conducted on-site [*e.g.*, biopiles and LTTD]).

The use of innovative and other alternative technologies may help accelerate the pace of, or reduce the cost of, remediating UST sites. Nevertheless, according to a more limited EPA study conducted in 1992, most site cleanups tended to involve more traditional approaches.[8] The use of innovative technologies often was hampered by a lack of cost or performance data, a lack of expertise among state and contractor personnel, and the need for additional permit requirements. To help overcome these barriers, EPA conducted demonstration projects and provided guidance, training, and workshops at UST sites. Technologies addressed in these efforts included soil vapor extraction, air sparging, enhanced bioremediation, and low-level thermal desorption. In recent years, EPA has made available reference materials and training programs to assist site managers, vendors, and others in these areas. These materials are listed in Section 5.7. [9][10][11][12][13][14][15]

The 1995 study found that data on technology performance and the availability of trained consultants and regulators had improved over the previous two years. The primary obstacles to the selection of alternative technologies have shifted from a lack of available information and trained personnel to the potentially high costs, long cleanup times, and lack of confidence in the technologies.

Exhibit 5-9: Changes in the Use of On-Site and Off-Site Treatment



Source: Tremblay, Deborah, L., D.S. Tulis, P. Kostecki, and K. Ewald, "Innovation Skyrockets at 50,000 LUST Sites," *Soil and Groundwater Cleanup*, December 1995.

5.7 References

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2. U.S. Environmental Protection Agency, "Underground Storage Tanks — Lender Liability; Final Rule," 40 CFR Parts 280 and 281," *Federal Register*, Vol 60, September 7, 1995, p. 46692.

3. U.S. Environmental Protection Agency, Office of Underground Storage Tanks, *Survey of Underground Storage Tanks*, Spring 1991.

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5. U.S. Environmental Protection Agency, Office of Underground Storage Tanks, *TC [Toxicity Characteristic] Study of Contaminated Media and Debris*, Draft, July 1992.

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7. Tremblay, Deborah, L., D. S. Tulis, P. Kostecki, and K. Ewald, "Innovation Skyrockets at 50,000 LUST Sites," *Soil and Groundwater Cleanup*, December 1995.

8. U.S. Environmental Protection Agency, Office of Underground Storage Tanks, and Technology Innovation Office *Technologies and Options for UST Corrective Actions: Overview and Current Practice*, EPA/542/R-92/010, August 1992.

9. U.S. Environmental Protection Agency, Office of Underground Storage Tanks, *How to Evaluate Alternative Cleanup Technologies for UST Sites: A Guide for Corrective Action Plan Reviewers*, EPA-510-B-95-007, May 1995.

10. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Technology Innovation Office, Cleanup Information Bulletin Board System (CLU-IN). CLU-IN may be accessed by: (a) using a modem to dial 301-589-8366; (b) or (b) a World Wide Web connection: *http://www.Clu-in.com*

11. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Office of Underground Storage Tanks, World Wide Web connection: *http://www.epa.gov/OUST*.

12. University of Massachusetts, Contaminated Soils Conferences, University of Massachusetts, N344 Morrill, Amherst, Massachusetts 01003, attention Linda Rosen.

13. U.S. Environmental Protection Agency, Office of Underground Storage Tanks, *Tank Racer: Cost Estimation Software for LUST Cleanups*, March 1996.

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CHAPTER 6
DEMAND FOR REMEDIATION OF DEPARTMENT OF DEFENSE SITES

The Department of Defense (DOD) has undertaken the task of cleaning up wastes that have resulted from numerous industrial, commercial, training, and weapons testing activities, as well as cleaning up closing military bases so that the properties can be transferred to local communities for economic revitalization. This task is formidable, especially in view of the overall limitation of DOD resources and proposals to reduce the defense budget. DOD has estimated that of the sites it has begun investigating, over 8,300 sites on over 1,500 installations or formerly used defense sites (FUDS) that will ultimately require remediation have not begun remedial design or remedial action. These facilities contain hazardous waste contamination involving soil, groundwater, and other media. Typical contaminants include petroleum products, solvents, heavy metals, explosives, polychlorinated biphenyls (PCBs), pesticides, and munitions residues from weapons testing.

Much of DOD's past efforts in environmental restoration were devoted to investigating the problem. In fiscal year (FY) 1995, DOD reported that for the first time it was devoting more resources to actual cleanup of contaminated sites than to site investigations and analyses. This trend has continued through 1996 and DOD anticipates that it will continue into the future. DOD has been incorporating a prioritization scheme for sequencing work based on the relative risk of individual sites. Under DOD's relative risk management approach, decisions regarding such issues as cleanup standards, remedy selection, and no further action determinations are made site-by-site rather than for an entire installation. Decisions on these issues are based on the relative threat to human health and the environment, reasonable anticipated land use, cost-effectiveness, and speed of cleanup, and depend on early and meaningful public participation. DOD works with the regulatory agencies and other interested parties to streamline and find economies in the restoration process.

To accomplish the cleanups, DOD will need the services of firms that can clean up wastes similar to those found at private sector industrial facilities as well as firms that can remediate wastes that are unique to DOD, such as unexploded ordnance. These environmental service firms will have to understand DOD operating procedures and keep abreast of the overall direction of its environmental programs.

6.1 Program Description

The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), and the Resources Conservation and Recovery Act (RCRA) are the primary federal laws governing the investigations and cleanup of DOD contaminated sites. DOD installations typically have multiple contaminated sites regulated by either CERCLA, RCRA corrective action provisions, RCRA underground storage tank (UST) provisions or all three. Through Executive Order 12580, signed in January 1987, the President directs the Secretary of Defense to implement investigation and cleanup measures, in consultation with EPA, for releases of hazardous substances from facilities under the jurisdiction of the Secretary. The interface between CERCLA and RCRA authorities is determined by the circumstances at specific sites, including factors such as: the source and cause of the contamination, the status of the installation as either a National Priorities List (NPL) or non-NPL site, and whether the installation has or is seeking a RCRA permit to manage hazardous wastes. DOD cleanups also must consider the requirements of state laws and the Base Closure and Realignment Acts of 1988 and 1990 (BRAC).[1] Partnering efforts allow DOD, EPA, and the states to work through overlaps and inconsistencies in regulatory requirements to ensure the most effective and timely cleanup of DOD sites. A detailed description of their remediation programs is included in the *Defense Environmental Restoration Program Annual Report to Congress*.[2]

The implementation process for the DOD regulatory program generally follows those of the environmental statutes. Although the regulatory frameworks of CERCLA and RCRA differ in many ways, their implementation processes generally parallel one another. Each requires assessments and investigations to determine the need for cleanup, and to select and design appropriate remedies to ensure protection of human health and the environment. However, each program has its own nomenclature for the various phases of study, design, and cleanup.

6.1.1 Installation Restoration Program

The task of promoting and coordinating the evaluation and cleanup of contamination at DOD sites has been assigned to the Defense Environmental Restoration Program (DERP). The Superfund Amendments and Reauthorization Act of 1986 (SARA) authorizes DOD to carry out this program in consultation with EPA. Executive Order 12580 assigned the Secretary of Defense responsibility for establishing and managing DERP within the overall framework of SARA and CERCLA. The Defense Appropriations Act provides the funding for DERP. Restoration activities, including work conducted under the BRAC program, are under the authority of the Assistant Deputy Under Secretary of Defense (Environmental Cleanup).

DOD refers to the program for meeting its responsibilities under CERCLA as the Installation Restoration Program (IRP). Under IRP, DOD cleans up all contaminated sites for which cleanup is required by environmental statutes, whether or not the sites are on the NPL. Although policy direction and oversight of IRP are the responsibility of the Assistant Deputy Under Secretary of Defense (Environmental Cleanup), each individual DOD Component (Army, Navy, Air Force, and Defense Logistics Agency) is responsible for program implementation. The Army Corps of Engineers (Corps) is the execution agent for all FUDS as well as for the Defense and State Memorandum of Agreement (DSMOA) program which funds states and territories for technical services they provide to support the cleanup of DOD facilities.

DERP has specified procedures for evaluating sites and procuring cleanup services under IRP that conform to the requirements of the National Oil and Hazardous Substances Contingency Plan (NCP), and follow EPA guidelines for site investigations and remediation. These procedures cover all phases of site operations, including preliminary assessment (PA), site inspection (SI), remedial investigation / feasibility study (RI / FS), remedial design (RD), and remedial action (RA). In most cases, activities related to preliminary assessment through remedial design are conducted by different contractors than are those related to remedial action. Activities conducted under IRP are classified as follows:

- Investigation: Analysis to characterize the nature, extent, and risk of releases of hazardous substances to the environment and to develop and select a cleanup remedy.
- Interim Action: Early measure to reduce the risk of releases of hazardous substances before the initiation of more complicated, comprehensive, and long-term cleanup remedies. For example, placing fences around contaminated areas or removing and treating or disposing of contaminated soil.
- Design: Performance specifications or detailed engineering plans and specifications to construct and implement a final cleanup remedy.
- Cleanup: Action to construct and implement a final cleanup remedy.

In selecting and designing remedies, DOD officials coordinate with EPA Regional officials to ensure that cleanup goals meet regulatory requirements. Most contracting is done by installations, either through centralized contracting service centers or directly with the installation. Although the DOD Components follow the general procedures specified by DERP, each DOD Component procures its own cleanup services. Section 6.5 describes typical procurement practices.

6.1.2 Base Realignment and Closure (BRAC)

Additional procedures have been established for the cleanup at bases being closed or realigned. Known as DOD's Fast Track Cleanup Program, these procedures have influenced the sequence of work to be conducted. This program has been designed to ensure that environmental policies take into account the relative risks of individual sites on an installation and the potential and need for reuse of the property. In the past, most restoration projects included the same overall cleanup timeline for an entire installation, regardless of the relative threat to human health and the environment that individual sites caused. In implementing the new relative risk approach, DOD is working with EPA, the states, and the public to review the prioritization process.[3]

A major influence on the selection of projects for remediation is DOD's effort to speed the economic recovery of communities where installations are scheduled to close. In prioritizing sites and developing cleanup plans DOD considers the following: the potential for local job creation and economic development; the use of transition coordinators at bases slated for closure; larger economic development planning grants to communities affected by base closures; and accelerated pace of site investigation, evaluation, and cleanup efforts. The key features of the program are:

- A BRAC Cleanup Team (BCT) is established at each installation slated for closure, to enhance environmental decision-making at the installation. Each BCT includes representatives from the installation, state environmental regulatory agency, and EPA Regional Office. These teams have the authority, responsibility, and accountability for environmental restoration programs at those installations.

- A BRAC Cleanup Plan (BCP) is prepared for each installation slated for closure and updated annually to reflect new information and changing conditions. The BCP serves as a comprehensive and consolidated statement of the status of the installation and strategy to expedite its cleanup. The BCT is responsible for the preparation of this plan.

- A Restoration Advisory Board (RAB) is established in communities where interest is sufficient to warrant it. RABs are intended to bring together people who reflect diverse interests within the community, in order to foster the early and continual flow of information between the affected community, the installation, and the state and federal regulatory agencies.[4]

- An Environmental Baseline Survey (EBS) is conducted for each closing installation, as mandated by the Community Environmental Response Facilitation Act (CERFA), which is an amendment to CERCLA signed on October 19, 1992. The CERFA requires DOD to identify and document all uncontaminated parcels of land at installations undergoing closure. These properties quickly can be turned over to communities for economic reuse.

The BRAC environmental program encompasses more than environmental restoration efforts. BRAC environmental funding also addresses closure-related environmental compliance, which includes such actions as the removal of USTs, closure of hazardous waste treatment, storage, and disposal facilities (TSDFs), radon surveys, and asbestos abatement. In addition, DOD is committed to accelerating the preparation of final Environmental Impact Statements (EIS), environmental planning, or other analyses required under the National Environmental Policy Act (NEPA). To undertake this effort, DOD may need to evaluate all reasonable reuse scenarios or alternatives based on its experience and judgment and on consultations with community planning entities.

After completing these efforts at a site, DOD will be in a position to determine, in coordination with EPA and the state, whether a parcel of land is suitable for lease or transfer to the community for reuse.

6.2 Factors Affecting Demand for Cleanup

The following factors could alter the scope of the cleanup needed as well as the technologies used:

- The pace of remediating sites is subject to change in response to general budgetary and political developments. The entire DOD budget for restoration, including the Defense Environmental Restoration Account (DERA) and BRAC funds, decreased from $2.5 billion in FY 1994 to $2.1 billion in FY 1995 and FY 1996, and is expected to remain at that level for FY 1997. Of these amounts, BRAC accounts for $523 million in FY 1994, $624 million in FY 1995, $717 million in FY 1996, and $777 million in FY 1997. Thus, BRAC projects account for 37 percent of all DOD restoration funds budgeted for 1997. In addition, the DOD Components may add funds for base realignments and closure by transferring funds from other accounts.[1]

- DOD anticipates that the proportion of the IRP budget allocated to remedial design and remedial action will continue to increase while a smaller portion of the budget will be allocated to site investigation and evaluation activities. In FY 1994, 48 percent of the Defense Environmental Restoration Account (DERA) funds were spent for remedial design and remedial action. DOD reports that this percentage grew to 61 percent in FY 1995 and 64 percent in FY 1996, and is expected to grow to 74 percent in FY 1997.[2]

- Although DOD believes that most sites have been located, new sites continue to be identified. DOD's list of identified sites has increased about six percent annually for the last four years. Most of these sites are on installations already identified as containing hazardous waste sites.[2]

- In determining the priorities for funding, DOD gives top priority to cleanup activities necessary to: prevent near-term adverse impacts to workers, the public, or the environment; accelerate the conversion of military properties to economic reuse; and satisfy agreements with local, state, or other federal agencies. In implementing its priorities, DOD may assign varying levels of priority to different sites on a given installation. This policy may lead to the acceleration of some projects at a given installation while causing other projects at the same installation to be postponed.

- DOD is in the process of classifying more than half its sites where response action is not complete on a relative risk basis as high, medium, or low relative risk. The classification is based upon three key factors: the amount and extent of contamination, migration pathways, and human and ecological receptors. The resulting relative risk evaluation is not an estimate of absolute risk or a substitute for a baseline risk or health assessment. It serves as a basis for discussing the relative risk of sites with involved stakeholders.[5]

- The rate of closures and realignments of bases and installations will affect the scheduling of site cleanup. Prior to closing or realigning a base, DOD may be required to clean up the site, although cleanup activity may continue after closure. Pursuant to the Base Realignment and Closure Acts of 1988 and 1990, DOD designates military installations for closure or realignment. Of the BRAC installations designated in the first four rounds (BRAC 1988, 1990, 1993, and 1995), 206 have or are suspected to have contamination and 108 have been designated "fast-track" cleanup sites.[6]

- DOD policy calls for extensive coordination with EPA, state environmental authorities, local communities, local planning authorities, and other interested parties in planning and implementing its cleanup programs. These requirements may influence the sequence of work and types of technologies selected for a site.

- Changes in regulatory requirements also may affect cleanup goals, technologies used, and cost. For example, some categories of DOD sites are likely to be affected when the recently proposed regulations for munitions cleanup at training ranges becomes final. In February 1997, EPA promulgated new rules for remediation of munitions at training ranges which could significantly reduce the cost of cleaning up DOD munitions sites. However, because more bases and ranges are expected to close, DOD may incur significant costs for these closure-related cleanups. DOD now will be required to treat or dispose of wastes that, heretofore, were being contained.

- Cleanup requirements are uncertain because the nature and magnitude of the contamination at many identified sites are still only partially known. As DOD continues to characterize its contamination problem and accumulate data from site investigations and cleanups, its cleanup needs will become more clearly defined.

6.3 Number and Characteristics of Sites

Data on site characteristics presented in this chapter are based on an analysis of DOD's Restoration Management Information System (RMIS), which is an important tool used throughout DOD for program management and oversight. RMIS contains data provided by the Components on the status of the DOD sites for which they are responsible.[7]

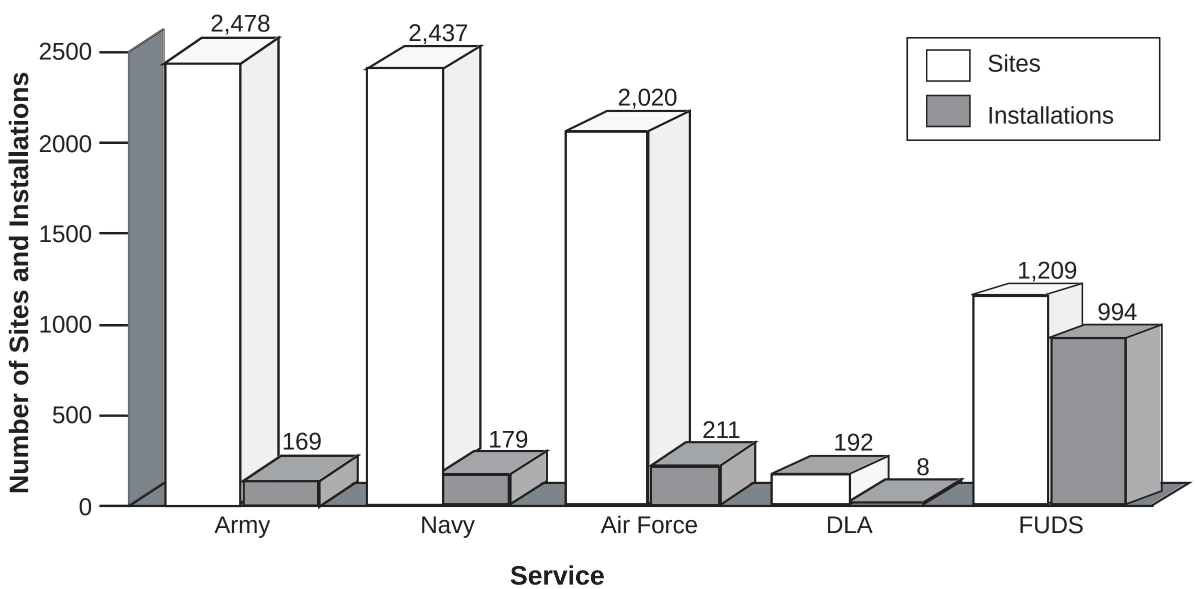
6.3.1 Number and Types of Sites

As of September 30 1995, DOD had identified 22,089 sites located on 1,705 installations, and 8,830 FUDS properties with potential hazardous waste contamination involving soil, groundwater, or other media.[2] Of these, response actions were completed at 10,372 sites on DOD installations and facilities. In addition, 5,141 FUDS properties were determined to require no further action or be ineligible for DERA funding, and the eligibility of 1,048 FUDS properties had not yet been determined. Thus, 15,406 (11,717 DOD sites and 3,689 FUDS sites) were in various stages of site investigation or cleanup. The number of identified sites has grown about 26 percent from FY 1991 to FY 1995. Most of the newly identified sites are on installations that have other contaminated areas. A site is a distinct area of contamination and there may be more than one site on an installation or facility.

Of the 15,406 sites, DOD estimated that 8,336 eventually will require remediation of contaminated materials and, for most of these sites, DOD had not selected RA contractors. The remaining sites either were being cleaned up, have been completely remediated, or were found to require no further work. A breakdown of the 8,336 sites by DOD component is shown in Exhibit 6-1. More than 85 percent of the sites are almost evenly distributed among the Air Force, Army, and Navy, and most of the remainder are FUDS. Although FUDS are managed by the Army, they are the result of activities from all the services.

DOD derived these estimates from a combination of data in RMIS, and information provided by the DOD Components as of September 30, 1995. However, because the SIs and RI/FSs have not been completed at a number of these sites, these estimates, as well as program cost estimates, may be revised somewhat over the next several years. Exhibit 6-2 shows the geographic distribution of these sites, and Appendix Exhibit C-1 shows the

Exhibit 6-1: Number of DOD Sites and Installations Needing Cleanup



Note: Totals equal 8,336 sites and 1,561 installations to be remediated as of September 30, 1995.

Source: DOD, Office of the Deputy Under Secretary of Defense (Environmental Security), Restoration Management Information System, November 1996.

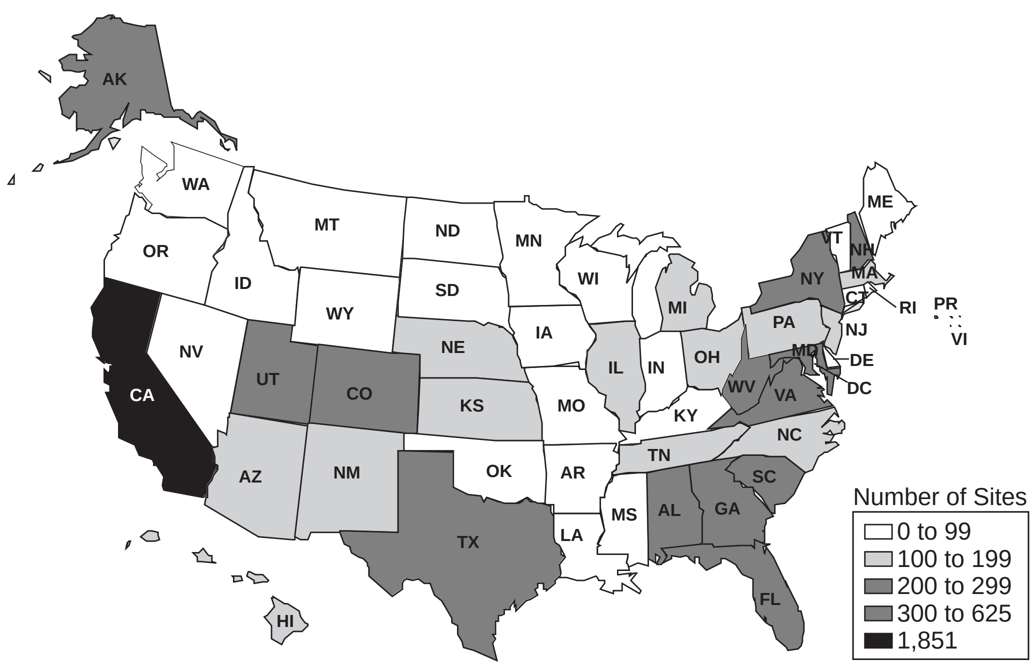
breakdown by DOD Component and state. The states with the most DOD sites needing cleanup are California with 1,851 sites, Maryland with 434 sites, Alaska with 416 sites, Florida with 390 sites, Texas with 344 sites, and Virginia with 306 sites. DOD categorizes its sites into 45 types, which are different than the site types used to categorize the NPL sites in Chapter 3 of this report. The DOD system of site nomenclature uses categories that include both activities and physical descriptions. Exhibit 6-3 shows the number of sites for each of these 10 site types that need cleanup. These 10 site types account for 75 percent of all DOD sites needing remediation. Although some sites may have resulted from more than one type of activity, each site is placed in only one category. The definitions of all the site types are provided in Appendix Exhibit C-2. Appendix Exhibit C-3 details, by DOD Component, the number of each site type needing remediation.

6.3.2 Contaminated Matrices

The data on matrices and contaminants used for this chapter are from RMIS as of September 30, 1994. Of the 9,331 sites then needing cleanup, data that identified the type of matrix (contaminated soil, groundwater, surface water, and sediment) were available for 3,212 sites (over 34 percent). The analysis of site characteristics in the remainder of this report is based on this 1994 data set. Exhibit 6-4 shows, by DOD Component, the number of sites that contain each type of matrix. Seventy-one percent of the sites have contaminated groundwater and 67 percent have contaminated soil, which indicates that many sites have both. Contaminated surface water and sediment are associated with only 19 percent and six percent of the sites, respectively. The totals add to more than the number of sites, since a site may contain more than one type of contaminated media.

The relevant media vary from one site type to another (Exhibit 6-5). For example, contaminated groundwater was found at 83 percent of disposal pit/dry well sites, but only 51 percent of the storage area sites. Likewise, 58 percent of underground storage tank sites had soil contamination, compared to 100 percent of the building demolition sites and 84 percent of storage area sites. However, the amount of

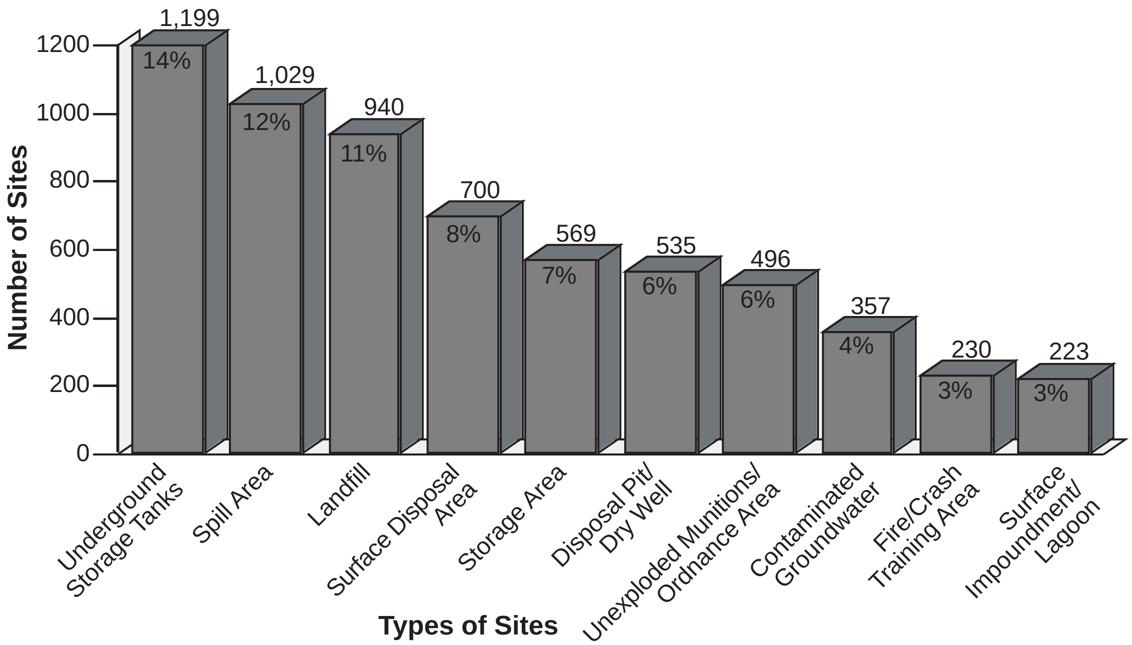
Exhibit 6-2: Location of DOD Sites Needing Cleanup



Note: Total equals 8,336 sites to be remediated as of September 30, 1995. Appendix Exhibit C-1 provides the data by state and DOD component.

Source: DOD, Office of the Deputy Under Secretary of Defense (Environmental Security), Restoration Management Information System, November 1996.

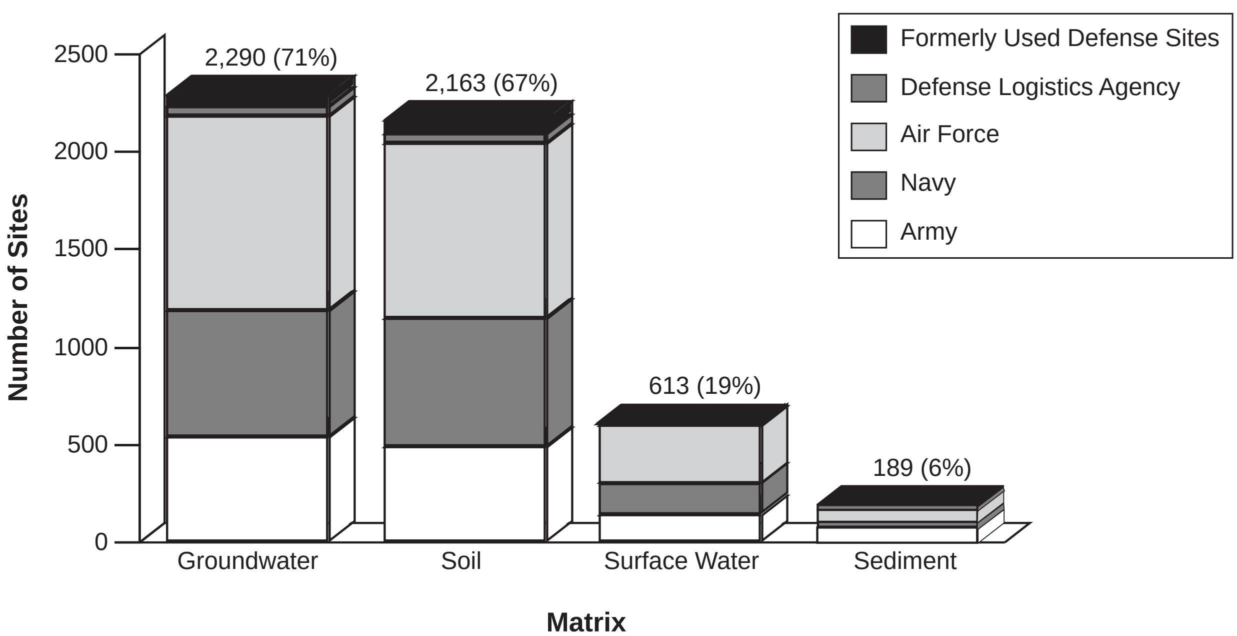
Exhibit 6-3: Most Common Types of DOD Sites Needing Cleanup



Notes: These 10 site types account for 6,278 (75%) of the 8,336 DOD sites to be remediated as of September 30, 1995. Appendix Exhibit C-2 gives definitions of the 45 site types. Appendix Exhibit C-3 lists the frequencies of all 45 site types.

Source: DOD, Office of the Deputy Under Secretary of Defense (Environmental Security), Restoration Management Information System, November 1996.

Exhibit 6-4: Frequency of Contaminated Matrices at DOD Sites Needing Cleanup



Notes: Based on 3,212 sites on 480 installations for which data were available as of September 30 ,1994. Appendix Exhibit C-4 shows the breakdown of these data by site type. Appendix Exhibit C-5 shows the breakdown by DOD component.

Source: DOD, Office of the Deputy Under Secretary of Defense (Environmental Security), Restoration Management Information System, November 1995.

Exhibit 6-5: Frequency of Contaminated Matrices by Site Type at DOD Sites Needing Cleanup

Site Types	No. of Sites	No. of Sites W/Data	Ground-water Contami-nation	Soil Contami-nation	Surface Water Contami-nation	Sediment Contami-nation
Underground Storage Tanks	1,361	444 (33%)	75%	58%	4%	1%
Spill Area	1,234	539 (44%)	71%	66%	66%	19%
Landfill	914	491 (54%)	79%	62%	35%	8%
Unexploded Ordnance	784	14 (2%)	43%	79%	29%	7%
Surface Disposal Area	748	347 (46%)	66%	72%	25%	5%
Disposal Pit/ Dry Well	612	334 (55%)	83%	76%	19%	8%
Storage Area	608	181 (30%)	51%	84%	69%	6%
Contaminated Groundwater	357	86 (24%)	97%	33%	13%	7%
Fire/Crash Training Area	271	157 (58%)	80%	77%	17%	5%
Building Demolition/ Debris Removal	225	6 (3%)	0	100%	0	0

Notes: The 10 most common site types account for 7,114, or 76% of the 9,331 DOD sites to be remediated as of September 30, 1994. Appendix Exhibit C-4 lists the frequency of contaminated matrices for all 45 site types to be remediated as of September 30, 1995.

Source: DOD, Office of the Deputy Under Secretary of Defense (Environmental Security), Restoration Management Information System, November 1995.

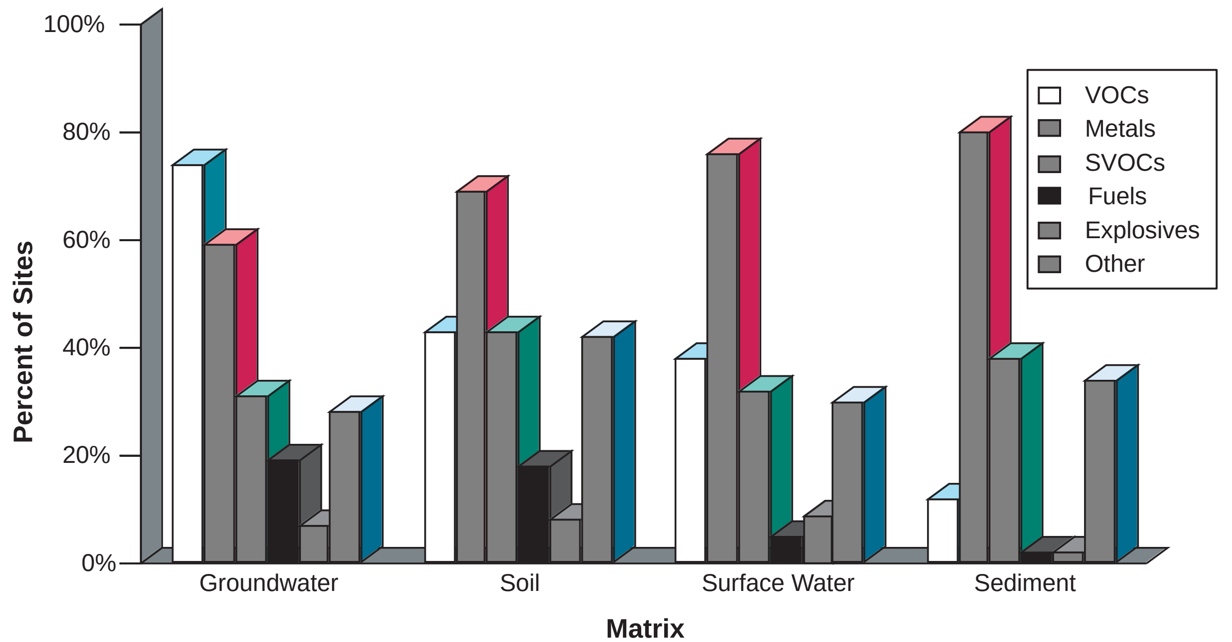
available data varies from one site type to another. Of the top 10 site types, data were available for a low of two percent of the unexploded ordnance sites to a high of 58 percent of the fire/crash training areas. Appendix Exhibit C-4 provides the matrices associated with all 45 site types.

6.3.3 Types of Contaminants

As is the case for the analysis of matrices above, contaminant data are available for 3,212 (over 34 percent) of the 9,331 sites that needed cleanup as of September 30, 1994. For this study, the contaminants were grouped into six categories: volatile organic compounds, (VOCs), semivolatile organic compounds, (SVOCs), metals, fuels, explosives, and "other." "Other" primarily includes inorganic elements and compounds such as asbestos, arsenic, inorganic cyanides, corrosives, pesticides, and herbicides. Exhibits 6-6 and 6-7 show the major contaminant groups by matrix and DOD component. The data used to create these exhibits are in Appendix Exhibit C-5.

The most prevalent contaminant groups in groundwater are VOCs and metals, which appear in 74 percent and 59 percent of DOD groundwater sites, respectively (Appendix Exhibit C-9). However, while metals appear in the majority of sites in all matrices, VOCs are present in only 43 percent and 38 percent of the soil and surface water sites, respectively. SVOCs and metals were more consistent across different media than VOCs. SVOCs were found at between 31 and 43 percent of the sites, and metals were found at between 59 and 80 percent of the sites. Fuels were found at fewer than 22 percent of all sites

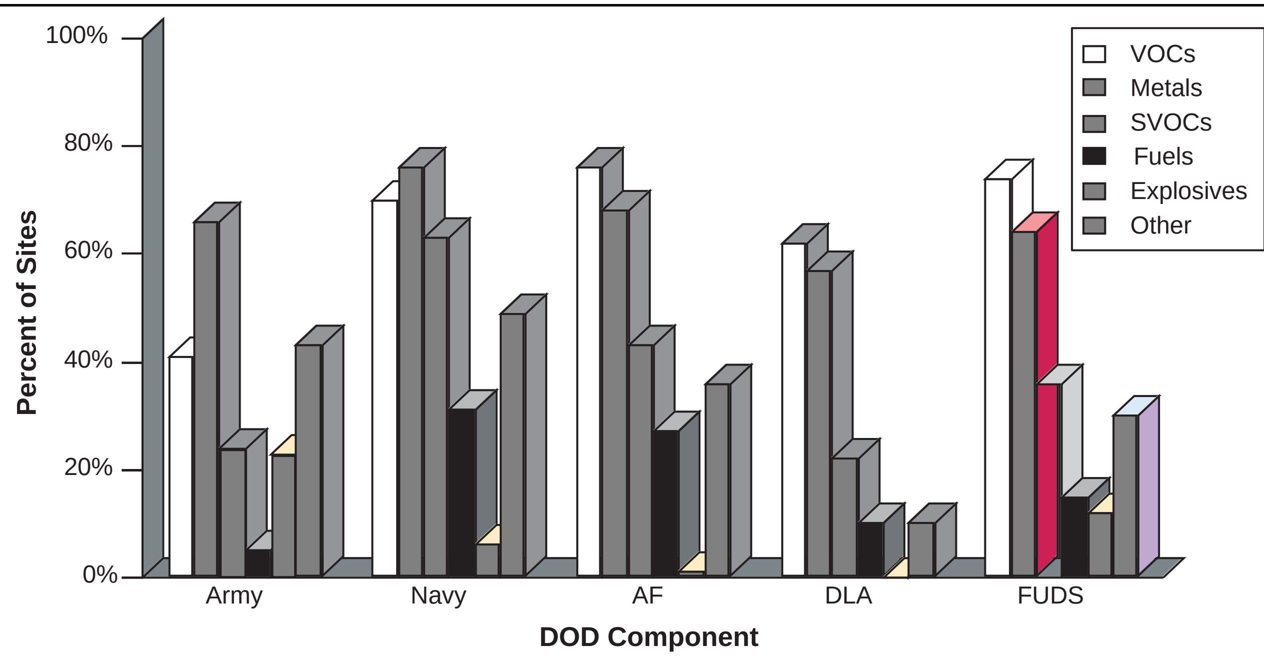
Exhibit 6-6: Major Contaminant Groups by Matrix at DOD Sites Needing Cleanup



Notes: Based on 3,212 sites needing cleanup at 480 installations for which data were available as of September 30, 1994. A contaminant group may appear in more than one matrix at a site. Appendix Exhibit C-5 provides the supporting data.

Source: DOD, Office of the Deputy Under Secretary of Defense (Environmental Security), Restoration Management Information System, November 1995.

Exhibit 6-7: Frequency of Major Contaminant Groups by Component at DOD Sites Needing Cleanup



Notes: Based on 3,212 sites needing cleanup at 480 installations for which data were available as of September 30, 1994. More than one contaminant group can appear at a site. Appendix Exhibit C-5 shows the supporting data.

Source: DOD, Office of the Deputy Under Secretary of Defense (Environmental Security), Restoration Management Information System, November 1995.

(Appendix Exhibit C-5), which is surprisingly low, given DOD's substantial use of fuels at many facilities. However, it may be due to the reporting of the benzene, toluene, ethylbenzene, and xylene (BTEX) constituents of fuels and petroleum products under VOCs.

Exhibit 6-7 and Appendix Exhibit C-5 show the major contaminant groups by DOD Component. The most frequently occurring group—metals—is found at 69 percent of all sites with data, followed by VOCs at 65 percent, and SVOCs at 43 percent. VOCs and metals are found at most sites in all the services, except at Army sites, where VOCs account for only 41 percent of the sites. SVOCs and fuels show more variations (24-63 percent and 5-31 percent, respectively) (Appendix Exhibit C-5). These waste groups also are frequently found at sites related to non-defense industrial facilities. In addition, some sites contain contaminants that are found less frequently in industry and that present unique problems for selecting remediation approaches. For example, over eight percent of the DOD sites contain explosives, and an unspecified number contain low-level radiation. Explosives are found at 23 percent of Army sites, 6 percent of Navy sites, and only 1 percent of Air Force sites. Appendix Exhibit C-5 shows a breakdown of these data into the frequencies of the most common contaminant groups for each medium and DOD Component.

The frequency of occurrence of contaminants also varies by site type. Exhibit 6-8 shows the relative frequency of occurrence of the major contaminant groups for five of the six most common site types. The contaminant data for the fourth most common site type, unexploded munitions/ordnance areas, are not shown in this exhibit because the available contaminant data for these sites were sparse. Metals and organics occur frequently in all five site types, although the frequencies vary. For example the occurrence of metals ranges from 50 percent of underground storage tank sites to 84 percent of landfills. Appendix Exhibit C-6 shows contaminant group occurrences for all 45 site types.

To describe the details of the contaminants present at DOD sites, the data are further broken out into 19 subgroups, such as halogenated VOCs, nonhalogenated VOCs, and BTEX. Exhibit 6-9 shows the frequency of occurrence of these subgroups. Heavy metals is the most prevalent subgroup, in part because, for this analysis, it is a major contaminant group and is not divided into narrower categories as are the organics.

Most of these subgroups also are found at non-defense industrial facilities. In addition, about eight percent of the sites contain explosive and propellant materials and about one percent of the sites contain radioactive metals. The contaminant subgroups of importance to each medium are shown in Appendix Exhibit C-7 and by site type in Appendix Exhibit C-8.

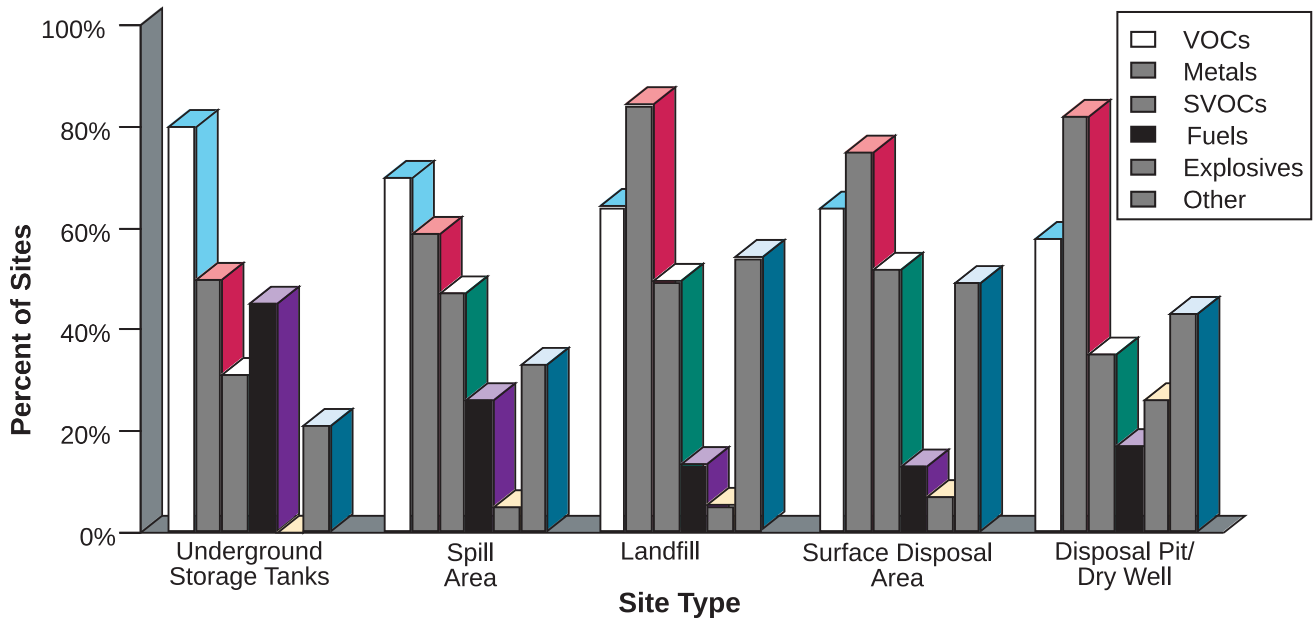
RMIS also contains data on specific contaminants present at each of the 3,212 sites for which information is available. The eight most frequently found contaminants in each matrix are shown in Exhibit 6-10. The most frequently found specific contaminants in all media are the metals lead, zinc, barium, nickel, cadmium, and copper. The most common organic chemicals are trichloroethylene and benzene.

6.4 Estimated Cleanup Costs

DOD annual funding for DERP and BRAC grew from $150 million in FY 1984 to $2.5 billion in FY 1994 and declined to $2.1 billion in FY 1995. It has remained at this level for FYs 1996 and 1997. These figures include funding for BRAC which began in FY 1991. However, as explained below, not all of the BRAC funds are used for site restoration. This point is especially important, since BRAC funds have been accounting for an increasing share of the DOD restoration budget. DOD expects that BRAC funding, which accounted for 25 percent of total DOD restoration funding over the 1991 through 1995 period, has grown to 37 percent of all DOD restoration funds budgeted for FY 1997.

BRAC environmental funding also may be used for other closure-related environmental expenses and environmental compliance. Compliance efforts may include actions such as the removal of underground storage tanks, closure of hazardous waste TSDFs, radon surveys, and asbestos abatement. Planning may involve environmental analyses required under NEPA, and to aid decisions related to property reuse and redevelopment. On the other hand, BRAC

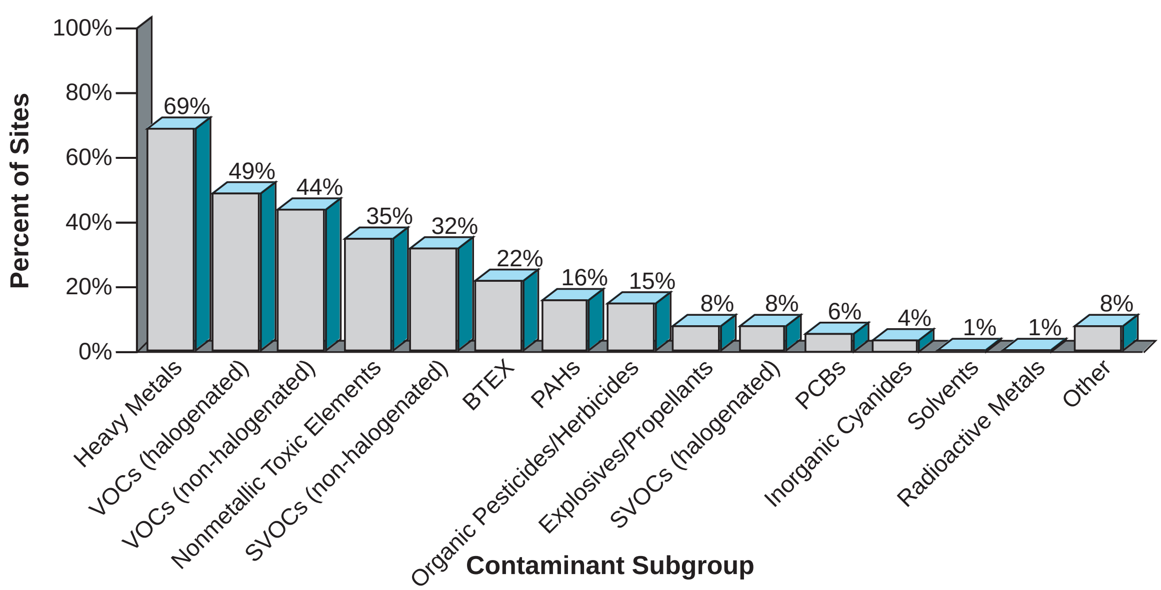
Exhibit 6-8: Frequency of Major Contaminant Groups for the Most Common DOD Site Types Needing Cleanup



Notes: Based on 3,212 sites needing cleanup at 480 installations for which data were available as of September 30, 1994. More than one contaminant group can appear at a site. Appendix Exhibit C-6 shows the breakdown of the data for all site types.

Source: DOD, Office of the Deputy Under Secretary of Defense (Environmental Security), Restoration Management Information System, November 1995.

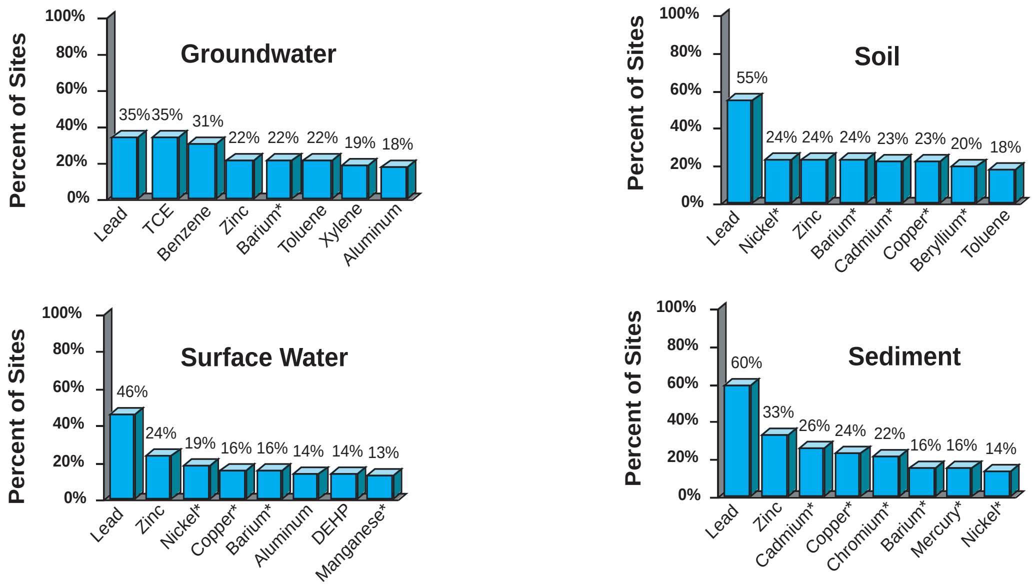
Exhibit 6-9: Frequency of Contaminant Subgroups at DOD Sites Needing Cleanup



Notes: Based on 3,212 sites needing cleanup at 480 installations for which data were available as of September 30, 1994. Subgroups found at fewer than one percent of the sites include: dioxins/furans, organic corrosives, inorganic corrosives, and organic cyanides. “Other” primarily includes inorganic elements and compounds such as asbestos, arsenic, inorganic cyanides, pesticides, and herbicides. Totals may exceed 100% because more than one contaminant may occur at a site.

Source: DOD, Office of the Deputy Under Secretary of Defense (Environmental Security), Restoration Management Information System, November 1995.

Exhibit 6-10: Frequency of the Most Common Contaminants by Matrix at DOD Sites Needing Cleanup



Notes: TCE = Trichloroethylene; DEHP = Bis (2-ethylhexyl) phthalate
* Also includes compounds.
Percent of 3,212 sites with data. 2,290 had contaminated groundwater; 2,452 had contaminated soil; 613 had contaminated surface water; and 189 had contaminated sediment.

Source: DOD, Office of the Deputy Under Secretary of Defense (Environmental Security), Restoration Management Information System, November 1995.

environmental funding is not limited to the aforementioned amounts. These amounts are considered minimum amounts, and DOD Components may allocate additional funds from other accounts.

DOD estimates that the cost of completing the remaining remediation work at all DOD sites from FY 1997 until all sites are cleaned up will be over $28.6 billion, distributed as follows: Army $10.6 billion; Air Force $7.4 billion; Navy $5.6 billion; Defense Logistics Agency (DLA) $0.4 billion; Defense Nuclear Agency $0.1 billion; and FUDS $4.5 billion. Most of the past DOD expenditures for restoration have gone for site investigation and analysis. Since 1984, DOD has identified over 29,000 sites with a reported potential for significant contamination. These sites had to be investigated and evaluated to determine the extent of the problems and potential remedies. Beginning in FY 1995, more than half the restoration budget was spent on actual cleanup as compared to investigations. DOD estimates that by FY 1997, 74 percent of its restoration funds will go to cleanups. DOD estimates that it will take until 2015 before all of its sites are cleaned up.

6.5 Market Entry Considerations

Although policy is determined centrally by the Deputy Under Secretary of Defense (Environmental Security), each service is responsible for investigating and restoring its own sites and uses its own approach to this work. Almost all DOD site assessments and remedial actions are done by contractors. Generally, there are two groups of contractors: those that work on site investigations and assessments and those that do remedial actions. Contractors in the first group seldom do the construction work. Vendors interested in innovative technologies should take action to ensure that their technologies are considered at the earlier stages of site investigation and assessment. For example, even if a vendor is precluded from working on the RI/FS of a particular site, he or she may provide information on their technology to the DOD officials and contractors working on the RI/FS. Appendix E lists the contract management or program offices. The following is a summary of the practices of each DOD Component.

Army

The management of the *Army* IRP is the responsibility of the U.S. Army Environmental Center (USAEC), which sets overall policy and determines the sequence of work to be done. The Corps of Engineers implements the program, including developing schedules for all activities and studies for PAs, SIs, and RI/FSs, through more than two dozen contractors. RD/RA is done by the Corps under the direction of USAEC. The Corps also implements the remediation programs for DLA and FUDS and conducts more than half of the site investigation and remediation work for the Air Force. The Corps also supports EPA, other federal agencies and states in environmental restoration activities. For EPA, the Corps provides design, construction, and technical assistance in support of the Superfund program. In FY 1994, the Corps conducted $264 million of work for the Superfund program, of which 80 percent was for remedial action. The Corps also does restoration work for the Economic Development Agency, Farmers Home Administration, Federal Aviation Administration, Commodity Credit Corporation, Federal Emergency Management Agency, and the Department of Energy. These efforts amounted to over $100 million in FY 1994.[8]

In the past, most of the design work was done by the Corps' Missouri River Division (MRD) in Omaha, Nebraska, although some work is also done by other Corps divisions and districts. The MRD contains the Hazardous, Toxic, and Radioactive Waste (HTRW) Mandatory Center of Expertise whose 76-person staff serves as a technical resource for environmental restoration. The center is responsible for maintaining state-of-the-art technical expertise for all aspects of restoration activities and providing technical assistance to designated Corps design districts. The Corps uses four basic types of contractors:

- Total Environmental Response Contracts (TERC). These contracts are designed to enable DOD to use a single contractor for all work at a site, from initial studies through construction and to perform multiple tasks at multiple sites on an installation. The Army anticipates that when all these contracts are in place, each of the 12 Corps divisions will have at least one TERC contract, and the work under these contracts primarily will be for construction and for sites for which the remediation approach is relatively well defined. As of November 1995 there were 10 TERC contracts and three in the process of evaluation and selection.
- Pre-placed Remedial Action Contracts. These contracts are exclusively for construction work managed by the Corps divisions. Each division has at least one contract and remedial action contractors are prohibited from working on site investigation and related work that contribute to the preparation of Records of Decision (RODs) and remedial designs.
- Rapid Response Contracts. The Corps's MRD manages two rapid response contracts that provide a nationwide capability to respond to requests for action within 45 days. The work under this contract may include administrative, engineering, and construction work.
- Architectural and Engineering Contracts. These contracts cover a wide variety of activities, such as new construction, renovation, maintenance, and planning. Although they generally are not specifically for remediation work, remediation or related investigations and studies may be conducted under some of these contracts, depending on their specific statements of work.

Navy

The management of the *Navy* IRP is the responsibility of the Navy Facilities Engineering Command (NAVFAC), which reports to the Assistant Secretary of the Navy for Installations and Environment. The day-to-day work of the IRP is run by ten field divisions that operate within distinct geographical boundaries. Each division has at least one contract for its region, known as the Comprehensive Long-Term

Environmental Action Navy (CLEAN) contract. These contracts, which are issued through NAVFAC, are primarily for work relating to PA through RD. As of November 1995, the Navy had 13 active CLEAN contracts and two additional potential contracts were undergoing evaluation and selection. Remedial action work is conducted through large pre-placed remedial action contracts (RACs) and, generally, the contractors that do the construction work are prohibited from working on site investigations and assessments. As of November 1995, there were 10 RAC contracts. The CLEAN and RAC contracts are multi-year, task-order type contracts ranging from $75 million to $300 million in potential work.

Air Force

The *Air Force* IRP is decentralized, and executed by the 11 Air Force Major Commands. Each may use specialized technical support from environmental contractors. Contractors are accessed either through pre-established task-order contracts administered through five contract service centers, individual contracts let by the commands themselves, or by individual installations. For example, environmental officials at McClellan Air Force Base have procured multi-million dollar contracts for environmental remediation work. A majority of the Air Force's site investigation and restoration work has been conducted by the Corps.

The Air Force base conversion program is separately managed by the Air Force Base Conversion Agency (AFBCA). The overall policy for this agency is determined by the Deputy Assistant Secretary of the Air Force for Environment, Safety and Occupational Health. About 15 percent of the work is done by the Corps, and the remainder through direct contracts, usually the same contractors used for the IRP program. The minimum budget for the Air Force BRAC was $147 million in FY 1994 and $107 million in FY 1995. As previously stated, the BRAC funds may be used for more than environmental restoration.

The Defense Logistics Agency's sites are managed by the Huntsville, Alabama, District of the Corps.

6.6 Technologies Used and Research, Development and Demonstrations

A partial list of DOD and other federal sites using innovative technologies appears in the EPA report *Innovative Treatment Technologies: Annual Status Report*.[9] The following are examples of innovative technology applications at DOD sites known to EPA: bioremediation has been selected to treat for VOCs and PAHs; soil vapor extraction has been selected for VOCs, polynuclear aromatic hydrocarbons (PAHs), and gasoline; and soil washing has been selected for PCBs and metals.

DOD actively participates in technology innovation to meet its environmental restoration needs more efficiently and effectively. The Department's efforts predominately focus on three major areas:

- Technology transfer,
- Demonstration and certification of emerging technologies, and
- Development of new technologies.

Technology Transfer

DOD has been active in facilitating technology transfer among development and demonstration programs and technology users. For example, DOD is working with the Federal Remediation Technologies Roundtable, an interagency organization created to facilitate collaboration among federal agencies, such as the Department of Energy (DOE) and EPA, which also have a stake in technology development. The Federal Remediation Technologies Roundtable is described in Chapter 3.

DOD has been especially active in Roundtable initiatives to develop the *Remediation Technologies Screening Matrix and Reference Guide, Second Edition (Screening Matrix)*, an easy-to-use compendium of current information on available remediation technologies.[10]

DOD is using the latest communications technologies to disseminate technology information, including the World Wide Web. DOD has provided many Technology Application Reports on the Web and plans to add the Screening Matrix and additional Technology Application Reports as they become available (http://www.frtr.gov). Installations across the country also are using the Web to share information on technology application with local communities and the environmental technology industry.

The BRAC Public Affairs Office at the Presidio of San Francisco provides information regarding restoration activities, including cleanup technology information on the Web. The home page is intended for use by the public as well as other environmental technology users in the field (http://www.envcleanup.gov).

Demonstrations and Certification of Emerging Technologies

DOD's demonstration programs provide project managers with a set of previously tested and certified technologies, which they can then apply with greater assurance of acceptable cost and performance. DOD's flagship demonstration program is the Environmental Security Technology Certification Program (ESTCP), which DOD established to demonstrate and certify emerging technologies. Through this program, DOD ensures that technologies that appear promising based on laboratory work are demonstrated at military installations, where their cost, performance, and market potential are documented. In FY 1995, the ESTCP initiated 27 demonstration projects, 15 of which were related to environmental cleanup. For example, the Army Environmental Center jointly with EPA is currently evaluating a more cost-effective advanced oxidation technology at Cornhusker Army Ammunition Plant in Nebraska. DOD shares these technologies with other federal agencies and brings them to the commercial market. Under ESTCP, EPA has initiated joint projects with DOE, where technologies developed by DOE will be demonstrated and validated at DOD sites.

The Defense National Environmental Technology Test Site Program (NETTSP) established national test centers to compare demonstrations and evaluate cost-effective innovative technologies, thereby enabling the technologies to be transferred from research to full-scale use. Under this program, DOD Components and EPA select sites with appropriate contaminants to serve as test locations; develop common quality assurance/quality control procedures; and develop coordinated dissemination mechanisms for reporting results of technology demonstrations and evaluations. The DOD Components and EPA are establishing partnerships with government and private interests to carry out the technology demonstrations at the selected installations and provide researchers and developers with technical and field support. DOD plans technology demonstrations at the following installations:

- Port Hueneme Naval Construction Battalion Center sites for technologies to remediate fuel hydrocarbons;
- Volunteer Army Ammunition Plant sites for demonstrations involving technologies for the remediation of energetics and heavy metals contamination;
- Wurtsmith Air Force Base for development and testing of integrated biological/physiochemical processes and evaluation of innovative monitoring and measurement technologies;
- McClellan Air Force Base sites for demonstrating technologies for solvent remediation; and
- Dover Air Force base to house the Groundwater Remediation Field Laboratory.

Each of the individual services also maintains technology development and demonstration programs. The Air Force Center for Environmental Excellence, Army Environmental Center, and Naval Facilities Engineering Service Center are leaders in cleanup technology demonstration.

For example, the Navy has had success in demonstrating the TerraKleen™ soil washing technology at North Island Naval Air Station, California in FY 1994, in cooperation with the EPA Superfund Innovative Technology Evaluation (SITE) Program. The technology was placed into full-scale operation to remediate soil contaminated with polychlorinated biphenyls at several sites on the installation. This action may lead to closing the three sites with no further action required. Technology demonstration and full-scale performance data were distributed Navy-wide to facilitate the use of the technology at other Navy installations.

DOD also participates in another demonstration program, the Clean Sites Public-Private Initiative, described in Section 2.5.

Development of New Technology

DOD also supports basic and applied research and development on environmental technologies based on user-generated requirements. To coordinate and focus these activities, the services work together to define technology needs and DOD then prioritizes and communicates service-validated requirements to the technology development community.

DOD coordinates new technology development through the Tri-Service Environmental Quality Laboratory Plan (sometimes called the Green Book), which allows program funding to be matched to identified needs. To coordinate and leverage resources, DOD has implemented a plan in which services are designated as leads for various cleanup technology focus areas. For example, researchers at the Air Force's Armstrong Laboratory are developing a bioslurping system that improves the effectiveness of bioventing by removing free product before treatment.

DOD also participates in the Strategic Environmental Research and Development Program (SERDP). SERDP was established by Congress in 1990 to address environmental technology needs of the Departments of Defense and Energy. It is managed by DOD, DOE, and EPA and is supported by DOD funds. The program funds government laboratory, academic, and private industry research and the development of technologies needed by DOD, DOE, and EPA. Most of the funding is used to support technology development in the areas of cleanup, compliance, conservation, and pollution prevention. The cleanup area accounts for the largest percentage of program funds and includes 34 cleanup-related technology projects. For example, through the Mobile Underwater Debris Survey System (MUDSS) project, SERDP hopes to provide the DOD services with an effective technology for detecting unexploded ordnance at underwater ranges.

Examples of technologies being developed or demonstrated in DOD programs include: *in situ* vapor extraction for petroleum, oil and lubricants (POLs), VOCs, and solvents in soil, *in situ* vapor extraction for VOCs in groundwater, *ex situ* vapor extraction, *in situ* soil venting of POLs and solvents, *in situ* bioventing of POLs in soil and groundwater, *in situ* bioremediation of POLs and solvents in soil and groundwater, *ex situ* bioremediation of POLs in soil and groundwater, *ex situ* bioremediation of explosives and propellants in soil, chemical detoxification of chlorinated aromatic compounds in soil, *in situ* carbon regeneration, incineration of explosives-contaminated soil, infrared thermal destruction, low temperature thermal stripping of VOCs in soil, mobile rotary kiln incineration of soils, thermal destruction, radio frequency thermal soil decontamination for POLs and solvents, xanthate treatment for heavy metals in groundwater or wastewater, stabilization/solidification, and compacting of explosives contaminated soils.

DOD work on these and other technologies are summarized in several EPA and DOD documents.[11] [12] [13] [14] [15]. In addition to a brief summary of each project, these documents provide a contact for further technical information. A list of relevant DOD program offices appears in Appendix E.

6.7 References

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4. U.S. DOD, Deputy Under Secretary of Defense (Environmental Security), *Restoration Advisory Board (RAB) Implementation Guidelines*, Memorandum, October 13, 1994.

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6. U.S. Environmental Protection Agency, Office of Administration and Resources Management, *Fiscal Year 1997 Justification of Appropriation Estimates for the Committees on Appropriations*, EPA 206-R-96-001, March 1996.

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12. U.S. EPA, et al, *Federal Publications on Alternative and Innovative Treatment Technologies for Corrective Action and Site Remediation*, prepared by the member agencies of the Federal Remediation Technologies Roundtable, Fifth Edition, EPA-542-B-95-004, 1995.

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CHAPTER 7
DEMAND FOR REMEDIATION OF DEPARTMENT OF ENERGY SITES

One of the most serious and costly environmental remediation tasks facing the federal government is the cleanup and restoration of more than 100 major installations and other locations that are the responsibility of the U.S. Department of Energy (DOE). Environmental problems at DOE installations stem from activities that began in the 1940s with the Manhattan Project and continued throughout the Cold War. In the 50 years since the Manhattan Project, the United States has spent more than $300 billion (in 1996 dollars) on nuclear weapons research, production, and testing—manufacturing tens of thousands of nuclear warheads and detonating more than 1,000.[1]

The environmental problems associated with DOE properties, unlike those of other industries, include unique radiation hazards, unprecedented volumes of contaminated soil and water, and a large number of contaminated structures ranging from nuclear reactors to chemical plants for the extraction of nuclear materials to evaporation ponds.[1] DOE estimates that environmental restoration, the cleanup of its hazardous waste sites, will cost $63 billion and take about 75 years.[2][3] Environmental restoration accounts for 28 percent of the $227 billion life-cycle-cost DOE has estimated for all environmental management activities at its facilities. The other 72% of DOE's environmental management costs are for the following types of activities: waste management, nuclear material and facility stabilization, national program planning and management, landlord activities, and technology development. DOE's environmental cleanup program offers an enormous opportunity for firms that provide remediation services.

Although DOE has come a long way, particularly over the last two years, in defining the scope of the remediation needed for many of the 10,500 "sites" the agency has identified to date, most of them still are being evaluated.[2] Throughout this chapter the term "site" will be used to indicate an individual area of contamination. In June 1996, the agency issued its most comprehensive report to date on the status and potential cost of cleaning up the backlog of accumulated problems, as well as the wastes to be generated from ongoing national security operations and from the cleanup efforts themselves. The report, *The 1996 Baseline Environmental Report,* which will be updated and reissued periodically, summarizes environmental management activities—including environmental restoration (cleanup), waste management, nuclear material and facility stabilization, technology development, and landlord responsibilities—and provides tentative schedules and estimates of the life-cycle costs involved in completing the agency's Environmental Management program (See Sections 7.3 and 7.4 for additional information).

7.1 Program Description

DOE's environmental programs are managed by its Office of Environmental Restoration and Waste Management (EM) through six major program offices: Office of Waste Management, Office of Management and Finance, Office of Nuclear Material and Facilities Stabilization, Office of Site Operations, Office of Science and Technology, and Office of Environmental Restoration.[4] As its name implies, the *Office of Waste Management* is concerned with the treatment, storage, and disposal of wastes generated from DOE's ongoing operations. The Office of Waste Management also is responsible for DOE's waste minimization effort and for corrective activities at the agency's waste management facilities. These programs are intended to bring all DOE waste management facilities into compliance with applicable federal, state, and local regulations related to health, safety, and the environment.

In addition to overall EM administrative and budget functions, the *Office of Management and*

Finance conducts cost and performance analyses related to the agency's environmental management programs. The *Office of Nuclear Materials and Facilities Stabilization* implements DOE's efforts to deactivate and properly maintain closed facilities until they can be decontaminated and decommissioned or released for other uses. The *Office of Site Operations* is responsible primarily for programs related to integrating good risk management practices and credible risk assessment procedures into the environmental management decision-making process, increasing public understanding of and involvement in environmental decision-making, and developing the agency's environmental justice public participation strategy.

The *Office of Science and Technology* is responsible for developing technologies to meet DOE's goals for environmental restoration and waste management. Its activities include research and development; demonstration, testing, and evaluation; technology integration; and technology transfer.

The *Office of Environmental Restoration* is the primary focus of this chapter. The Office of Environmental Restoration is responsible for all activities to assess and clean up inactive hazardous and radioactive "facilities"—such as reactors, laboratories, equipment, buildings, pipelines, waste treatment systems, and storage tanks—and sites at all DOE installations and at some non-DOE locations that have been specified by Congress. This program includes cleanup activities at 25 DOE installations and other locations listed on the National Priorities List (NPL); corrective actions under the Resource Conservation and Recovery Act (RCRA), which are necessary for sites at about one-quarter of DOE's installations; and cleanup required under other environmental programs.[5] [6]

Environmental Restoration activities include:

- **Decontamination and decommissioning (D&D)**—decontamination and safe disposition of deactivated and surplus equipment, buildings, and other facilities;

- **Remedial actions**—site characterization to identify the contaminants and physical properties at a site, and remediation actions to stabilize, reduce, or remove contaminants at a site; and

- **Long-term surveillance and maintenance (S&M)**—monitoring the site to ensure that contamination has been successfully addressed and providing maintenance services to ensure the long-term integrity of containment remedies or continued effective operation of pump-and-treat remedies.[5]

These three activities are described in the following subsections.

7.1.1 Decontamination and Decommissioning (D&D)

Decontamination and Decommissioning (D&D) is DOE's program to manage government-owned, surplus, deactivated "facilities" that were used for early nuclear energy research and defense programs. These "facilities" could include reactors, hot cells, processing plants, storage tanks, research facilities, and other structures where releases or spills have occurred. DOE is responsible for decontaminating and safely disposing of these surplus facilities. Disposal could include demolishing the building and removing rubble from the facility, collapsing the facility to a below-ground level and burying rubble under a protective cap, or converting a completely decontaminated facility for non-nuclear use. D&D operations are ongoing or planned at just over 30 DOE installations and other locations. Overall, the program is addressing about 5,000 contaminated buildings that require deactivation, 1,200 buildings that require decommissioning, and 550,000 metric tons of metals and 23 million cubic meters of concrete in buildings that require disposition. [2][5]

7.1.2 Remedial Actions

Remedial action at sites throughout the DOE complex involves treatment, disposal, and, in some cases, transfer to the Waste Management Program of a variety of wastes. These wastes are categorized as:

- hazardous—containing hazardous constituents but no radionuclides;

- mixed—containing both hazardous and radioactive materials;
- low-level—containing a small amount of radioactivity in large volumes of material;
- 11e(2) byproduct material—containing very low concentrations of naturally occurring alpha-emitting radionuclides in large volumes of generally soil-like materials;
- transuranic—containing plutonium, americium, and other elements with atomic numbers higher than uranium; and
- high-level—containing highly radioactive material—including fission products, traces of uranium and plutonium, and other transuranic elements—resulting from chemical reprocessing of spent fuel.[1] [2]

DOE expects to remediate almost 3.8 million cubic meters of the hazardous waste, and nearly 5.7 million cubic meters of mixed waste, at its installations and other locations over the life of the program.[7] DOE's Environmental Restoration Program addresses waste through remediation (including *in situ* and *ex situ* treatment and disposal) or, in some cases, through transfer of the waste to the agency's ongoing Waste Management Program.

Most of DOE's installations require remedial action under one or more environmental statutes. These installations vary widely in size. For example, the Laboratory for Energy-Related Health Research in Davis, California, occupies 15 acres, while Hanford Reservation in the southeastern part of Washington covers 560 square miles. Overall, DOE installations encompass 2.3 million acres of land.[3]

Characterization and assessment (C/A) activities are in progress at most installations and other locations. Much of this work will continue for years, and complete remediation will take longer still. However, by the end of 1995, DOE had completed 198 remedial actions (including cleanup at a variety of operable units [OUs], closures, etc.) and over 100 others were underway.[5] In addition, DOE continues to implement, as needed, interim actions (limited actions to mitigate risks from contamination) as the process of characterization, assessment, and cleanup moves forward at its installations.[2][3]

More than half of the installations and other locations in DOE's Environmental Restoration program are managed under the Formerly Utilized Sites Remedial Action Program (FUSRAP) and the Uranium Mill Tailings Remedial Action (UMTRA) Project. FUSRAP involves the cleanup or control of 46 locations—some owned or leased by DOE or other government agencies, some privately owned—where there is residual radioactive material from the early years of the Nation's atomic energy program. By the end of 1995, cleanup at 22 of these installations had been completed, and cleanup work currently is in progress at nine of the 24 remaining installations to be remediated under the program. DOE anticipates that remediation activities under FUSRAP will continue through 2016.[2][5][7]

UMTRA provides for stabilizing and controlling surface contamination from 39 million cubic yards of uranium mill tailings at 24 former uranium ore processing sites and for addressing groundwater contamination beneath and, in some cases, downgradient of the mills.[5] The tailings resulted from the production of uranium between the early 1950s and the early 1970s. In addition to the 24 processing sites, mill tailings remediation also has been completed at over 97 percent of the over 5,000 private residential and commercial properties, under the UMTRA project. These "vicinity" properties are contaminated because tailings were used as fill for construction and landscaping, or were carried by the wind to open areas. By the end of 1996, DOE had completed surface remediation at 18 processing sites and their associated vicinity properties; and remediation was ongoing at six others. Surface remediation is expected to be completed by the end of 1998.[5]

DOE currently estimates that about 4.7 billion gallons of groundwater at 23 of the ore processing sites being addressed under UMTRA are contaminated. The Lowman, Idaho, UMTRA location is the only one which shows no sign of groundwater contamination. Restoration of groundwater has yet to begin at UMTRA locations. DOE published a draft programmatic environmental impact statement for this portion of the program in April 1995.[8] Site-specific remedial action plans for the UMTRA groundwater projects are expected to be prepared beginning in 1997 and continuing through 2007. DOE anticipates that active remediation of these locations will begin as early as 2002 and be completed by 2014.[5]

7.1.3 Long-term Surveillance and Maintenance

Long-term surveillance and maintenance activities are integral to the environmental restoration process. In decontamination and decommissioning projects, DOE's S&M activities include monitoring and maintaining facilities awaiting D&D to prevent worker, public, and environmental exposure to potential hazards. The agency conducts post-S&M activities when remediation projects have been completed. These include monitoring sites to demonstrate that actions to contain, reduce, or stabilize contamination are effective over time; to ensure that any new problems are detected if they occur; and to provide ongoing maintenance—for example, at sites where containment remedies, such as capping or entombment, have been implemented and at groundwater sites where the remedy involves long-term pump-and-treat operations.[2]

7.2 Factors Affecting Demand for Cleanup

The following factors affect the demand for remediation of DOE installations.

- Cleanup and restoration work at most DOE installations is in the early stages. The nature and magnitude of the contamination at many sites are still only partially known; only about 46 percent of the more than 10,500 sites have been fully characterized.[2]

- Although DOE estimates that it will take 75 years (1996 to 2070) to complete the cleanup, it expects to remediate nearly 80 percent of its currently known sites by 2021. Thus, the next about 25 years is a "window of opportunity" for vendors of remediation technologies and services. An indication of the scheduling of he work is provided by a review of the milestones in Records of Decision (RODs) for NPL-listed DOE sites. RODs for 32 hazardous waste OUs at DOE NPL sites were expected to be completed in 1996. RODs for another 104 hazardous waste OUs, about 50 percent of the remaining ones for which a completion milestone is known, are expected to be completed by 2000 (Exhibit 7-1). These figures refer to operable units as defined under the Comprehensive Environmental Response, Compensation, Liability Act (CERCLA)). DOE uses a different definition for its OUs. DOE expects to complete cleanup of all sites and bring all its installations into environmental compliance by 2070.[2]

- In developing its 75-year estimate of the time required for cleanup of all installations, DOE assumed a greater emphasis on containment than on treatment and other active remediation strategies.[2]

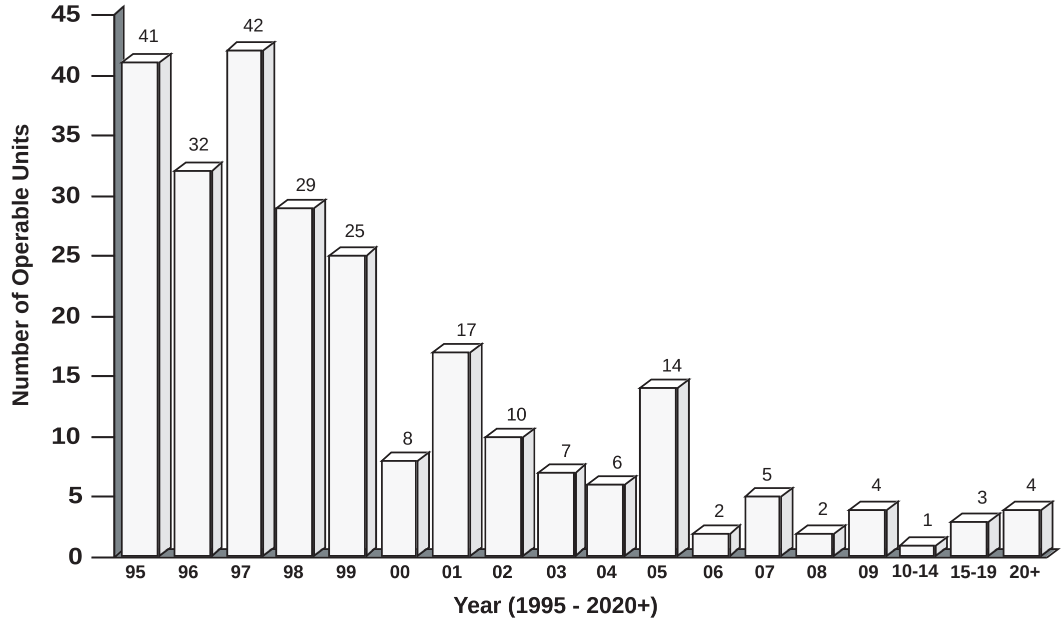
- The 75-year estimate to remediate all DOE installations could be lengthened or shortened depending on the funds appropriated by Congress for DOE programs. Cleanup schedules are heavily dependent on available funds. DOE officials have indicated from time-to-time that proposals for significant reductions in the agency's future budgets likely would delay cleanups at some installations and, in some cases, interfere with the agency's ability to meet milestones in existing compliance agreements.[9]

- DOE gives top priority to cleanup activities necessary to prevent near-term adverse impacts to workers, the public, or the environment and to activities required to meet the terms of agreements between DOE and local, state, or federal agencies.[2]

- The type and extent of remediation required will be affected significantly by the level of residual contamination after cleanup that will be acceptable to regulators and the public. The acceptable residual contamination level is unknown for most DOE installations, since cleanup agreements for many installations have not been completed.[2]

- Acceptable cleanup levels and the type of remediation required also will be influenced by decisions concerning how land and facilities are expected to be used in the future. The process of making decisions on these

Exhibit 7-1: Estimated ROD Completion Dates for CERCLA Operable Units at DOE Installations and Other Locations



Notes: Includes 252 CERCLA operable units for which a completion milestone is known at all DOE installations and other locations that the Environmental Restoration Program is responsible for remediating through its various programs, including Decontamination and Decommissioning, FUSRAP, and UMTRA. An "operable unit" consists of one or more "sites" (individual areas of contamination).

Source: U.S. Department of Energy, *Environmental Restoration Program at a Glance*, March 1995 (Rev. 1.0).

matters still is underway for most DOE installations and facilities.[2]

- As with DOD, cleanup requirements at DOE installations and other locations are extremely sensitive to changes in a wide variety of environmental statutes and regulations. Remedial, decontamination, decommissioning, and waste management and compliance-related corrective activities overlap at many installations. The requirements of a variety of federal and state laws simultaneously impact decision-making. In addition to CERCLA and RCRA, other relevant statutes include the Atomic Energy Act, the National Environmental Policy Act (NEPA), and the Federal Facility Compliance Act. Vendors in this market should keep up to date on regulatory and legislative developments of concern to DOE remediation efforts.

7.3 Number and Characteristics of Sites

DOE is responsible for environmental restoration at 137 installations and other locations in 33 states and Puerto Rico. Many installations contain more than one site. Depending on the size and complexity of the installation, sites may be aggregated into one or more OUs and each OU may require a different remedy. DOE has identified about 10,500 contaminated sites that require some remediation, and that number may grow as assessment and characterization activities continue. The contaminated sites that have been identified to date have been aggregated into over 700 OUs. DOE periodically increases or decreases the number of OUs, as a result of continual reevaluations of the designation of OUs as the program progresses.

Twenty-five DOE installations and other locations in 15 states are on the Superfund National Priorities List (NPL). In some cases, the Superfund cleanup may involve only one operable unit at the installation; in others multiple operable units may be affected. DOE has lead responsibility in the cleanup of 22 of these installations and other locations. The other three—Maxey Flats, Kentucky; Shpack Landfill, Massachusetts; and South Valley, New

Mexico—are being managed under the Superfund program by EPA, and DOE shares financial responsibility for the cleanup with other responsible parties.[2][5]

Exhibit 7-2 lists 86 installations and other DOE locations at which assessment and characterization of soil, groundwater, or both are in progress or have yet to be initiated for some or all operable units.[2] These installations represent the potential market for hazardous waste remediation services. The list includes 20 of the 25 DOE installations and other locations on the NPL. Appendix Exhibit D-1 provides similar information for DOE installations, including the other five on the NPL, where remedial work already is in progress or has been completed and, thus, does not represent many vendor opportunities.[2][3]

Some installations are listed in both Exhibit 7-2 and Appendix Exhibit D-1. While remedial action may be ongoing at some operable units at these installations, they continue to represent opportunities for vendors because other operable units still are being characterized and assessed.

DOE estimates that 64 percent of the total estimated cost of environmental management activities over the 75-year life of the program will be expended at five major installations—Rocky Flats Environmental Technology Site (Colorado), Idaho National Engineering Laboratory (Idaho), Savannah River Site (South Carolina), Oak Ridge Reservation (Tennessee), and Hanford Reservation (Washington).[2] These installations contain 406 operable units, more than half of the operable units DOE is responsible for addressing. Points of contact for each of these installations are listed in Appendix E.

Information about the extent of contamination at many of the installations listed still is incomplete. DOE has made substantial progress, however, in identifying specific contaminants of concern for many individual sites. Exhibit 7-3 shows the frequency with which major contaminants and categories of contaminants have been identified at the DOE installations and other locations where characterization and assessment (C/A) has not been completed. This Exhibit is derived from Appendix Exhibit D-2, which shows the contaminants of concern, to the extent they are known, at each of the 86 DOE installation and other locations where C/A has not been completed. These data were compiled from four sources: March 3, 1995 tabulations from the DOE/EM-40 Contaminated Media/Waste Database; DOE's *Estimating the Cold War Mortgage: The 1995 Baseline Environmental Report*, published in March 1995; DOE's *1996 Baseline Environmental Report*, published in June 1996, and the agency's *Draft Programmatic Environmental Impact Statement for the Uranium Mill Tailings Remedial Action Ground Water Project*, published in April 1995. The contaminant information in these sources indicate only that a contaminant has been identified at an installation. The data do not indicate if specific contaminants have been identified at only one site or at more than one site at the installation.

Organics are among contaminants at about 38 percent of the DOE installations that have not begun remediation. Among these are polychlorinated biphenyls (PCBs), petroleum/fuel hydrocarbons, solvents, trichloroethylene (TCE), "unspecified" volatile organic compounds (VOCs), and "unspecified" semivolatile organic compounds (SVOCs).

Metals are listed as contaminants of concern at 55 percent of DOE installations yet to start remediation. Those cited most often are lead, beryllium, mercury, arsenic, and chromium.

Radioactive contaminants are present at most DOE installations and other locations. The most frequently cited are uranium, tritium, thorium, and plutonium.

Mixed waste, containing both radioactive and hazardous contaminants, is a particular concern to DOE because of the lack of acceptable treatment technology and the high cost and scarcity of disposal facilities. Mixed waste is the focus of one of DOE's major technology development thrusts (see Section 7.6).

Exhibit 7-2: DOE Installations and Other Locations Where Waste Characterization and Assessment Are Ongoing

State	Installation/Site	Program[2]	Status[3]	No. of Operable Units[3,4]	Estimated Budget FY 1997 (millions)[3]	Estimated Life-Cycle Cost (millions)[3]
AK	Amchitka Island	ER	Not Initiated	1	$0.22[5]	$6.3[5]
AZ	Monument Valley	ER/UMTRA	C/A ongoing (ground water)	1	$1.0	$112.6
	Tuba City	ER/UMTRA	C/A ongoing (ground water)	1	$3.56	$99.2
CA	Energy Technology Engineering Center	ER (including D&D)	C/A ongoing	16	$4.21	$131.0
	General Atomics	ER (including D&D)	C/A, D&D ongoing	1	$3.6	$17.0
	General Electric/Vallecitos Nuclear Center	ER (including D&D)	C/A ongoing	2	$0	$23.3
	Geothermal Test Facility	ER	Not Initiated	1	$0	$5.1
	Laboratory for Energy-Related Health Research	ER (including D&D) on NPL	C/A, D&D ongoing	9	$3.55	$21.1
	Lawrence Berkeley Laboratory	ER	C/A ongoing	4	$3.19	$54.4
	Lawrence Livermore Laboratory	ER (including D&D) on NPL (2 sites)	C/A ongoing	11	$22.51	$639
	Oxnard	ER	Complete	1	$0	$0.5
	Salton Sea Test Base	ER	C/A ongoing	Included in data for Sandia National Laboratory-Albuquerque through which this site is managed.		
	Stanford Linear Accelerator Center	ER	C/A ongoing IA in progress	1	$1	$5.0

Exhibit 7-2: DOE Locations Where Characterization and Assessment Are Ongoing (continued) [1]

State	Installation/Site	Program[2]	Status[3]	No. of Operable Units[3,4]	Estimated Budget FY 1997 (millions)[3]	Estimated Life-Cycle Cost (millions)[3]
CO	Durango Site	ER/UMTRA	C/A ongoing (ground water)	1	$0.02	$12.1
	Grand Junction Mill Tailing Site	ER/UMTRA	C/A ongoing (ground water)	1	$12.8	$73.3
	Gunnison	ER/UMTRA	C/A ongoing (ground water)	1	$0.9	$12.3
	Maybell	ER/UMTRA	C/A ongoing (ground water)	1	$4.3	$22.3
	Naturita	ER/UMTRA	C/A ongoing (ground water)	1	$12.35	$43
	Old North Continent (Slick Rock)	ER/UMTRA	C/A ongoing (ground water)	1	$9.1	$32.9
	Project Rio Blanco	ER	C/A ongoing	1	$0.7[5]	$6.7
	Project Rullison	ER	C/A ongoing	1	$0.18[5]	Included in Proj. Rio Blanco
	Rifle Mill (New)	ER/UMTRA	C/A ongoing (ground water)	1	$1.4	$20.3
	Rifle Mill (Old)	ER/UMTRA	C/A ongoing (ground water)	1	included in New Rifle	included in New Rifle
	Rocky Flats Environmental Technology Site	ER (including D&D) on NPL	C/A ongoing	16	$484.3	$5,874.2
	Union Carbide (Slick Rock)	ER/UMTRA	C/A ongoing (ground water)	2	included in Old North Continent	included in Old North Continent
FL	Pinellas Plant	ER	IA in progress RA pending	12	$4.0	$44.8
HI	Kauai Test Facility	ER	RA pending	Included in data for Sandia National Laboratory-Albuquerque		
IA	Ames Laboratory	ER	C/A, S&M ongoing	3	$0.19	$2.2

Exhibit 7-2: DOE Locations Where Characterization and Assessment Are Ongoing (continued) [1]

State	Installation/Site	Program[2]	Status[3]	No. of Operable Units[3,4]	Estimated Budget FY 1997 (millions)[3]	Estimated Life-Cycle Cost (millions)[3]
ID	Argonne National Laboratory-West	ER (including D&D)	C/A ongoing IA in progress	6	$2.6	$21
	Idaho National Engineering Laboratory	ER (including D&D) on NPL	C/A, D&D, RA ongoing	106	$112.8	$3,049.1
IL	Argonne National Laboratory-East	ER (including D&D)	C/A, D&D ongoing	22	$8.5	$169.6
	Madison	ER/FUSRAP	Not initiated	1	$0.0	$2.5
	Site A/Plot M, Palos Forest Preserve	ER	C/A ongoing	1	$0.17	$6
KY	Paducah Gaseous Diffusion Plant	ER (including D&D) on NPL	C/A, S&M ongoing	19	$39.7	$4,830.7
MA	Chapman Valve	ER/FUSRAP	Not initiated	1	$0	NA
	Shpack Landfill[8]	ER/FUSRAP on NPL	C/A ongoing	1	$0.04	$0.4
MD	W.R. Grace & Company	ER/FUSRAP	RA pending	1	$0.0	$21.5
MO	Kansas City Plant	ER (including D&D)	C/A, RA ongoing	13	$3.5	$28.1
	St. Louis Airport Site	ER/FUSRAP on NPL	RA pending	1	$10.4[9]	$243.8[10]
	Weldon Spring Site	ER (including D&D) on NPL	C/A, RA ongoing	8	$66	$447.9

Exhibit 7-2: DOE Locations Where Characterization and Assessment Are Ongoing (continued) [1]

State	Installation/Site	Program[2]	Status[3]	No. of Operable Units[3,4]	Estimated Budget FY 1997 (millions)[3]	Estimated Life-Cycle Cost (millions)[3]
NJ	DuPont & Company	ER/FUSRAP	RA pending	1	$0.003	$7.6
	Maywood Chemical Works	ER/FUSRAP on NPL	RA pending	1	$10.9	$254.9
	New Brunswick Site	ER/FUSRAP	RA pending S&M ongoing	1	$0.5	$5.8
	Princeton Plasma Physics Laboratory	ER	C/A ongoing	2	$0.5	$59
	Wayne	ER/FUSRAP on NPL	RA pending	1	$6.1	$98.9
NM	Ambrosia Lake	ER/UMTRA	C/A ongoing (ground water)	1	$0.17	$1.2
	Gasbuggy Site	ER	C/A ongoing	1	$0.79	$14.5[11]
	Gnome-Coach Site	ER	C/A ongoing	1	$0.36	Include in Gassbuggy site
	Los Alamos National Laboratory	ER (including D&D)	C/A, D&D, RA ongoing	6	$48.5	$623.7
	Sandia National Laboratory	ER (including D&D)	C/A ongoing	18	$17.8	$231.2
	Shiprock Site	ER/UMTRA	C/A ongoing (ground water)	1	$1.7	$7.6
NV	Central Nevada Test Site	ER	C/A ongoing	6[10]	$0	$8.2[11]
	Nevada Test Site	ER (including D&D)	C/A ongoing	31	$51	$2,235.8[13]
	Shoal Test Site	ER	C/A ongoing	[10]	$0	[11]
	Tonopah Test Range	ER	C/A ongoing	[10]	[12]	[12]

Exhibit 7-2: DOE Locations Where Characterization and Assessment Are Ongoing (continued) 1

State	Installation/Site	Program[2]	Status[3]	No. of Operable Units3,4	Estimated Budget FY 1997 (millions)[3]	Estimated Life-Cycle Cost (millions)[3]
NY	Ashland Oil Co.#1	ER/FUSRAP	RA pending	1	$0	$21.3
	Ashland Oil Co.#2	ER/FUSRAP	RA pending	1	$0	$8
	Bliss & Laughlin Steel	ER/FUSRAP	RA pending	1	$0.49	$1
	Brookhaven National Laboratory	ER (including) D&D on NPL	C/A, S&M ongoing	9	$15.1	$332.4
	Linde Air Products	ER/FUSRAP	RA pending	1	$0	$28.2
	Seaway Industrial Park	ER/FUSRAP	RA pending	1	$0	$28.3
	Separation Process Research Unit	ER (including D&D)	Not initiated	1	$0.0	$144.9
OH	B and T Metals	ER/FUSRAP	Not initiated	1	$0.13	$3
	Fernald Site	ER on NPL	RA, D&D ongoing	11	$260.3	$2.523.7
	Luckey	ER/FUSRAP	Not initiated	1	$2.9	$62.7
	Mound Plant	ER (including D&D) on NPL	C/A ongoing	14	$50	$892.9
	Painesville	ER/FUSRAP	Not initiated	1	$4.8	$88
	Portsmouth Gaseous Diffusion Plant	ER (including D&D)	C/A, RA, D&D ongoing	30	$45.9	$3,959.7
	RMI Site	ER (including D&D)	C/A ongoing	3	$18	$131.3
OR	Lakeview Site	ER/UMTRA	C/A ongoing (ground water)	1	$0.03	$5.8

Exhibit 7-2: DOE Locations Where Characterization and Assessment are Ongoing[1]

State	Installation/Site	Program[2]	Status[3]	No. of Operable Units[3,4]	Estimated Budget FY 1997 (millions)[3]	Estimated Life-Cycle Cost (millions)[3]
PA	Canonsburg Site	ER/UMTRA	C/A ongoing (ground water)	1	$0.28	$2.5
PR	Center for Environmental Research	ER	RA pending			
SC	Savannah River Site	ER (including D&D) on NPL	C/A, RA ongoing	92	$111.7	$12,687
TN	Oak Ridge K-25 Site	ER (including D&D) on NPL	C/A, S&M ongoing	33	$64.8	$4,465.6
	Oak Ridge National Laboratory	ER (including D&D) on NPL	C/A ongoing	48	$46.4	$4,872.6
	Oak Ridge Reservation Offsite	ER	C/A ongoing	9	$11.8	$267.1
	Oak Ridge Y-12 Plant	ER (including D&D) on NPL	C/A ongoing	31	$23.2	$1,742.9
TX	Falls City Site	ER/UMTRA	C/A ongoing (ground water)	1	$0.4	$5.5
	Pantex Plant	ER on NPL	C/A ongoing	16	$9.1	$51.6
UT	Green River Site	ER/UMTRA	C/A ongoing (ground water)	1	$0.02	$8.2
	Mexican Hat Site	ER/UMTRA	C/A ongoing (ground water)	1	$0.5	$3.4
	alt Lake City Site	ER/UMTRA	C/A ongoing (ground water)	1	$0.5	$7.3

Exhibit 7-2: DOE Locations Where Characterization and Assessment Are Ongoing (continued) [1]

State	Installation/Site	Program[2]	Status[3]	No. of Operable Units[3,4]	Estimated Budget FY 1997 (millions)[3]	Estimated Life-Cycle Cost (millions)[3]
WA	Hanford Site	ER (including D&D) on NPL (4 sites)	C/A, D&D, RA, S/M ongoing	78	$138.8	$8,349.2
WY	Riverton Site	ER/UMTRA	C/A ongoing (ground water)	1	$0.4	$9.9
	Spook Site	ER/UMTRA	C/A ongoing (ground water)	1	$0.3	$1

ER Environmental Restoration
UMTRA Uranium Mill Tailing Remedial Action
C/A Characterization and Assessment
D&D Decontamination and Decommissioning
FUSRAP Formerly Utilized Sites Remedial Action Program
RA Remedial Action
NPL National Priorities List
IA Interim Action
S & M Surveillance and Monitoring

Notes:

1 This table includes installations and other locations where characterization and assessment are in progress or have yet to be initiated for some or all operable units. Some installations and other locations included here also may appear in Exhibit A-1, because they have both ongoing and completed remedial actions and characterization and assessment activities.

2 U.S. Department of Energy, "The 1996 Baseline Environmental Report," DOE/EM-0290, June 1996.

3 U.S. Department of Energy, "The 1996 Baseline Environmental Report," DOE/EM-0290, June 1996; data as of June 1996 from DOE's "1996 Baseline Environmental Report" Database and other internal DOE databases provided by the Systems Management Division, Office of Program Integration, Office of Environmental Restoration and interviews with selected site operations staff at DOE Headquarters, June 1995. Actual Congressional appropriations for FY 1997 may differ from the amounts printed here. Data on operable units and life-cycle costs come from several different sources, which are continuously being revised by DOE staff as conditions at specific installations and other locations change and as new sites are identified. In addition, these data were extracted from these sources at different times. Therefore, although these data provide an indication of the approximate level of effort needed at a given location, their sum may not accurately reflect the program total.

Exhibit 7-2: DOE Locations Where Characterization and Assessment Are Ongoing (continued) [1]

Notes (continued):

[4] "Operable unit" consists of one or more "sites" (individual areas of contamination). DOE aggregates sites with similar characteristics or sources into operable units to facilitate remedy selection and operations for all its remediation projects, whether they are conducted under CERCLA, RCRA, or other authorities.

[5] Work at Amchitka Island (AK), Project Rio Blanco and Project Rulison (CO), Salmon Test Site (MS), Project Gassbuggy and Gnome-Coach Site (NM), and the Central Nevada, Shoal, and Tonopah Test Sites (NV) is managed by and funded through DOE's Nevada Operations Office.

[6] DOE does not manage the cleanup work at this site. The agency is providing support to the Potentially Responsible Party.

[7] Total estimated FY97 budget for all Missouri FUSRAP sites is $10.4 million.

[8] Total estimated life-cycle cost for all Missouri FUSRAP sites is $243.8 million. Site-by-site estimates are not available.

[9] Includes Gassbuggy and Gnome-Coach sites.

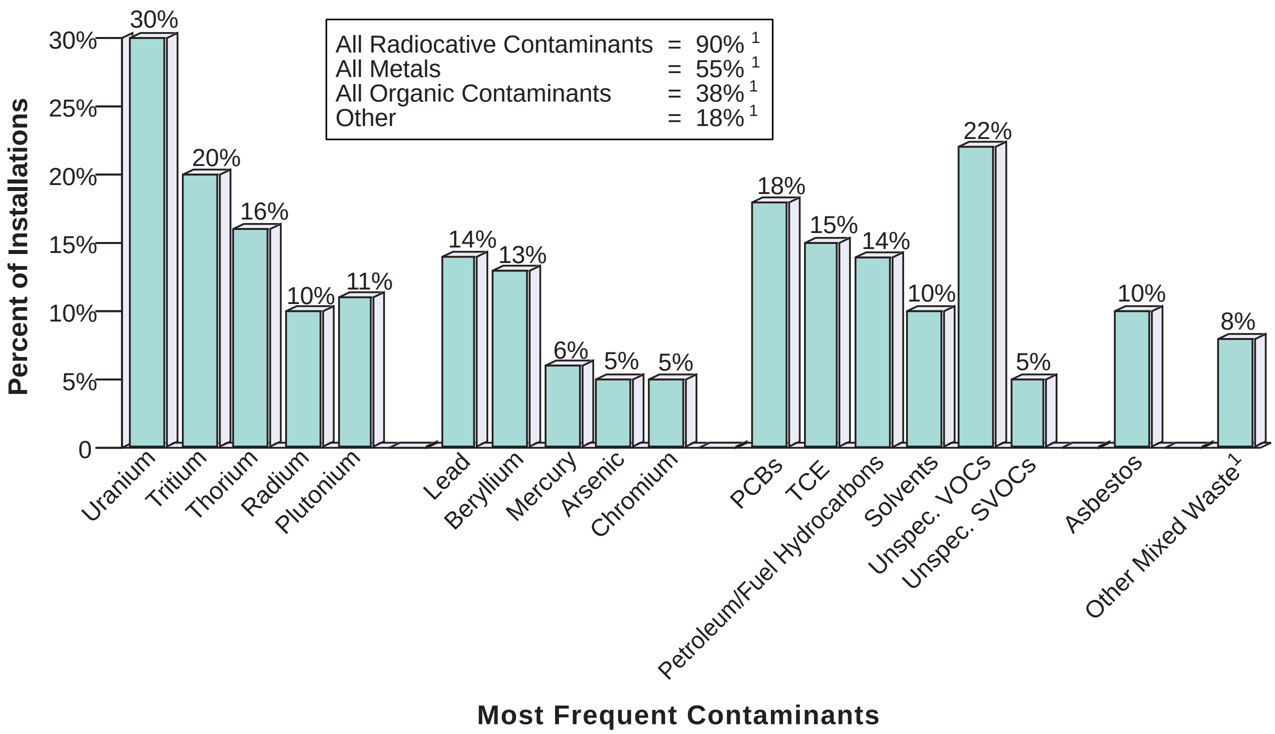
[10] A total of six operable unit equivalents has been identified for the Central Nevada, Shoal, and Tonopah Test Sites.

[11] Includes estimated life-cycle cost for Central Nevada and Shoal.

[12] Included in Nevada Test Site.

[13] Included in estimated life-cycle cost for Nevada test sites and Tonopah.

Exhibit 7-3: Percent of DOE Installations and Other Locations Containing Specific Contaminants



Notes: [1] Includes all contaminants in a group; not only those indicated by the bars. A site may contain more than one contaminant. Other mixed waste indicates installations and other locations with mixed waste for which specific contaminants have not been delineated.

Sources: U.S. Department of Energy, *Estimating the Cold War Mortgage: The 1995 Baseline Environmental Report*, DOE/EM-2032, March 1995; DOE/EM-40 Contaminated Media/Waste Database as of March 3, 1995; and UMTRA Project Office, “Draft Programmatic Environmental Impact Statement for the Uranium Mill Tailings Remedial Action Ground Water Project,” DOE/EIS-0198, April 1995.

DOE installations and other locations contain contaminated soil and sediment, groundwater, and rubble and debris. Estimates of the volumes of these media that still need to be remediated at each installation are included in Appendix Exhibit D-2. Since characterization and assessment are ongoing at most of these installations, these estimates may change. Individual estimates of the volume of groundwater to be remediated are not available for the 23 UMTRA project locations included in this Exhibit, but DOE estimates that a total of about 4.7 billion gallons of groundwater are contaminated at these UMTRA locations.[8]

7.4 Estimated Cleanup Costs

DOE estimates that it will take about $63 billion (28 percent of the estimated $227 billion cost of all environmental management activities) over a 75-year period to substantially complete environmental restoration—including cleanup of contaminated soil and groundwater, decontamination and decommissioning of nuclear reactors and chemical processing buildings, and exhumation of buried waste—at its installations and other locations. These expenditures will not be evenly distributed over the 75-year life of the agency’s environmental cleanup program. After peaking at about $2 billion in 2000, they will decline gradually until the program is substantially complete in 2070 (Exhibit 7-4). The agency expects to expend about $12 billion (five percent of the $227 billion total) for technology development to support cleanup and other DOE environmental management activities over the life of the program. These estimates are the result of a comprehensive analysis of the status and potential cost of cleaning up contamination accumulated as a result of past activities, as well as the wastes to be generated from ongoing national security operations and from the cleanup efforts themselves.[2]

Because of the wide variance in size and complexity of installations and other locations to be remediated, life-cycle-cost estimates vary among installations as well. For example, cleanup of the 82-acre Geothermal Test Facility in Imperial Valley, California, is expected to cost a total of about $5.1 million, while cleanup of the 11-square-mile Rocky Flats Plant northwest of Denver, Colorado, is expected to require about $5.8 billion. The methodology in the "Baseline" report for calculating the cost of accomplishing DOE's environmental cleanup responsibilities involved the use of a "base-case" scenario, the agency's best estimate of the environmental management activities to be undertaken at each site, which was developed using data and assumptions supplied by DOE field offices. Life-cycle cost estimates were generated for each of about 40 percent of the agency's major installations and other locations. Aggregate state-by-state estimates were generated for the 70 sites managed under the FUSRAP and UMTRA programs and for nine off-site locations managed by the Nevada Operations Office.[2] These estimates, as well as estimates for FY 1997 expenditures, are shown in Exhibit 7-2 and Appendix Exhibit D-3.

These "base-case" estimates provide the most reliable information to date on the value of the DOE market. However, the actual value may be higher or lower for a number of reasons. First, as with any such analysis, the DOE estimates were based on a set of assumptions. For example:

- Activity will significantly increase between 1995 and 2000 and will shift from characterization to include more active remediation at DOE contaminated sites. In addition, major facilities will be deactivated.

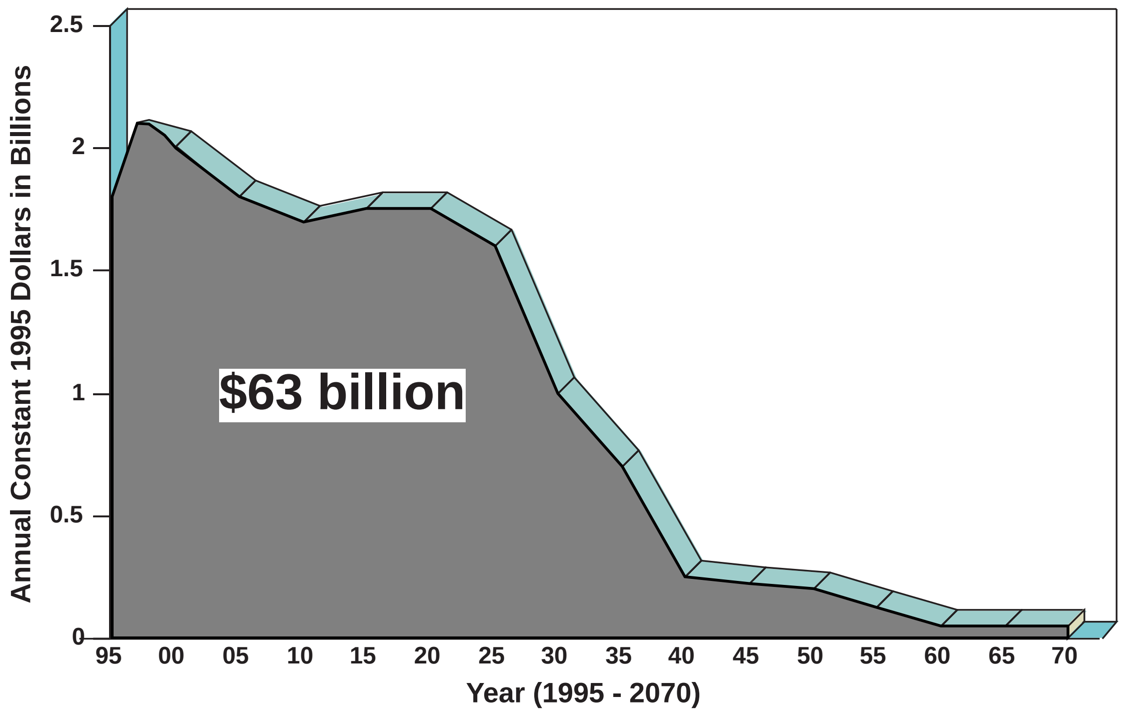
- Milestones in existing compliance agreements will be completed. Compliance agreements affecting DOE cleanups under CERCLA and RCRA at 17 DOE installations are in place (Appendix Exhibit D-4). DOE currently is committed to meeting more than 70 compliance milestones, most of which do not extend beyond 2000. The only funding increases assumed beyond 2000 were those dictated by existing compliance agreements.

- Most remediations will use existing technologies. Assumptions about the nature and extent of contamination were developed at the field level and, therefore, varied from installation to installation. Based on these individual assumptions, field personnel selected one of two types of assumed remedial actions: strategies to contain contamination or strategies to eliminate contamination. Since radionuclides and other contaminants such as heavy metals cannot be destroyed, containment was the option usually assumed for contaminated soil and buried waste. Measures to prevent further contaminant migration and protect off-site populations—removing or capping the source to prevent leaching, using slurry walls and other technologies to contain contamination in groundwater, natural attenuation, or pump-and-treat—were the options assumed for groundwater.[2]

Second, the estimates could not include projected costs for cleanup where no feasible cleanup technology exists—such as nuclear explosion sites and much of the groundwater contamination the agency is responsible for addressing.

Third, some of the same factors that influence the demand for DOE installation remediation (see Section 7.2) will affect the actual costs of cleanup activities. These include the relatively limited characterization of the problems at many sites; uncertainty about what level of residual contamination after cleanup will be acceptable to regulators and the public; the lack of definitive policies on future use of land and facilities; uncertainty about the consistent availability of funding; and the inherent uncertainty in a program that is expected to last at least 75 years.[2] For example, the ultimate cost of groundwater cleanup at DOE's UMTRA sites is uncertain, because the program still is in its early planning stages. According to a December 1995 report by the General Accounting Office, its final scope and cost will depend largely on the methods chosen to conduct the cleanups, which cannot be determined until site characterization studies and environmental assessments have been completed, and the capability and willingness of

Exhibit 7-4: Life Cycle Cost Profile for DOE's Environmental Restoration Program



Source: U.S. Department of Energy, *The 1996 Baseline Environmental Management Report,* DOE/EM-0290, June 1996.

the affected states, which are required to contribute 10 percent of the cost of remedial actions under the UMTRA program, to pay their share.[10]

In preparing the "Baseline" report, DOE developed hypothetical cases to examine the potential impact of land use, residual contamination, funding/scheduling, and innovative technology issues on the agency's overall environmental management cost estimate. These "alternative-case" analyses primarily were prepared to assist in future policy-making efforts and were not factored into the baseline $63 billion life cycle cost estimate for environmental restoration and $227 billion for all of DOE environmental management. The agency used a standardized modeling approach for the analyses, rather than relying on the field estimates and assumptions that were the foundation for the "base-case" estimates. Major conclusions regarding the overall DOE program included the following:

- **Projected future land use will dramatically affect costs.** The most restrictive hypothetical land-use scenario would cost about 90 percent more than the least restrictive use. These estimates are for all of environmental management. Separate figures were not published specifically for site restoration. In this comparison, the most restrictive land use is "off-limits to human activity," and the cost estimate was based exclusively on containing contamination by capping contaminated soil and buried wastes, controlling the spread of groundwater contamination by hydraulic controls and barriers, and entombing contaminated facilities in place. In this comparison, the least restrictive hypothetical scenario is essentially unrestricted use, which would be achieved by implementing aggressive removal strategies at operable units for which technologies are available. In cases where current technologies are unavailable or where sites are being used for active disposal, the scenario was based on using containment and restricted land use only.

- **Reducing DOE's annual environmental cleanup budget and extending the program's schedule would significantly increase life-cycle costs.** If the DOE annual budget were restricted to 65 percent of the baseline cost estimate, total program costs would be increased by 30 percent. Most of this cost would be due to increased pretreatment storage, increased storage and maintenance for plutonium storage buildings and chemical separation facilities, and support costs.[2]

- **A hypothetical program involving only minimal action to stabilize sites up to 2070 would require 44 percent less funding than the base case, from 1997 through 2070.** However, costs after 2070 would be higher than now projected. This hypothetical program would include treatment and disposal of all high-level waste and spent nuclear fuel; stabilization and surveillance and maintenance of surplus facilities; and safe storage of all low-level, low-level mixed, and transuranic wastes. No environmental restoration, decontamination and decommissioning, or treatment and disposal of low-level, low-level mixed, and transuranic wastes would be carried out under this scenario.[2]

- **Development of new technologies will reduce certain cleanup costs and make some currently infeasible cleanups possible.** For the 1995 annual report,[3] DOE selected a number of specific technologies scheduled to be available by 2000 for this analysis. These included electrokinetics, innovative soil washing (specifically used for removal of normally immobile metal ions, including radioactive contaminants like cesium), and *in situ* vitrification for soils; recirculating wells, microbial filters, *in situ* bioremediation, dynamic underground stripping, and biosorption of uranium for groundwater; plasma hearth technology for mixed low-level waste treatment; as well as technologies potentially applicable for facility decontamination, buried waste, characterization, and high-level waste. The analysis showed that use of these technologies at selected operable units could save as much as $9 billion when applied to the 1995 "base-case" scenario and as much as $80 billion when applied to the least restrictive hypothetical land-use scenario. This type of analysis was not included in the 1996 report, but some of these potential savings were incorporated into the 1996 baseline cost estimates.[2][3]

7.5 Market Entry Considerations

Contractors perform virtually all cleanup and restoration work at DOE installations. DOE issues "requests for proposals" and awards contracts on a competitive basis. DOE awards remedial action contracts on an installation-by-installation basis. DOE Operations Offices, each of which is responsible for one or more installations, manage the contracts. Operations Offices are listed in Appendix E. Contracts related to the FUSRAP and UMTRA programs, both of which include sites in many states, are managed through the Oak Ridge and Albuquerque Operations Offices, respectively.

A list of DOE's current management and operations (M&O) contractors is presented in Appendix E. Depending on the installation, these contractors may be responsible for management tasks, actual cleanup work, waste management duties, or various combinations. For example, under the Environmental Restoration Management Contract (ERMC) awarded at Fernald and the Environmental Restoration Contract (ERC) awarded at Hanford, contractors are responsible for day-to-day project management; have the option of performing the remedial investigation/feasibility study portions of the cleanup process; and, after a ROD is issued for a given operable unit, will be responsible for subcontracting the remaining work to companies with specialized expertise and technology.

DOE has begun to implement a number of contract reforms that emphasize performance-based approaches (focusing on desired endpoints instead of level of effort) and risk sharing (contractors assuming more of the financial risk over time) and provide incentives for M&O contractors to reduce cost, increase safety, and identify tasks that should be undertaken by qualified subcontractors. The first two integrated management contracts awarded under the new system have been multi-year efforts for management and cleanup of Idaho National

Engineering Laboratory (INEL), awarded in August 1994, and Rocky Flats, awarded in April 1995.[11] These measures may influence not only the overall value of the DOE market but also the amount of work available to subcontractors, because of its emphasis on increasing the use of subcontractors for some specialized functions.

7.6 Technologies Used and Research, Development, and Demonstrations

Information on the innovative technologies being used at DOE installations is too limited to predict future technology use. However, insight into potential applications may be obtained from the following examples of applications at Superfund cleanups at DOE installations: *in situ* bioremediation is currently operational at DOE's Savannah River installation; soil vapor extraction (SVE) is being installed in an Interim Action at Rocky Flats' Operable Unit 2; a SVE system is in the design phase for use at Lawrence Livermore National Laboratory; and chemical leaching is being used with incineration at the Idaho National Engineering Laboratory's Pit 9.[12]

DOE recognizes that much of the cleanup and environmental restoration at its installations cannot be accomplished without new technological solutions. Thus, DOE cleanups provide an opportunity for developers of innovative technologies. Early in 1995, DOE reorganized its technology-related research and development activities to target five of the most important remediation and waste management problems within the DOE complex. In addition, the reorganization established five areas for the development of cross-cutting technologies.

The agency's new approach emphasizes: 1) teaming with technology customers within the Office of Environmental Management and industry to identify, develop, and implement needed technologies; 2) more effectively focusing the available resources in DOE's national laboratories; 3) involving academia and other research organizations in basic research programs; 4) expanding the participation of regulators and stakeholders in technology development; and 5) enhancing the agency's ability to implement the results of technology development efforts.

Focus Areas

Four "Focus Areas" have been targeted on the basis of the risk they present, their prevalence at DOE sites, or the lack of technology to meet environmental requirements and regulations. Each of the "Focus Areas" has identified specific categories of technologies on which research and development work is needed. These are:

- Subsurface Contaminants Focus Area — Includes containment and treatment of soil, water, vegetation, and other wastes. Includes aquifer properties characterization, on-line remediation process controls, and subsurface access and exploration; reactive barriers, deep subsurface barriers, temporary barriers, and barrier emplacement; and *in situ* physical, chemical, and biological treatment. This focus area plans to concentrate over the next three years on technology development to expedite the characterization of contaminant plumes and ways to control sources and migration, and to facilitate implementation of emerging remediation technologies. Over the next six years, the goal of development work in this Area is to achieve breakthroughs on problems for which remediation technologies do not exist, especially dense non-aqueous phase liquids (DNAPLs), heavy metals, and radionuclide contamination in aquifers and overlying soils.

  This focus area also addresses landfill stabilization, including the following activities: site and waste characterization, full-scale and "hot spot" retrieval, treatment, subsurface caps and barriers, and stabilization. This Focus Area is concentrating on developing, demonstrating, and implementing technologies to remediate about three million cubic meters of buried waste in landfills located predominantly at Hanford, Savannah River, Idaho National Engineering Laboratory, Los Alamos National Laboratory, Oak Ridge Reservation, the Nevada Test Site, and Rocky Flats.[13]

- Mixed Waste Characterization, Treatment, and Disposal Focus Area — characterization, thermal treatment, non-thermal treatment, and effluent monitoring and control. This Focus Area plans to conduct a minimum of three pilot-scale demonstrations of mixed waste treatment systems, using actual mixed waste, by 1997.[14]

- Radioactive Tank Waste Remediation Focus Area — characterization, retrieval and conveyance, separation and pre-treatment, low-level waste treatment and disposal, and immobilization. Development work in this focus area has concentrated on four DOE installations—Hanford, Idaho National Engineering Laboratory, Oak Ridge Reservation, and the Savannah River Site—where most of the DOE inventory of underground storage tanks containing radioactive waste is located.[15]

- Facility Deactivation, Decontamination and Material Disposal Focus Area — deactivation, decontamination, dismantling, and material disposal. This focus area currently is in the process of selecting an installation for a full-scale demonstration of facility decommissioning technology with an emphasis on the recycling of contaminated building materials for reuse within the DOE complex.[6]

A list of the points of contact for each of the agency's five technology development focus areas is included in Appendix E.

In preparing the alternative-case analyses for its "Baseline" report, DOE selected 15 new technologies, scheduled to be available by 2000, to analyze the potential cost savings the agency could realize through the use of innovative technologies in its environmental restoration efforts. They provide developers and vendors with specific examples of the types of technologies the agency expects to need in the next few years. A list of these technologies is presented in Exhibit 7-5.

Cross-Cutting Technologies

Cross-cutting technologies are defined as those which overlap the boundaries of "Focus Areas." Technologies developed in these areas will be used in "Focus Area" testing and evaluations programs wherever they are applicable. These areas are: Characterization, Monitoring, and Sensor Technology; Efficient Separations and Processing; Robotics; and Industry Programs.

The Industry Programs Area has set aside funding to foster research and development partnerships with the private sector for introducing innovative technologies into the technology development programs managed by the agency's Office of Science and Technology. Support in this area will concentrate on two types of technologies: technologies that show promise for addressing specific DOE problems and require proof-of-principle experimentation, and technologies proven in other fields that require critical path experimentation to demonstrate feasibility for adaptation to specific DOE problems.[6]

The "Focus Area" concept builds on the work carried out under DOE's Integrated Programs and Integrated Demonstrations, through which the agency managed the research, development, demonstration, testing, and evaluation of technologies for application at DOE installations and other locations.

Private Sector Involvement

DOE uses several mechanisms to invite the private sector to participate in its technology research and development programs. These include Cooperative Research and Development Agreements (CRADAs), technology development contracts issued under Program Research and Development Announcements (PRDAs), Research Opportunity Announcements (ROAs), and the Small Business Technology Integration Program.

DOE uses CRADAs as an incentive for collaborative research and development. CRADAs are agreements between a specific DOE laboratory and a non-federal source to conduct mutually beneficial research and development that is consistent with the laboratory's mission. DOE has issued 62 CRADAs to date to support its environmental programs.

Technology development contracts under PRDAs and ROAs, which support technology development to meet EM program needs, are managed by DOE's Energy Technology Center (Morgantown, West Virginia). DOE issued its first

Exhibit 7-5: Examples of Innovative Technologies Useful to DOE

Technology	Analysis
Soil remediation	**Electrokinetics** — Mobilizes contaminant ions in the subsurface by the application of a direct electrical current between buried electrodes. Contaminants then are collected and removed from the vicinity of the electrodes for disposal or further processing. A pilot-scale demonstration of this technology for the remediation of chromium contamination is underway at Sandia National Laboratory. **Innovative Soil Washing** — *Ex-situ* treatment metal contaminated soils by the adaptation of standard mining technologies. Particulate and absorbed/adsorbed contaminants can be removed allowing the "cleaned" soil to be replaced. The collected metals then are disposed of or reprocessed for recycle/reuse. Several such technologies have been demonstrated by the Mackay School of Mines at the University of Nevada at bench and pilot scale. Sites for full-scale demonstration are being investigated. ***In Situ* Vitrification (ISV)** — *In situ* heating of soil to above its melting temperature. Upon cooling, the molten soil mass creates a glass-like monolith that essentially immobilizes contaminants. The glass is resistant to leaching and weathering and can be left in place; no further treatment is necessary. Field-scale demonstrations of this technology have been conducted at Hanford and Oak Ridge sites. A large-scale demonstration also has been performed at Hanford.
Groundwater	**Dynamic Underground Stripping** — Surrounding of an underground contaminant plume with injection wells and electrical heating of clay-rich soil layers while sandy layers are flooded with steam. This combination volatilizes contaminants (NAPLs and other inorganic solvents) which are carried by the steam to a central extraction well. The steam is condensed, extracted, and treated above ground; the water is reinjected, and the contaminants are removed for disposal. A full-scale demonstration was conducted at Lawrence Livermore National Laboratory in 1994. The technology currently is available for licensing. ***In Situ* Bioremediation** — Stimulation of indigenous microbes or introduction of foreign microbes in the contaminated region. The microbes stimulate the remediation of the area through the metabolism of the contaminant or by causing reactions to occur which release the contaminants from the soil, allowing a conventional removal action (such as pump-and-treat) to remediate the site more efficiently. A field demonstration was undertaken at Hanford in 1995; results are pending. **Biosorption of Uranium** — Remediation of uranium-contaminated ground and surface water using biosorbents (sorptive biomass or biological material) immobilized in permeable beads that, in turn, are contained within a flow-through bioreactor system. The technology is a partnership between Oak Ridge National Laboratory and Ogden Environmental and Energy Services, Inc. Bench-scale testing has been completed. **Recirculating wells** — Use of specially designed wells to pump water or soil air through a screened interval and to transfer it back into the aquifer through a separate interval. Treatment occurs below ground within the well casing, thereby reducing utility and maintenance expense and regulatory costs. Recirculation also provides better control of groundwater flow through hydrodynamically connected wells. Demonstration is underway at the Portsmouth Gaseous Diffusion Plant on a 0.5-mile plume that contains high levels of TCE and Tc-99. **Microbial filters** — Placement of a permeable wall of TCE-degrading microorganisms in the subsurface to intercept a contaminant plume. Contaminants are degraded by microorganisms in the biofilter as the plume passively flows through it with the natural hydraulic gradient. The filter can be formed by direct injection of microorganisms into the subsurface to form a wall or by injecting them into an emplaced sand trench. Field-scale tests of this technology have been conducted at sites at Kennedy Space Center in Florida and Chico Municipal Airport, California.

Exhibit 7-5: Examples of Innovative Technologies Useful to DOE (continued)

Technology	Analysis
Facilities	**Gas Phase Decontamination** — Treatment of gaseous diffusion plant equipment interiors contaminated with solid uranium deposits with chlorine trifluoride gas. The gas is introduced in the process equipment and volatilizes the uranium deposits into a product gas mixture, which is removed, separated, and recovered.
Buried waste	**Cooperative Telerobotic Retrieval** — Selective and remote retrieval of buried radioactive and hazardous wastes to reduce exposure risks to remediation workers and the environment and costs associated with full-pit retrieval. The system consists of telerobotic manipulators, mounted on a gantry crane, that are capable of performing a variety of tasks—for example, retrieving intact containers and deploying dig face characterization sensors and ancillary tools (such as a camera, a soil vacuum, dust suppression sprays, and cutting equipment). A full-scale demonstration is being performed at Idaho National Engineering Laboratory. **Automated Waste Conveyance System** — Remote and safe transportation of retrieved radioactive and mixed wastes from the dig face to a waste processing and packaging area to reduce exposure risks to remediation workers and the environment. After retrieved waste is loaded into the container of the system, the container lid is remotely closed and locked to contain dust generated during conveyance. A full-scale demonstration was performed at Idaho National Engineering Laboratory in FY 1995.
Mixed low-level waste treatment	**Plasma Hearth System** — Thermal treatment characterized by high-efficiency destruction of organics, encapsulation of heavy metals and radionuclides in a vitrified final waste matrix, maximum reduction of waste volume, low off-gas rates, and the capability of processing many waste types in a single step process without the need for expensive pre-treatment.
Characterization	**Expedited Site Characterization** — Process with a regulator-accepted work plan that permits a multi-disciplinary team of experts concurrently to collect and integrate field data to develop and evaluate a site model. Sampling locations are determined daily in the field, based on evolving site model knowledge and results, yielding a faster, less expensive, and superior model.
High-level waste	**Efficient Separations** — Chemical processes and chemical reactions, which enhance separations or eliminate a separation step by destroying a contaminant, for use in treating and immobilizing a broad range of radioactive wastes. In some cases, separation technologies do not exist; in others, improvements are needed to reduce costs, reduce secondary waste volumes, and improve waste form quality. **Robotic Systems** — Remotely operated equipment for retrieving and handling high-level waste stored in underground tanks.

Source: U.S. Department of Energy, "Estimating the Cold War Mortgage: The 1995 Baseline Environmental Report," DOE/EM-0230, March 1995.

PRDA in December 1991, for $10 million. This PRDA focused on groundwater and soils technologies and resulted in the award of 21 contracts to the private sector and university technology developers. A second PRDA, of equal value, was issued in 1992. It solicited for novel decontamination and decommissioning technologies and resulted in the award of 18 contracts to private sector technology developers.

Two ROAs also have been issued, soliciting for technologies in the areas of *in situ* remediation; characterization, sensing, and monitoring; efficient separations for radioactive wastes; and robotics. Twenty-seven contracts have been awarded under these ROAs to the private sector. DOE has established a 20-percent set-aside for small firms (500 employees or fewer) for applied research projects funded through ROAs. To date, however, 30 to 50 percent of these contracts have gone to small businesses.[16]

By early 1995 a total of 55 PRDA and ROA contracts had been awarded for a sum of $93.4

million. PRDAs and ROAs are published in the *Federal Register* and their availability is listed in the *Commerce Business Daily*. Information about announcements also is available on the Internet on the Federal Information Exchange, Inc. —FEDIX Home Page (http://web.fie.com/fedix/index.html).

DOE maintains a Web site to connect DOE's site specific needs with private industry capabilities (http://www.ead.anl.gov/techcon/). The web site is part of DOE's overall effort to better match site needs with commercial or emerging capabilities that will enable performance improvement while limiting risk.

DOE's Small Business Technology Integration program identifies funding to support innovative technology development by small businesses. The Program also sponsors workshops as a forum for face-to-face meetings between small business operators and DOE staff who can provide information on specific business opportunities. In addition, a small business coordinator is available at DOE Headquarters to provide one-on-one counseling for small, disadvantaged, or minority businesses and provide access to procurement offices at DOE installations. For additional information about DOE's small-business-oriented programs, contact the U.S. Department of Energy, Office of Technology Development/Technology Exchange Division (EM-521), Washington, DC 20585.[17]

DOE also is one of 11 agencies involved in the Small Business Innovation Research (SBIR) Program, administered by the Small Business Administration (SBA). The three-phase program is designed to facilitate technology transfer by identifying funding to support innovative technology development by small businesses. Proposals for work under the program are invited through an annual solicitation announcement. Grants or contracts awarded under phase one of the program provide $60,000 to $100,000 for up to six months to conduct feasibility studies for research ideas that appear to have commercial potential. Phase-two funding of up to $750,000 provides for 12 to 24 months of additional research, development, demonstration, and evaluation of the technology. Phase three of the project involves commercializing the technology and using it for full-scale remediation. About two percent of DOE's extramural research budget for FY 1996 is expected to be available to small businesses under this program. Notices of all federal SBIR opportunities are published by the SBA on its SBA Bulletin Board. The bulletin board can be accessed, by modem, 800-697-4636). SBA Bulletin Board technical support is available by addressing specific DOE problems and require proof-of-principle experimentation, and technologies proven in other fields that require critical path calling 202-205-6400. The SBA Bulletin Board also is available via Telnet at sbaonline.sba.gov.[18]

Developers and vendors of innovative technologies interested in more information about DOE's technology development efforts may contact the DOE's Center for Environmental Management Information (800-736-3282).

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CHAPTER 8
DEMAND FOR REMEDIATION OF CONTAMINATED WASTE SITES MANAGED BY CIVILIAN FEDERAL AGENCIES

This chapter describes the market for the cleanup of "civilian" federal agency (CFA) sites. "Civilian" federal agencies include all federal agencies except the Department of Energy (DOE) and Department of Defense (DOD). Each agency is responsible for cleaning up contaminated waste sites at facilities it owns or operates. Collectively, these agencies are responsible for thousands of sites.[a]

The CFA market can be estimated in terms of the number of sites or the number of facilities that will require remediation. A facility can contain more than one contaminated site.

Estimates of the approximate number of contaminated sites at the U.S. Department of Interior (DOI), U.S. Department of Agriculture (USDA), and National Aeronautics and Space Administration (NASA) facilities are available from a 1995 report by the U.S. Council on Environmental Quality and Office of Management and Budget.[1] DOI is responsible for a large number of potentially contaminated sites on the more than 440 million acres of federal land it manages. According to preliminary DOI estimates, the department may have as many as 26,000 sites requiring some cleanup. USDA currently estimates that, including sites at facilities listed on the Docket, there are 3,000 potentially contaminated sites on land under its management. NASA has identified 730 potentially contaminated sites at the facilities listed on the Docket. Site inventories and evaluations are ongoing at these agencies. The CEQ report did not address other CFAs.

The "Federal Agency Hazardous Waste Compliance Docket," is a more comprehensive source of information on contaminated facilities for which CFAs are responsible.[2] The Docket is based on reports filed by the agencies on the number of contaminated facilities, including those containing the aforementioned DOE, NASA, and USDA sites. The estimates in this chapter of the total number of CFA facilities that will require remediation were derived from this docket.

As of April 1995, 1,047 facilities, distributed among 17 civilian federal agencies, were listed on the Docket. About 700 of these facilities eventually could require some environmental cleanup.[2] April 1995 is the most recent date for which data are available. EPA plans to update it in the summer of 1997. The Docket, mandated under Section 120(c) of the Comprehensive Environmental Response, Compensation, Liability Act (CERCLA) is a repository for information about federal facilities that manage hazardous waste or have the potential to release hazardous substances into the environment.

Although an overall estimate of the potential cost of cleaning up these facilities is not available, estimates have been generated for DOI, USDA, and NASA, which together account for over 70 percent of the civilian federal agency facilities listed on the Docket. Cleanup of the over 500 facilities for which these agencies are responsible is expected to cost between $8 billion and $13 billion in 1994 dollars. Extrapolating this estimate for these 500 facilities to the over 700 civilian facilities and updating to 1996 dollars results in an estimated life-cycle-cost of $15 billion for the entire market segment. This estimate is about half the projected cost of the cleanup of DOD sites and less than 25 percent of the anticipated cost of the cleanup of DOE's sites (see Chapters 6 and 7).

[a] Throughout this chapter, the term "site" will be used to indicate an individual area of contamination. The term "facility" identifies an entire tract, including all contiguous land, that is the responsibility of the subject agency. A "facility" may contain one or more contaminated areas or "sites."

8.1 Civilian Federal Agency Cleanup Programs

The federal government must comply in the same manner as private parties with the provisions of CERCLA and the Resource Conservation and Recovery Act (RCRA). These statutes make federal agencies liable for the cleanup of contaminated waste at currently or formerly owned facilities. Under the 1986 Superfund Amendments and Reauthorization Act (SARA), the federal government also may be liable for cleaning up contaminated waste at facilities acquired through foreclosure or other means and facilities purchased with federal loans. To meet these requirements, civilian federal agencies have established programs to assess potentially contaminated sites, including leaking underground storage tanks, and clean them up if necessary. Most agencies have established central offices to manage these programs; others have adopted a decentralized approach, organizing their programs by function or geographical location.

NASA, for example, uses a decentralized management approach, but provides policy guidance, priority setting, and oversight from a central Environmental Management Office.[b] The central office has delegated responsibility for environmental cleanup and compliance to the directors of its 10 major centers around the country. NASA's plans call for completing its cleanup program within the next 25 years.[1]

At many DOI facilities, the responsibility for cleanup will be shared with the private parties or other agencies that undertook activities that produced the contamination. DOI has established a Central Hazmat Fund to provide funding for some cleanup projects. This fund may be used for remedial investigations, feasibility studies, and cleanups at sites for which DOI may be liable. Additional cleanup activities are funded through the appropriations of the DOI bureaus (such as the U.S. Bureau of Mines) with responsibility for the facilities.[1]

USDA's overall program is at an early stage of development, but its plans call for completing site cleanup and natural resource restoration at its facilities within the next 50 years. A complete inventory of potentially contaminated sites still is underway by the agencies within USDA. The USDA expects that private sector responsible parties (RPs), such as mining companies whose past activities may have contributed to the contamination of land under USDA's management, will pay a share of the cost of cleanup of their facilities.[1]

8.2 Factors Affecting Demand for Cleanup

Four primary factors influence the market for remediation of civilian federal agency contaminated waste sites.

- All federal agencies are constrained by budget considerations when planning for site remediation. Even though agencies may request funds for contaminated site management and remediation, Congress may not provide the necessary funding. As the availability of resources to meet the full range of national needs becomes less and less certain, agencies are intensifying their efforts to prioritize cleanup activities within and across facilities by doing a better job of evaluating alternative future land uses, estimating risks, evaluating available technologies, and analyzing the relative costs and benefits of various approaches to cleanup.[1]

  In addition, the federal budget process has created incentives for agencies to implement management reforms that will reduce the costs of operations. Some of these include encouraging and eliminating barriers to the use of less costly, innovative technologies; using more cost-effective contracting procedures; streamlining management structures and processes; and using the "lessons learned" from other agencies and the private sector.[1]

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[b] NASA centers are Lewis Research Center Ohio, Langley Space Center Virginia, Goddard Spaceflight Center Maryland, Kennedy Space Center Florida, Marshall Space Center Alabama, Stennis Space Center Alabama, Johnson Space Center Texas, Ames Space Center California, Jet Propulsion Laboratory California, and Dryden Space Center California.

- Federal agencies may be liable for cleaning up contamination at properties acquired through foreclosure or other means. In a September 1995 memorandum, EPA and the Department of Justice stated the government's intention to enforce the CERCLA Lender Liability Rule on federal regulatory, lending, and credit agencies that have "involuntarily acquired" contaminated property through foreclosure or other mechanisms, such as civil and criminal seizures and asset forfeitures.[3]

  In general, federal agencies that "involuntarily" acquire contaminated property are exempt from CERCLA liability. However, if a federal agency loans money to, and actively participates in the management of, organizations using or generating hazardous waste, it may be liable for remediating these sites if hazardous waste is spilled or improperly disposed.[4] For example, federal credit agencies, such as the Small Business Administration (SBA), often provide loans and advice to businesses that use or generate hazardous materials. If SBA actively participated in management decisions and acquired the business through foreclosure, it may be liable for the cost of cleanup. Federal liability must be determined separately for each site acquired through foreclosure or other means. Data are not available on the number of sites for which civilian agencies could be liable under this rule.

- Changes in state and federal environmental regulations and standards could impact the level and pace of the cleanup required at civilian federal facilities. If cleanup standards become more rigorous in the future, the market may require more advanced technologies or longer-term and more intensive use of existing technologies than is currently anticipated. Conversely, if standards become less stringent in the future, the need and market for new remedial technologies could be reduced.

- The transfer of public properties to private use may require agencies to reallocate resources to clean up properties designated for transfer.

8.3 Number of Facilities and Sites

There are two potential approaches to estimating the CFA market for hazardous waste remediation services: estimating the number of facilities and estimating the number of sites that will require some type of remedial action. The estimates in this chapter are derived from the "Federal Agency Hazardous Waste Compliance Docket," which provides estimates of the number of facilities reported by 17 CFAs.[2] Data for the number of contaminated sites are available for only three agencies, DOI, NASA, and USDA. These data are discussed at the end of this section.

The Docket, maintained by EPA, contains information about federal facilities that manage hazardous waste or may have had releases of hazardous substances into the environment. Although the statute calls for the Docket to be updated every six months, the last update occurred in April 1995, because of resource constraints and other factors. Since many sites at federal facilities still are being inventoried and characterized, the facilities listed on the Docket may not account for all potentially contaminated sites on land owned or operated by CFAs

Civilian federal agencies submit information for the Docket to EPA as required under RCRA and CERCLA. Because the Docket contains information that is broader than hazardous waste site remediation programs, it does not specifically indicate the number of federal facilities that require remediation. Also, once a facility has been added to the Docket, it is not removed, even after it is cleaned up. In addition, the Docket excludes federal facilities that have been sold; private facilities where the federal government may have contributed to site contamination; and facilities that generate small quantities of hazardous waste.

The April 1995 Docket included 732 facilities that had been listed as a result of a notification of a release or potential release under CERCLA Section 103 (Exhibit 8-1).[2] These facilities, owned or operated by 17 civilian federal agencies, comprise the estimated market for the cleanup of civilian federal agency sites. Not all of the facilities on the Docket contain contaminated sites. After further study, some sites may be designated as requiring

Exhibit 8-1: Number of Civilian Federal Facilities Potentially Requiring Cleanup

Agency	Facilities Listed on Docket[a]	Facilities Reported Under CERCLA 103	Facilities Reported Under CERCLA 103 with NFRAP Status
Department of Agriculture	148	121	37
Central Intelligence Agency	1	1	0
Department of Commerce	11	9	3
Army Corps of Engineers[b]	51	20	5
Environmental Protection Agency	25	9	3
General Services Administration	23	11	3
Department of Health and Human Services	8	6	2
Department of Housing and Urban Development	3	1	0
Department of the Interior	432	389	169
Department of Justice	21	14	0
Department of Labor	2	2	1
National Aeronautics and Space Administration	17	13	4
U.S. Postal Service	23	12	4
Tennessee Valley Authority	40	21	12
Department of Transportation	121	86	43
Department of the Treasury	9	3	1
Veterans Administration	29	14	5
Total	1,047	732	292

Notes:
a The number of "sites" (individual areas of contamination) at each facility is not included in the "Federal Agency Hazardous Waste Compliance Docket."
b The U.S. Army Corps of Engineers manages environmental cleanup projects for a variety of civilian federal agencies as well as for the U.S. Department of Defense and the U.S. Department of Energy. The facilities to which this table refers are *civilian* federal facilities for which the Corps of Engineers has environmental cleanup management responsibility.

Source: Source: U.S. Environmental Protection Agency. "Federal Agency Hazardous Waste Compliance Docket," 60 *Federal Register*, pp. 18474-18518, April 11, 1995.

no further response or action planned and do not need to undergo remediation. Also, the Docket does not indicate the number of contaminated sites at each facility. The Docket also contained another 315 facilities that had been listed under other environmental statutes.

A Preliminary Assessment (PA) is conducted under Section 120(d) of CERCLA for all facilities listed on the Docket to evaluate the threat they pose to public health or the environment.[4] As of April 1995 EPA had determined that 292 of the 732 facilities listed under CERCLA Section 103 were unlikely to require listing on the National

Priorities List (NPL). EPA uses the term NFRAP (No Further Remedial Action Planned) to designate these facilities (Exhibit 8-1).

While the NFRAP designation means that EPA anticipates no further involvement in site assessment or cleanup, it does not mean that the facility poses no environmental threat or that some type of environmental response action is not needed. It simply indicates that the problems at the facility are not severe enough to warrant an NPL listing and Superfund cleanup.[5] Thus, at least some of these facilities still may require cleanup under other environmental programs.

Estimates of the approximate number of contaminated sites at DOI, USDA, and NASA facilities are available from a 1995 report by the U.S. Council on Environmental Quality.[1] DOI is responsible for a large number of potentially contaminated sites on the more than 440 million acres of federal land it manages. DOI estimates that it may have as many as 26,000 sites requiring some cleanup. These sites, which include those at facilities listed in the Docket, are located at abandoned mines, oil and gas production sites, underground storage tanks, landfills, and other facilities. Contaminants at these sites are primarily from sedimentation in surface waters, acid mine drainage, and household chemical wastes.[1] USDA currently estimates that, including sites at facilities already listed on the Docket, there are 3,000 potentially contaminated sites on land under its management. USDA has about 25,000 abandoned and inactive mining sites, but only about 10 percent are expected to require CERCLA or RCRA cleanup. Contaminants at USDA sites are primarily the result of hazardous waste from mining, chemical wastes, and sediment in surface waters. A complete inventory of potentially contaminated sites is underway.

NASA has identified 730 potentially contaminated sites at the 17 facilities listed on the Docket. These sites are the result of such problems as leaking underground storage tanks, exposed asbestos, and mercury spills. The primary contaminants are fuels, solvents, and industrial waste constituents. As of October 1995, no further action was required or active remediation had been completed at 155 of these sites, 75 sites were undergoing active remediation, and 350 were undergoing site evaluation and preliminary assessment.[1]

As illustrated by DOI, USDA, and NASA, the types of contamination problems at facilities managed by civilian federal agencies vary from agency to agency. Examples of the types of contaminated facilities at selected agencies are presented in Exhibit 8-2.

8.4 Estimated Cleanup Costs

Developing accurate cost estimates for cleaning up contaminated CFA sites is difficult, primarily because detailed site information is not available. However, budget data for most federal civilian agencies are available in the FEDPLAN-PC database maintained by EPA, in accordance with Office of Management and Budget Circular A-106.[6] FEDPLAN-PC, which is updated regularly by agencies with responsibilities for contaminated waste site management, provides a mechanism for: characterizing environmental activities at federal facilities; establishing priorities for these activities; and identifying resources needed to comply with federal, state, and local environmental requirements.

As of December 1996, budget data for fiscal year (FY) 1996 and FY 1997 were available in FEDPLAN-PC for 14 civilian federal agencies. These agencies reported spending a total of $322.1 million in FY 1996 for cleanup activities.[7] The agencies estimated budgetary needs of $288.0 million for hazardous waste activities in FY 1997.[7] The FY 1996 budgets and FY 1997 estimates for the 14 civilian federal agencies listed in the FEDPLAN-PC database are presented in Exhibit 8-3. Life-cycle cost estimates are available for DOI, USDA, and NASA in 1994 dollars. Based on current information, DOI estimates that it will take between $3.9 billion and $8.2 billion to complete cleanup of its contaminated sites. USDA's current estimate of its overall cleanup cost is $2.5 billion. NASA estimates its overall cleanup cost will be between $1.5 billion and $2 billion.[1] The range for these estimates is $7.9 to $12.7 billion in 1994 dollars and $8.4 to $13.5 billion in 1996 dollars. Assuming that these costs represent 70 percent of that of all CFA sites (based on the number of facilities), the life-cycle-cost for all CFA sites is estimated to be $12.0 to $19.0 billion, with an average of $15.0 billion.

Exhibit 8-2: Examples of Types of Contaminated Facilities at Civilian Federal Agencies

Department of Agriculture	
Forest Service	➠ Abandoned mining sites—mine tailings were disposed on-site in unlined pits. ➠ Sanitary landfills and aboveground dumps—hazardous waste may have been disposed at Forest Service landfills. ➠ Wood preservation sites and three laboratories. ➠ Uninvestigated sites—hundreds of sites need to be investigated for contamination.
Agricultural Research Service	➠ Research laboratories—hazardous chemicals were used and disposed on-site in dry wells, surface impoundments, septic tanks, and other areas.
Commodity Credit Corporation (CCC)	➠ Grain storage facilities—carbon tetrachloride and other fumigants were applied to protect grain stored in the facilities. The CCC has not assessed most of the 2,000 sites it once operated.
Farmers Home Administration	➠ Farms acquired through foreclosure—pesticides and other hazardous chemicals may have been disposed of on the land.
Department of Commerce	➠ Research laboratories operated by the National Oceanographic and Atmospheric Administration. ➠ Properties acquired through foreclosure by the Economic Development Administration—industrial solvents and other wastes were generated from production activities at steel mills, iron foundries, leather tanneries, furniture manufacturers, and other heavy industries.
Environmental Protection Agency (EPA)	➠ EPA laboratories—hazardous wastes were either generated or stored for research purposes.
General Services Administration (GSA)	➠ GSA buildings and sites—although few locations have contamination problems, GSA may be liable for contaminated sites it has sold
Department of Interior	
Bureau of Land Management (BLM)	➠ Approximately 3,400 closed landfills may exist on BLM land—hazardous wastes may have been disposed at these BLM landfills. ➠ Abandoned mining operations—tailings were left on-site at many mines. ➠ Unauthorized hazardous waste sites—contaminants may have been illegally dumped on BLM land. The extent of the problem is unknown as BLM has not conducted a complete survey of its lands.
Department of the Interior (continued)	
Bureau of Mines	➠ Research laboratories—hazardous materials were used, stored, or disposed on-site in landfills.
Bureau of Reclamation	➠ Reservoirs and drinking water supplies contaminated with agricultural runoff.
National Park Service	➠ Landfills and dumps inherited when the land was acquired. ➠ Abandoned mining operations—tailings were left on-site at many mines.
Fish and Wildlife Service	➠ Polluted sites—agricultural runoff of pesticides and fertilizers or upstream discharges of pollutants have contaminated some land. ➠ Inherited land previously used for industrial or defense purposes—industrial pollutants were disposed of on-site at inherited property. Some of these sites are former Department of Defense properties.
Department of Justice	➠ Federal penitentiaries—hazardous materials were generated from industrial activities, including printing, woodworking, metalworking, and other activities. ➠ Illegal drug laboratories confiscated by the Drug Enforcement Agency—toxins were improperly stored or disposed at these drug laboratories.

Exhibit 8-2: Examples of Types of Contaminated Facilities at Civilian Federal Agencies (continued)

National Aeronautics and Space Administration (NASA)	➠ Field installations, research laboratories, or industrial plants—hazardous materials were used, stored, or disposed on-site. Some NASA plants may have groundwater contamination.
Small Business Administration	➠ Properties acquired through foreclosure—hazardous materials may have been improperly used or disposed on the property.
Tennessee Valley Authority	➠ Power generating plants and a fertilizer development laboratory—wastes, primarily consisting of fly ash and coal piles, have been disposed in on-site landfills.
Department of Transportation	
Federal Aviation Administration (FAA)	➠ FAA Technical Center—soil and groundwater may be contaminated at 22 areas of the center. This site is on the NPL and assessment and remedial work is underway. ➠ Airfields—hazardous solvents and oils may have been spilled at airfields. As many as 53 Alaskan airfields may be contaminated.
U.S. Coast Guard	➠ Central storage areas for fuel and operation and maintenance facilities—solvents, fuel, or waste by-products leaked into the ground.
Department of Veterans Affairs	➠ Medical centers—hazardous and medical wastes were produced, stored, and incinerated.

Source: U.S. Council on Environmental Quality, Office of Management and Budget, *Improving Federal Facilities Cleanup*, October 1995, and Congressional Budget Office, *Federal Agency Summaries:. A Supplement to Federal Liabilities Under Hazardous Waste Laws*, May 1990.

8.5 Remedial Technologies

Little information is available on the technologies being used to cleanup facilities owned or operated by civilian federal agencies. To the extent that the contaminants and media at these sites are similar to those of other industrial facilities, similar technologies can be used. EPA's "Innovative Treatment Technologies: Annual Status Report (Eighth Edition)"[8] describes technology use trends at NPL, DOD and DOE sites, and a related database[9] provides more detailed data on the sites and applications.

Exhibit 8-3: Funding for Cleanup at Civilian Federal Agencies[a]

Agency	FY 1996 Expenditures for Hazardous Waste Cleanup (thousands)	FY 1997 Budget for Hazardous Waste Cleanup (thousands)
Department of Agriculture	34,204	45,108
Department of Commerce	6,387	6,261
Army Corps of Engineers[b]	8,487	667
Environmental Protection Agency	0	0
General Services Administration	0	0
Department of Health and Human Services	3,075	1,050
Department of the Interior	101,438	24,066
Department of Labor	0	0
National Aeronautics and Space Administration	151,691	193,259
Department of State	19	1,080
Tennessee Valley Authority	0	5,880
Department of Transportation	16,819	17,975
Department of Treasury	0	0
Veterans Administration	0	0
Total (14 agencies)	**322,120**	**288,024**

Notes:

[a] The U.S. Army Corps of Engineers manages environmental cleanup projects for a variety of civilian federal agencies as well as for the U.S. Department of Defense and the U.S. Department of Energy. Budgetary data presented in this table is for the Corps of Engineers' environmental cleanup work at *civilian* federal facilities.

[b] As of December 1996, budget data for the Central Intelligence Agency, the Department of Housing and Urban Development, the Department of Justice, and the U.S. Postal Service for FY 1995 and FY 1996 were not available in FEDPLAN-PC. The fact that budget data were unavailable or that some agencies estimate no FY 1996 budget expenditures for hazardous waste cleanup does not mean that the environmental cleanup work for which these agencies are responsible has been completed.

Source:. U.S. Environmental Protection Agency, Federal Facilities Enforcement Office, "FEDPLAN-PC," December 1996.

8.6 References

1. U.S. Council on Environmental Quality, Office of Management and Budget, *Improving Federal Facilities Cleanup*, October 1995.

2. U.S. Environmental Protection Agency. "Federal Agency Hazardous Waste Compliance Docket," 60 *Federal Register*, 18474-18518, April 11, 1995.

3. U.S. Environmental Protection Agency, "Policy on Enforcement of Lender Liability Rule on Federal Agencies," 60 *Federal Register*, 63517, December 11, 1995.

4. U.S. Environmental Protection Agency, "National Oil and Hazardous Substances Pollution Contingency Plan; Lender Liability Under CERCLA," 57 *Federal Register* No. 83, 18344, April 29, 1992.

5. Federal Agency Hazardous Waste Compliance Docket, *Docket Revision Preamble*, Federal Facilities Enforcement Office, U.S. Environmental Protection Agency, March 14, 1995.

6. Office of Management and Budget, Executive Office of the President, *Circular A-106: Reporting Requirements in Connection with the Prevention, Control, and Abatement of Environmental Pollution at Existing Federal Facilities*, December 31, 1974.

7. U.S. Environmental Protection Agency, Federal Facilities Compliance Office, *FEDPLAN-PC*, December 1996.

8. U.S. EPA, Office of Solid Waste and Emergency Response, Technology Innovation Office, *Innovative Treatment Technologies: Annual Status Report (Eighth Edition)*, EPA-542-R-96-010, November 1996.

9. U.S. EPA, Office of Solid Waste and Emergency Response, Technology Innovation Office, *Innovative Treatment Technologies: Annual Status Report Database, (ITT Database)*, EPA-542-C-96-002, January 1997.

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CHAPTER 9
DEMAND FOR REMEDIATION OF CONTAMINATED WASTE SITES MANAGED BY STATES AND PRIVATE PARTIES

The market to remediate contaminated waste sites includes thousands of sites managed by the states and private parties. All non-federal agency sites that are not being cleaned up under the federal Comprehensive Environmental Response, Compensation, Liability Act (CERCLA), Resource Conservation and Recovery Act (RCRA) corrective action, and Underground Storage Tank (UST) programs, but still need attention, become the responsibility of state cleanup programs. Private parties are individuals or companies not affiliated with federal or state governments.

Using data supplied by the states, EPA has determined that over 79,000 non-National Priorities List (NPL) sites have been identified that are known or suspected to be contaminated. Further, 29,000 of these sites will require some action beyond a preliminary assessment; however, the actual number of sites that will need remediation and the extent of contamination at these sites are largely unknown.

The majority of states have enforcement authority and state Superfunds to finance remediation of abandoned waste sites. At the end of 1995, the balance of state Superfunds was $1.46 billion. During 1995, states spent a total of $386 million and obligated an additional $363 million from state Superfunds for remediation of NPL and non-NPL sites.

In addition to direct state cleanups, many state sites are cleaned up by private parties in accordance with state cleanup standards. To encourage private party cleanups, many states have created voluntary cleanup programs that often provide incentives for private parties to control the assessment and cleanup of their sites with state oversight. An increasing number of states also are creating brownfields programs that target the cleanup and redevelopment of industrial properties that have been abandoned or are under-used because of the potential for environmental contamination. By the end of 1995, 34 states had established voluntary cleanup programs and 15 states had established brownfields programs. Based on an EPA survey of states, EPA estimates that private party expenditures on assessment and remediation of contaminated sites are roughly equal to state expenditures.

9.1 State Hazardous Waste Site Programs

Most states have established hazardous waste programs to ensure that potentially contaminated sites are assessed and cleaned up if necessary. Information on state programs, numbers of contaminated sites, and the status of those sites has been derived from existing published information. Contacting individual states to obtain data was outside the scope of this study. The primary sources of information are two EPA documents, *An Analysis of State Superfund Programs: 50-State Study, 1993 Update*[1] and *An Analysis of State Superfund Programs: 50-State Study, 1995 Update*[2]. These two studies include the 50 states, Puerto Rico, and District of Columbia; for convenience, these are referred to as 52 "states." The studies describe each of the states' programs, including enabling legislation, enforcement provisions, staffing levels, funding, and other aspects of the programs. The legal and financial resources available to states indicate the extent of the states' commitment to cleaning up contaminated sites. Two additional sources of information were a document prepared jointly by EPA and the Association of State and Territorial Solid Waste Management Officials (ASTSWMO), *A Report on State/Territory Non-NPL Hazardous Waste Site Cleanup Efforts for the Period 1980-1992*[3], and a report prepared by the Northeast-Midwest Institute with funding from the Economic Development Agency, U.S. Department of Commerce, *Coming Clean for Economic Development*.[4] Although the documents were developed primarily for policy purposes, the information provided is useful for defining the state market for hazardous waste remediation.

9.1.1 General Operations of State Cleanup Programs

Most of the states have enacted statutes patterned after CERCLA. These statutes typically include: provisions for emergency response and long-term remedial actions; cleanup funds or other mechanisms to finance remedial activities; enforcement authorities to compel responsible parties (RPs) to perform or pay for cleanup activities; and staff to administer state-lead cleanups and monitor RP-lead cleanups. As of December 1995, 45 states had authority to use funds for a full range of cleanup activities, five states had authority to use funds only for emergency responses or matching CERCLA expenditures, and two states had no fund or other account that could be used for cleanups (Nebraska and the District of Columbia). In addition, 47 states had enforcement authority provided through specific hazardous cleanup authority or a hazardous waste enforcement statute. Five other states derived their enforcement authority from statutes not specifically intended for hazardous waste activities, such as general environmental laws, and provisions within other state laws.

Many state statutes also authorize development of a priority list, inventory, or registry of state sites. Most states use their list to determine the order in which sites will be cleaned up. By the end of 1995, 30 states had statutory provisions requiring the use of a priority list, and 35 states reported that they had either state inventories or priority lists. The states use widely different criteria for placing sites on lists or within categories, and therefore, many lists are difficult to compare. Some state lists include all known and suspected sites, and others include only those sites that have completed a long evaluation process.

An important provision of some state statutes is that dealing with property transfers. These provisions are designed to ensure that real property being transferred between parties does not pose health or environmental threats stemming from hazardous releases. In general, these provisions require the owner or state to disclose that the property was contaminated by hazardous materials either by recording a notice with the deed or by disclosing such information at the time of the property transaction. Some of these laws require the seller of the property to remediate the site prior to any transfer of property. As of December 1995, 25 states had some type of property transfer provision in their laws or regulations.

The resource levels a state has committed provides a useful indicator of the level of activity in a state cleanup program. In 1995, the total number of state personnel working in state cleanup programs was 3,585. An additional 211 attorneys were reported by the states to be working on waste cleanup issues. Staff levels for state programs varied from three people in South Dakota to 650 staff positions in New Jersey. Eleven states had staffing levels exceeding 100 in 1995. Each of these states (California, Illinois, Kansas, Massachusetts, Michigan, New Jersey, New York, Ohio, Pennsylvania, Texas, and Washington) had a large number of confirmed or suspected contaminated sites. Six states (Connecticut, Florida, Indiana, Minnesota, Oregon, and Tennessee) had staff levels between 51 and 100 people. The majority of states (31) had staff levels between 11 and 50, while only four states had 10 or fewer staff positions for their hazardous waste programs.

9.1.2 Voluntary and Brownfields Programs

The states increasingly are adopting new programs to encourage private parties to voluntarily clean up sites rather than expending state resources or fund monies on enforcement actions or site cleanups. By the end of 1995, 34 states have established voluntary cleanup programs through statute, regulation, or policy.[2] Fifteen states have established "brownfields" programs that provide incentives for the cleanup and redevelopment of industrial sites that have been abandoned or are under-used because of fear of liability associated with potential environmental contamination. Exhibit 9-1 shows those states that have voluntary cleanup and brownfields programs.

The voluntary cleanup and brownfields programs incorporate efforts by the states to reduce factors that tend to discourage voluntary cleanup, such as liability for cleanups, lack of control over remediation, and cost.[2] Although the programs vary considerably, most voluntary cleanup programs include clear cleanup standards, timely cleanup oversight, cleanup closure procedures, and liability protection. Most states offer some form of protection from future liability to private parties when the site is voluntarily cleaned up to state standards. Liability protection is provided through covenants not to sue, no further action letters, certificates of completion, and other mechanisms. State brownfields programs typically extend liability protection to prospective purchasers, lenders, and real estate developers. Liability protection is contingent upon no further contamination being found or created at the site and does not always protect private parties from federal liability requirements.

Exhibit 9-1: State Voluntary Cleanup and Brownfields Programs

States	Voluntary Cleanup Program	Brownfields Program	States	Voluntary Cleanup Program	Brownfields Program
Alabama	yes	—	Montana	yes	—
Alaska	—	—	Nebraska	yes	—
Arizona	yes	—	Nevada	yes	—
Arkansas	yes	yes	New Hampshire	yes	—
California	yes	—	New Jersey	yes	yes
Colorado	yes	—	New Mexico	—	—
Connecticut	yes	yes	New York	yes	—
Delaware	yes	yes	North Carolina	yes	—
District of Columbia	—	—	North Dakota	—	—
Florida	—	—	Ohio	yes	yes
Georgia	—	—	Oklahoma	yes	—
Hawaii	—	—	Oregon	yes	yes
Idaho	—	—	Pennsylvania	yes	yes
Illinois	yes	yes	Puerto Rico	—	—
Indiana	yes	yes	Rhode Island	yes	yes
Iowa	—	—	South Carolina	yes	—
Kansas	—	—	South Dakota	—	—
Kentucky	—	—	Tennessee	yes	—
Louisiana	yes	—	Texas	yes	—
Maine	yes	—	Utah	yes	—
Maryland	—	—	Vermont	—	yes
Massachusetts	yes	yes	Virginia	yes	—
Michigan	yes	yes	Washington	yes	—
Minnesota	yes	yes	West Virginia	—	—
Mississippi	—	—	Wisconsin	yes	—
Missouri	yes	yes	Wyoming	—	—
			Total	34	15

Source: U.S. EPA, Office of Emergency and Remedial Response, *An Analysis of State Superfund Programs: 50-State Study, 1995 Update*, July 1996.

9.1.3 Federal Initiatives Affecting State Cleanup

The federal government has actively encouraged and assisted states in their efforts to clean up their contaminated properties. For example, EPA has a program dedicated to help states address brownfields sites, which potentially can affect a large number of sites. EPA defines brownfields as "abandoned, idle, or under-used industrial and commercial facilities where expansion or redevelopment is complicated by real or perceived environmental contamination." The U.S. General Accounting Office (GAO) estimated that there are between 130,000 and 450,000 brownfields sites that will cost over $650 billion to clean up.[5]

Where past use of a site raises the possibility that the site may be contaminated, fear of being caught in the Superfund liability net often stymies further development at the site. Lenders, developers, and prospective purchasers are discouraged from getting involved with a site, because of the risk of having to pay cleanup costs.

Current brownfields owners often are not willing to conduct an assessment of their sites for fear of finding contamination that may have been a result of their activities or those of past owners. Many brownfields end up as the property of local governments through foreclosure. Most brownfields are located in urban areas and are generally associated with unaddressed contamination, declining property values, increased unemployment, and movement of industries to the suburbs.

In January 1995, EPA announced the Brownfields Action Agenda that outlined EPA's activities and future plans to help states and localities clean up and reuse brownfields. EPA committed to the following four broad areas:

- EPA would fund at least 50 Brownfields Demonstration Pilots for up to $200,000 over two years so that states and municipalities can develop and test redevelopment models.

- EPA would work with states and municipalities to clarify agency guidance regarding the liability of prospective purchasers, lenders, property owners, and others associated with activities at potentially contaminated sites.

- EPA would work with states, municipalities, and community representatives to promote public participation and community involvement in brownfields redevelopment decision-making.

- EPA would establish partnerships with community colleges to develop strategies for allowing local residents an opportunity to qualify for jobs created as a result of brownfields activities.

By the end of FY 1996, Brownfields Pilots have been awarded to the 76 cities and states listed in Exhibit 9-2. EPA plans to fund additional pilots in FY 1997.

Another federal initiative, which is being implemented by the U.S. Department of Housing and Urban Development (HUD), is an Empowerment Zone (EZ) and Enterprise Community (EC) initiative designed to empower communities across the nation to work together to create jobs and opportunity. A key element of the EZ and EC programs is the development of community-based strategies for the cleanup and environmentally friendly reuse of brownfields, which have been identified as one of the major impediments to the creation of jobs and opportunity. The cities receiving these designations will receive flexible social services block grants of up to $100 million for EZs. In addition, tax incentives will be provided for businesses that are located in EZs and ECs. A primary goal of HUD's initiative is to increase cooperation among federal, state, and local governments to encourage more effective economic, human, environmental, and community development strategies. In selected cities, EPA will help to identify sites in need of environmental remediation.

9.2 Factors Affecting Demand for Cleanups

The state market for remediation services is largely dependent upon the commitment of states to establish and manage hazardous waste programs and the ability of states to finance cleanups or compel RPs to clean up sites. Enforcement authorities provided under state laws vary significantly among the states. As of

December 1995, 47 states had enforcement provisions contained in cleanup fund laws. Other states rely on their general environmental laws, groundwater laws, and other provisions for enforcement. For example, Nebraska relies on its groundwater protection laws, which apply only to contamination of groundwater. Virtually all state programs have authority to issue administrative cleanup orders and all states have authority to seek injunctions for cleanups. Recovery of punitive damages is provided in 25 states, and most states also have criminal and civil penalty provisions that may be used to enforce hazardous site cleanups. However, these provisions have not proven to be as effective in encouraging private-party cleanup actions as have some other incentive methods. The authority to perform fund-lead cleanups and recover punitive damages is the strongest incentive for securing private party cleanups. The potency of this incentive depends upon the resolve of a state to spend fund monies. Increases and decreases in state cleanup funds will affect the number and complexity of remedial actions undertaken by the states. State Superfunds may be impacted by economic and political conditions that influence state revenues. Except for the largest state programs, many states will have to rely on their ability to either compel private parties or encourage voluntary actions to clean up contaminated state sites.

Exhibit 9-2: Cities and States Awarded Brownfield Pilot Programs

- Birmingham, Alabama
- Prichard, Alabama
- Emeryville, California
- Oakland, California
- Richmond, California
- Sacramento, California
- San Francisco, California
- Stockton, California
- Sand Creek Corridor, Colorado
- Bridgeport, Connecticut
- Naugatuch Valley, Connecticut
- New Haven, Connecticut
- Clearwater, Florida
- Miami, Florida
- Atlanta, Georgia
- Panhandle Health District, Idaho
- East St. Louis, Illinois
- State of Illinois
- West Central Municipal Conference, Illinois
- Indianapolis, Indiana
- Northwest Indiana Cities, Indiana
- State of Indiana
- Louisville, Kentucky
- New Orleans, Louisiana
- Shreveport, Louisiana
- Portland, Maine
- Baltimore, Maryland
- Boston, Massachusetts
- Chicopee, Massachusetts
- Lawrence, Massachusetts
- Lowell, Massachusetts
- Somerville, Massachusetts
- Worcester, Massachusetts
- Chippewa County-Kinross Township, Michigan
- Detroit, Michigan
- Downriver Community Conference, Michigan
- Kalamazoo, Michigan
- State of Minnesota
- Bonne Terre, Missouri
- Kansas City, Kansas and Missouri
- St. Louis, Missouri
- Navajo Nation
- Concord, New Hampshire
- Camden, New Jersey
- Newark, New Jersey
- Trenton, New Jersey
- Buffalo, New York
- New York, New York
- Rochester, New York
- Rome, New York
- Charlotte, North Carolina
- Cincinnati, Ohio
- Cleveland, Ohio
- Lima, Ohio
- Oregon Mill Sites, Oregon
- Portland, Oregon
- Philadelphia, Pennsylvania
- Phoenixville, Pennsylvania
- Pittsburgh, Pennsylvania
- State of Rhode Island
- Sioux Falls, South Dakota
- Knoxville, Tennessee
- Dallas, Texas
- Houston, Texas
- Laredo, Texas
- Murray City, Utah
- Provo, Utah
- Salt Lake City, Utah
- West Jordon, Utah
- Burlington, Vermont
- Cape Charles-North Hampton County, Virginia
- Richmond, Virginia
- Bellingham, Washington
- Duwamish Coalition, Washington
- Puyallup Tribe, Tacoma Washington
- Tacoma, Washington

Source: U.S. EPA, Office of Solid Waste and Emergency Response, December 1996.

9.3 Number of Sites

The two 50-State Studies present the results of a survey in which each state was asked to identify the total number of "Known and Suspected Sites" and "Sites Needing Attention." The number of "Known and Suspected Sites" generally is the largest number of potentially contaminated sites known to the state and includes sites that have not yet undergone any type of assessment. The "Sites Needing Attention" are known and suspected sites that have been evaluated by the state and determined to require some further level of assessment or action. The studies do not present estimates of the number of sites that definitely require remedial action. Exhibit 9-3 presents each state's estimate for both categories of sites.

The total number of known and suspected sites reported in 1995 was 79,387 (up from 69,808 in 1991 but down from 101,796 in 1993). The largest decreases in known and suspected sites from 1993 to 1995 were in California, which decreased by 16,000; Michigan, which decreased by 9,700; and Pennsylvania, which decreased by 2,900. The decrease of sites reported by California was due to a reclassification of sites and better assessments of sites that will require action. The decrease of sites reported by Michigan was due to the elimination of underground storage tank sites from their estimate.

Exhibit 9-3: Number of Non-NPL State Hazardous Waste Sites

States	Known & Suspected Sites[a]		Sites Needing Attention[b]	
	1993	1995	1993	1995
Alabama	625	650	125	125
Alaska	1,051	1,347	1,051	1,347
Arizona	450	1,620	65	400
Arkansas	351	398	101	45
California	26,000	9,809	350	1,079
Colorado	420[c]	225	—	225
Connecticut	1,475	2,440	579	649
Delaware	288	280	89	120
District of Columbia	0	30	0	0
Florida	1,015	1,023	725	656
Georgia	800	904	0[c]	82
Hawaii	2,500	200	—	25
Idaho	220	59	50	59
Illinois	1,400	5,000	147	950
Indiana	1,549	2,500	82	200
Iowa	900	900	200	200
Kansas	450	609	200	324
Kentucky	1,000	1,000	500	600
Louisiana	1,014	690	184	136
Maine	370	419	160	92
Maryland	463	463	343	198
Massachusetts	6,328	7,500	5,867	4,500
Michigan	9,785	—	9,785	2,764
Minnesota	542	3,600	184	215
Mississippi	390	770	200	156
Missouri	1,253	1,475	163	200

Exhibit 9-3: Number of Non-NPL State Hazardous Waste Sites (continued)

States	Known & Suspected Sites[a] 1993	Known & Suspected Sites[a] 1995	Sites Needing Attention[b] 1993	Sites Needing Attention[b] 1995
Montana	265	277	265	240
Nebraska	370	400	120	200
Nevada	145	136	145	136
New Hampshire	250	250	250	250
New Jersey	18,519	20,000	12,894	6,500
New Mexico	600	278	220	182
New York	995	929	680	793
North Carolina	665	1,029	655	801
North Dakota	72[c]	0	0[c]	0
Ohio	1,200	1,190	771	406
Oklahoma	—	767	—	162
Oregon	1,235	1,559	102	218
Pennsylvania	3,000	100	50	50
Puerto Rico	246[c]	256	246[c]	256
Rhode Island	300	300	60	40
South Carolina	475	550	200	120
South Dakota	218	1,065	218	241
Tennessee	1,142	1,270	157	198
Texas	1,200	821	83	66
Utah	200	220	31	—
Vermont	1,291	1,700	1,291	931
Virginia	3,100	2,015	310	363
Washington	1,029	1,364	628	932
West Virginia	500	—	—	—
Wisconsin	4,000	4,000	565	565
Wyoming	140[c]	—	—	—
Totals	**101,796**	**79,387**	**41,091**	**28,997**

Notes:

[a] "Known and Suspected" sites are those that states have identified as being potentially contaminated. Many of these sites will not require action beyond a preliminary assessment. Site numbers are derived from Table V-5 of the 1993 *50-State Study* and Table V-3 of the 1995 *50-State Study* unless otherwise noted. The totals include an unknown, but small, percentage of UST and RCRA sites.

[b] "Sites Needing Attention" are those "Known and Suspected" sites that have been assessed and determined to require further assessment or cleanup. Many of these sites will require removal or remedial actions. Site numbers are derived from Table V-5 of the 1993 *50-State Study* and Table V-3 of the 1995 *50-State Study* unless otherwise noted. The totals include an unknown, but small, percentage of UST and RCRA sites.

[c] Because a number was not provided in Table V-5 of the 1993 *50-State Study*, information on non-NPL sites listed in EPA's CERCLA Information System (CERCLIS) provided in Chapter VI, "State Summaries" was used.

— Indicates that data were not provided.

Sources: U.S. EPA, Office of Emergency and Remedial Response, *An Analysis of State Superfund Programs: 50-State Study, 1993 Update*, EPA/540/R-94/008, December 1993.
U.S. EPA, Office of Emergency and Remedial Response, *An Analysis of State Superfund Programs: 50-State Study, 1995 Update*, EPA-540-R-96-036, July 1996.

The total number of sites determined to need further attention in 1995 was 28,997 (up from 19,266 in 1991 but down from 41,091 in 1993). The largest decreases in sites reported as needing further attention from 1993 to 1995 were in Michigan, which decreased by 7,000 sites; and New Jersey, which decreased by 6,000 sites. The total number of sites determined to need further attention includes an unknown—but small—percentage of RCRA and UST sites, which are addressed in Chapters 4 and 5 of this report. During collection of data from the states, authors of the *50-State Study* requested that the states exclude RCRA and UST sites from their reports, if they could. However, some states were unable to separate the RCRA and UST site data from other hazardous waste sites.

A central source of information that characterizes the types and quantities of contaminants found at state sites is not available. However, some states with established, well-funded programs are able to produce this type of information. For example, the California Department of Toxic Substances Control, within the state's Environmental Protection Agency, publishes a biennial report[6] that describes the Department's site mitigation and other environmental protection programs. The report includes a list of currently active sites, a list of certified remediated and delisted sites, and data on emergency response activities by county. The Department also maintains a database, called *CalSites*, that contains information on almost 10,000 potential and known sites. The Department provides access to *CalSites* through its headquarters and regional offices. Appendix E provides contacts for state environmental offices.

The types of contaminants present at some state sites can be inferred from sites listed in EPA's CERCLA Information System (CERCLIS), EPA's database of potentially contaminated sites. EPA has performed preliminary assessments at these sites to screen them for the federal NPL. The majority of these sites (those not listed on the NPL) are deferred to the states for action. CERCLIS data show that the most prevalent wastes at these sites are organic chemicals, metals, solvents, and oily waste.[7]

9.4 Estimated Cleanup Costs

This section describes the status of state cleanup funds and provides an estimate of recent annual expenditures and the total cost to complete the cleanup of all known state sites.

9.4.1 Status and Capacity of State Cleanup Funds

A fund is an essential element of a state's program to clean up sites. It allows a state to investigate, plan, design, and conduct emergency response and remedial actions at sites where immediate action is required or where RPs are unavailable, unable, or unwilling to conduct or pay for remedial actions. Fifty "states" have established cleanup funds or provided a mechanism for the state agency to pay for one or more types of cleanup activities at non-NPL sites. Nebraska and the District of Columbia are the only "states" without authorized cleanup funds.

The combination of fund balances, additions to funds, and expenditures can indicate the capability and stability of a state cleanup program. Exhibit 9-4 compares the fund balances, additions to funds, and expenditures of the states in 1991, 1993, and 1995.

Most of the state fund balances (including bonding authority) are concentrated in a relatively few states. In 1995, seven states (Alaska, California, Indiana, Michigan, New Jersey, New York, and Pennsylvania) accounted for $1.18 billion (80.8 percent) of the total fund balances for all states.

The annual contributions to state funds fluctuated sharply from 1991 to 1995. The states added $382 million to their cleanup funds during 1991, $957 million in 1993, and $445 million in 1995. As with fund balances, the amounts added to funds are concentrated in a relatively few states. Five states (Michigan, New Jersey, New York, Pennsylvania, and Washington) added $275.8 million (62 percent) of the total added to state funds in 1995.

Exhibit 9-4: Comparison of State Funds, Expenditures, and Sites 1991, 1993, and 1995 ($millions)

	1991	1993	1995
Total Fund Balances*	$2,218.5	$1,523.4	$1,464.9
Additions to Funds	$381.6	$957.3	$444.6
Expenditures/Obligations	$427.8	$1,170.9	$749.6
Number of Known and Suspected Sites	69,808	101,796	79,387
Number of Sites Needing Attention	19,266	41,091	28,997

* Fund balances include both money in the fund and authority to sell bonds to raise additional monies. The fund balances included the following amounts in the fund: $603.7 in 1991, $556.2 in 1993, and $609.0 in 1995. The rest of the fund balances were in bond authority.

Exhibit 9-5 presents the Superfund balances for each state as of December 1993 and 1995 and provides the total expenditures and obligations of funds by each state for hazardous waste activities in 1993 and 1995. The state fund balances totaled $1.46 billion in 1995, including bond authorizations (authority by state law to issue bonds and spend the proceeds on cleanups).

The states' experience with past cleanups indicates that the cost of a remedial action at a single site is likely to exceed $1 million.[2] While all but two states have some public funding capability, fund balances in some states are quite small or limited to emergency response or removal actions. At the end of 1995, eight of the 52 "states" did not have fund balances large enough to clean up at least one average-cost site (about $1 million) with fund monies (Alabama, District of Columbia, Kansas, Maryland, Nebraska, North Dakota, Rhode Island, and Wyoming). Another 14 states had balances between $1 million and $3 million. The remaining 30 of the 52 "states" had fund balances over $3 million. Although a state's fund balance indicates its ability to pay for a cleanup at any given time, this indication is only an approximation of cleanup activity in a state in a given year. The level of cleanup activity also depends on the rate that funds flow into and out of the fund, which differs from one state to another. Thus a state that rapidly replenishes its funds, for example by recovering cleanup costs from RPs, would have a high level of cleanup activity relative to the balance of the fund at any given time.

9.4.2 Annual and Projected Cleanup Costs

The estimate of the cost of cleanup for state and private party cleanups is based on the following assumptions:

- Non-NPL expenditures will average $203 million annually. This figure is the total 1995 non-NPL expenditures for 37 states that reported this item separately in the 1995 *50 State Study*.[2] This amount may be an underestimate of total national non-NPL expenditures, because it does not include 13 states for which data are not available. On the other hand these costs include some administrative and site investigation costs.

- Responsible party expenditures are estimated to be equal to state expenditures, based on the ASTSWMO study.[3] Based on cost data submitted for 3,395 CERCLIS sites during the period 1980-1992, RPs paid $555 million and the states paid $650 million to clean up these sites. Therefore, RP expenditures appear to be roughly equal to state expenditures at state sites. No centralized source of data is available that includes private party expenditures for cleanups through the states' voluntary cleanup or brownfields programs.

Exhibit 9-5: State Hazardous Waste Funds: 1993 and 1995 Expenditure/Obligations and Balances

	Expenditures & Obligations[a]		Fund Balances[b]	
States	1993	1995	1993	1995
Alabama	$80,230	$324,048	$379,690	$478,167
Alaska	$900,000	$16,500,000	$0	$73,356,000
Arizona	$7,272,900	$2,660,000	$3,743,000	$1,280,000
Arkansas	$1,459,951	$1,080,288	$6,202,997	$7,450,050
California	$88,600,000	$14,399,000	$26,908,000	$59,400,000
Colorado	$10,200,000	$12,800,000	$13,200,000	$16,200,000
Connecticut	$5,750,000	$18,000,000	$21,775,000	$10,575,000
Delaware	$4,890,000	$2,000,000	$4,000,000	$3,700,000
District of Columbia	$0	$0	$0	$0
Florida	—	$6,982,000	$8,363,000	$7,000,000
Georgia	$0	$7,438,889	$8,260,818	$13,029,281
Hawaii	$32,456	$1,700,000	$222,604	$3,000,000
Idaho	$1,009,625	$6,807	$3,139,032	$4,375,877
Illinois	$16,701,300	$4,474,000	$6,065,300	$6,400,000
Indiana	$11,691,535	$2,743,151	$14,907,856	$50,512,589
Iowa	$124,323	$40,000	$1,006,218	$1,300,000
Kansas	$1,864,000	$4,230,000	$1,868,000	$225,000
Kentucky	$1,785,000	$4,000,000	$5,000,000	$1,770,000
Louisiana	$2,867,909	$2,431,850	$3,056,023	$2,007,883
Maine	$11,703,000	$1,717,030	$5,700,000	$10,573,050
Maryland	—	—	$14,000,000	—
Massachusetts	$18,200,000	$20,027,186	$23,600,000	$2,513,036
Michigan	$60,456,000	$50,500,000	$18,200,000	$184,000,000
Minnesota	$8,451,000	$7,122,002	$5,252,000	$2,981,000
Mississippi	$440,000	$2,505,000	$2,700,000	$1,325,000
Missouri	$2,000,000	$2,800,000	$5,800,000	$5,300,000
Montana	$1,504,727	$2,780,258	$3,002,329	$1,451,893
Nebraska	$0	$0	$0	$0
Nevada	$250,000	$500,000	$6,000,000	$1,000,000
New Hampshire	$1,603,000	—	$3,000,000	$3,000,000
New Jersey	$313,100,000	$100,100,000	$161,500,000	$136,700,000
New Mexico	$350,841	$522,840	$103,634	$1,204,500
New York	$183,600,000	$252,900,000	$905,400,000	$599,100,000
North Carolina	$0	$4,784,196	$3,783,852	$7,800,000
North Dakota	$0	$0	$79,000	$129,000
Ohio	$21,723,044	$16,945,817	$34,680,714	$39,560,693
Oklahoma	$28,000	$696,230	$260,000	$2,096,005
Oregon	$18,746,169	$8,781,016	$5,476,340	$5,974,000
Pennsylvania	$34,401,000	$39,000,000	$60,500,000	$75,000,000

Exhibit 9-5: State Hazardous Waste Funds: 1993 and 1995 Expenditure/Obligations and Balances (continued)

States	Expenditures & Obligations[a] 1993	Expenditures & Obligations[a] 1995	Fund Balances[b] 1993	Fund Balances[b] 1995
Puerto Rico	$555,000	$986,717	$4,185,000	$2,482,111
Rhode Island	—	$2,377,000	$2,000,000	$2,655
South Carolina	$8,100,000	$1,504,045	$16,900,000	$18,635,064
South Dakota	$0	$61,885	$1,715,767	$1,750,000
Tennessee	$2,471,323	$3,154,805	$6,260,883	$8,036,052
Texas	$262,139,832	$28,615,006	$30,396,128	$47,361,124
Utah	$1,075,000	$5,288,000	$425,000	$5,100,000
Vermont	$3,387,596	$5,700,000	$1,544,426	$4,240,000
Virginia	$67,865	$73,926	$311,338	$2,575,861
Washington	$51,993,254	$72,960,209	$46,302,976	$28,536,973
West Virginia	$1,074,476	—	$2,200,000	$1,000,000
Wisconsin	$8,287,306	$15,350,000	$24,032,917	$3,472,400
Wyoming	—	—	$0	—
Totals	**$1,170,937,662**	**$749,563,201**	**$1,523,409,842**	**$1,464,960,264**

Notes:
[a] Includes funds expended and obligated by the states in 1993 and 1995 for NPL and non-NPL site cleanups.
[b] Includes unobligated funds and bonding authority for $967,200,000 available in four states (Massachusetts, Michigan, New York, and Wisconsin) for 1993 and unobligated funds and bonding authority in five states (California, Maine, Michigan, New York, and New Jersey) for 1995.
— Indicates that data were not provided.

Sources: U.S. EPA, Office of Emergency and Remedial Response, *An Analysis of State Superfund Programs: 50-State Study, 1993 Update*, EPA/540/R-94/008, December 1993.
U.S. EPA, Office of Emergency and Remedial Response, *An Analysis of State Superfund Programs: 50-State Study, 1995 Update*, EPA-540-R-96-036, July 1996.

- EPA assumes that it will take an average of 30 years for states to complete the cleanup of known sites (some states may take as many as 50 years, but 30 years is an approximate average of all states).

Thus, the total costs for both state and RPs is estimated to be $12.2 billion ($203 million X 2 X 30 years). As noted above, this amount does not include 13 states for which data are not available. On the other hand these costs include some administrative and site investigation costs. The states' annual expenditures and obligations for cleanup activities have fluctuated sharply from 1991 to 1995. The states expended or obligated a total of $428 million for cleanup activities in 1991, $1.17 billion in 1993, and $750 million in 1995. The four states that expended or obligated the most money in 1995 were Michigan, New Jersey, New York, and Washington, which accounted for $476.4 million (64 percent) of the total amount of money expended or obligated in 1995. Because the above expenditures and obligations data often combine expenditures and obligations on the one hand, and NPL and non-NPL site costs on the other, it is difficult to detail the trends in total non-NPL state and private party expenditures.

The states expended their funds for nine basic activities: emergency response, removals, site investigation, study and design, remedial actions, operation and maintenance, matching CERCLA funds to pay the state share for NPL sites, grants to cities and local governments, and victim compensation. The distribution of funds among these activities is unknown.

The states used RPs as the major funding source for site cleanups at 35,000 CERCLIS sites.[3] At these sites, RPs cleaned up 31 percent of the sites through enforcement actions and 55 percent through voluntary or property transfer actions.

9.5 Remedial Technologies

Based on state actions from 1980 to 1992 at 35,166 sites that had been listed on the CERCLIS database, the states selected the following as the predominant remedies: 1) containment, either on-site or off-site, at 76 percent of the sites; 2) treatment, either on-site or off-site, at 17 percent of the sites; 3) site security (*e.g.*, fences and warning signs) at 5 percent of the sites; 4) population protection at 2 percent of the sites; and 5) innovative technologies at less than one percent of the sites. This information is not broken out by year, so changes in technology use over time cannot be determined.[3] These data are somewhat dated, however, and the use of technology may have changed over the past five years, especially in light of the rapid development and acceptance of *in situ* technologies. The use of innovative technologies for underground storage tank sites, discussed in Section 5.6, has been growing rapidly, and this may be an indicator of current remedial approaches for state sites.

9.6 References

1. U.S. EPA, Office of Emergency and Remedial Response, *An Analysis of State Superfund Programs: 50-State Study, 1993 Update*, EPA/540/R-94/008, December 1993.

2. U.S. EPA, Office of Emergency and Remedial Response, *An Analysis of State Superfund Programs: 50-State Study, 1995 Update*, EPA-540-R-96-036, PB96-963249, July 1996.

3. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, and Association of State and Territorial Solid Waste Management Officials, *A Report on State/Territory Non-NPL Hazardous Waste Site Cleanup Efforts for the Period 1980-1992*, OSWER Pub. 9242.2-09, EPA/540/R-94/001, July 1994.

4. U.S. Environmental Protection Agency and Northeast-Midwest Institute, *Coming Clean for Economic Development*, December 1995.

5. U.S. General Accounting Office, *Community Development: Reuse of Urban Industrial Sites*, GAO Report #RCED-95-172, June 1995.

6. California Environmental Protection Agency, Department of Toxic Substances Control, *Biennial Report*, Sacramento, California, 1993-1994.

7. U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, *Superfund CERCLIS Characterization Project: National Results*, EPA/540/8-91/080, November 1991.

APPENDIX A

SUPPORTING DATA FOR

ANALYSIS OF NPL SITES

Exhibit A-1: Number of NPL Source Control RODs by Type

Fiscal Year	Source Control: Some Treatment (% of Source Control RODS)	Source Control: Containment or Disposal Only (% of Source Control RODS)	Source Control: Other Source Control	Source Control: Total Source Control	Other Remedies	Total RODs
1982	1 (25%)	3 (75%)	--	4	--	4
1983	0	7 (100%)	--	7	6	13
1984	5 (29%)	12 (71%)	0	17	21	38
1985	16 (28%)	34 (60%)	7	57	11	68
1986	27 (44%)	34 (56%)	0	61	24	85
1987	28 (50%)	28 (50%)	0	56	23	79
1988	72 (72%)	28 (28%)	0	100	52	152
1989	76 (74%)	29 (28%)	0	105	41	146
1990	88 (70%)	35 (28%)	2	125	45	170
1991	105 (74%)	34 (24%)	2	141	57	198
1992	86 (72%)	26 (22%)	7	119	54	173
1993	84 (71%)	31 (26%)	4	119	71	190
1994	58 (59%)	35 (36%)	5	98	67	165
1995	62 (53%)	48 (41%)	7	117	71	188
Totals	708 (63%)	384 (34%)	34	1,126	543	1,669

Notes:
- RODs denote Records of Decision.
- "Other Source Control" includes RODs calling for only institutional controls, monitoring, and relocation remedies.
- "Other Remedies" include RODs calling for "groundwater only" remedies and "no action."
- Numbers in italics are preliminary.

Exhibit A-2: Representative Hazardous Chemicals by Contaminant Group

The hazardous chemicals listed below are representative of those found at National Priorities List (NPL) sites. The list is developed from site assessment information for NPL sites without Records of Decision (RODs), based on the *Test Methods for Evaluating Solid Waste, Volume 1A: Laboratory Manual, Physical/Chemical Methods*, Third Edition, Proposal Update II, PB94-170321, November 1992. These chemicals represent many, but not all, of the contaminants found at NPL sites.

Volatile Organic Compounds (VOCs)	
1,1,1-Trichloroethane	Dibromochloromethane
1,1,2,2-Tetrachloroethane	Dibromochloropropane (DBCP)
1,1,2-Trichloroethane	Dibromomethane
1,1-Dichloroethane	Dichlorodifluoromethane
1,1-Dichloroethene	Dichloroethylene
1,1-Dichloropropylene	Dichloromethane
1,2,3-Trichloropropane	Dichlorpropene
1,2-Dichloroethane	Ethyl Ether
1,2-Dichloroethene	Ethyl Methacrylate
1,2-Dichloropropane	Ethylbenzene
1,2-Transdichloroethene	Iodomethane
1,3-Dichloropropane	Isopropanol
1,3-Trichloropropene	M-PSA
1,4-Dichloro-2-butene	M-Xylene
2-Butanone (MEK)	Methane
2-Chloroethyl Vinyl Ether	Methanethiol
2-Chloropropane	Methylene
2-Hexanone	Methylene Chloride
3-Hexanone	O-Xylene
4-Methyl-2-pentanone	P-PSA
Acetone	P-Xylene
Acrolein	Polyvinyl Chloride
Acrylonitrile	Styrene
Benzene	Tetrachloroethene
Bromodichloromethane	Tetrachloroethylene
Bromodichloroethane	Tetrahydrofuran
Bromoform	Toluene
Bromomethane	Total Xylenes
Carbon Disulfide	Trans-1, 2-dichloroethene
Carbon Tetrachloride	Trans-1,3-dichloropropene
Chlorobenzene	Trichloroethene
Chloroethane	Trichlorofluoromethane
Chloroform	Vinyl Acetate
Chloromethane	Vinyl Chloride
Cis-1,2-Dichloroethane	Vinylidene Chloride
Cis-1,2-Dichloroethylene	Volatile Organics
Cis-1,3-Dichloropropene	

Exhibit A-2: Representative Hazardous Chemicals by Contaminant Group (Continued)

Semivolatile Organic Compounds (SVOCs)	
(Lindane) Gamma-BHC	Acenaphthene
1,2,3-Trichlorobenzene	Acenaphthylene
1,2,4,5-Tetrachlorobenzene	Acetophenone
1,2,4-Trichlorobenzene	Aldrin
1,2-Dichlorobenzene	Alpha-BHC
1,2-Diphenylhydrazine	Amiben
1,3-Dichlorobenzene	Aniline
1,4-Dichlorobenzene	Anthracene
1-Chloroaniline	Benzidine
1-Naphthylamine	Benzo(a)anthracene
2,2-Dichlorobenzidine	Benzo(a)pyrene
2,3,4,5-Tetrachlorophenol	Benzo(b)fluorathene
2,4,5-Trichlorophenol	Benzo (ghi)perylene
2,4,6-Trichlorophenol	Benzo(k)flouranthene
2,4-Dichlorophenol	Benzo(j)flourathene
2,4-Dichlorotoluene	Benzo(k)pyrene
2,4-Dimethylphenol	Benzoic Acid
2,4-Dinitrophenol	Benzothiazole
2,4-Dinitrotoluene	Benzyl Alcohol
2,6-Dichlorophenol	Bis(2-chloroethoxy)methane
2,6-Dinitrotoluene	Bis(2-chloroethyl)ether
2-Chloronaphthalene	Bis(ethylhexyl)phthalate
2-Chlorophenol	Bis-2-chloroethoxyphthalate
2-Mercaptan-Benzothiazole	Butyl Benzyl Phthalate
2-Methyl-4,6-Dinitrophenol	Chlordane
2-Methylnaphthalene	Chrysene
2-Methylphenol	Cresote
2-Napthylamine	Delta-BHC
2-Nitroaniline	DHD
2-Nitrophenol	Di-n-octyl Phthalate
2-Picoline	Dibenzo(a,h)anthracene
3-Methylcholanthrene	Dibenzofuran
3-Methylphenol	Dibutyl Phthalate
3-Nitroaniline	Dimethyl Phthalate
4,4-DDD	Dinitrophenol
4,4-DDE	Dinoseb
4,4-DDT	Diphenylamine
4,6-Dinitro-o-cresol	DNB
4-Aminobiphenyl	Endosulfan I
4-Bromophenyl Phenyl Ether	Endosulfan II
4-Chloro-3-methylphenol	Endosulfan Sulfate
4-Chloroaniline	Endrin
4-Chlorophenyl Phenyl Ether	Endrin Aldehyde
4-Methylphenol	EPTC
4-Nitroaniline	Ethyl Methanesulfonate
4-Nitrophenol	Ethylamylketone (EAK)
7,12-Dimethylbenz(a)anthracene	Ethylene Dibromide
A,A-Dimethyl-b-phenylethlamine	Fluoranethene
Acenanthrene	Fluorene

Exhibit A-2: Representative Hazardous Chemicals by Contaminant Group (Continued)

Semivolatile Organic Compounds (SVOCs) (Continued)	
Heptachlor	Parathion
Heptachlorepoxide	PCB
Herbicides	Pentachlorobenzene
Hexachlorobenzene	Pentachloronitrobenzene
Hexachlorobutadiene	Pentachlorophenol
Hexachlorocyclohexan	Pesticides
Hexachlorocyclopentadiene	Phenacetin
Hexachloroethane	Phenanthrene
Hexadecanoic Acid	Phenol
Indeno(1,2,3-cd)pyrene	Phenothiazine
Isophorone	Polynuclear Aromatic Hydrocarbons
Kepone	Pronamid
Malathion	Pyrene
Methoxychlor	P-Dimethylaminoazobenzene
Methyl Ethyl Benzene	Resorcinol
Methylmethanesulfonate	Shell Sol 140
N-Methylpyrrolidene	TDX
N-Nitroso-di-n-butylamine	Tertbutylmethylether
N-Nitrosodimethylamine	Tetrahydrofuran
N-Nitrosopiperidine	TNB 1,3,5-Trinitrobenzene
Naphthalene	Toxaphene
Nitrobenzene	Vernolate
Oxazolidone	

Metals	
Aluminum	Molybdenum
Antimony	Nickel
Arsenic	Plutonium
Barium	Potassium
Beryllium	Radium
Boron	Selenium
Cadmium	Silicon
Calcium	Silver
Cesium	Sodium
Chrome	Strontium
Chromite	Technetium
Chromium	Thallium
Cobalt	Thorium
Copper	Tin
Iron	Titanium
Lead	Tritium
Magnesium	Uranium
Manganese	Vanadium
Mercury	Zinc
Metals	Zirconium

Exhibit A-3: Distribution of Quantities of Contaminated Soil, Sediment, and Sludge at NPL Sites With RODs

Quantity Estimate (Cubic Yards)	Number of NPL Sites with Data By Matrix					
	Soil		Sediment		Sludge	
	Federal Facilities	Non-Fed. Facilities	Federal Facilities	Non-Fed. Facilities	Federal Facilities	Non-Fed. Facilities
<1,000	3	47	0	16	0	6
1,000 - 5,000	6	65	1	16	0	7
5,001 - 10,000	6	46	1	10	0	4
10,001 - 30,000	7	83	1	8	0	8
30,001 - 50,000	5	42	1	8	1	10
50,001 - 100,000	1	32	0	5	0	7
>100,000	6	55	1	6	2	6
Total Number of Sites	34	370	5	69	3	48

Note: Data are derived from 510 Records of Decision (RODs) for 430 sites with data.

Source: U.S. EPA, Office of Emergency and Remedial Response, ROD Information Directory, December 1995.

Exhibit A-4: Estimated Quantity of Contaminated Soil, Sediment, and Sludge for Major Contaminant Groups at Non-Federal NPL Sites with Planned Remedial Actions

(1) Contaminant Subgroup	(2) Number of NPL Sites With Available Data[a]	(3) Average Based on Available Data (Cubic Yards)[a]	(4) Numbers of NPL Sites With Planned Remedial Action[b]	(5) Projected Total Quantity (Cubic Yards)[c]
Single:				
Metals	68	93,000	49	4,557,000
VOCs	35	19,000	60	1,140,000
SVOCs	77	23,000	26	598,000
Others	14	71,000	53	3,763,000
Double:				
VOCs & Metals	49	56,000	54	3,024,000
SVOCs & Metals	16	40,000	29	1,160,000
VOCs & SVOCs	32	69,000	52	3,588,000
VOCs, SVOCs, & Metals	129	68,000	224	15,232,000
TOTALS	420		547	33,062,000

Notes:
[a] Source of quantity data is U.S. EPA, RODs, fiscal years 1982-1994. Statistical outliers are not included. Site-specific data are not available for quantities of material to be remediated at all sites with planned remedial actions; these values are derived from estimates contained in the RODs for 420 sites containing similar contaminants.
[b] Based on the distribution of contaminant groups among the 944 sites with ROD data shown in Exhibit 3-4. Each site is placed in one subgroup only.
[c] The total for each subgroup is calculated by multiplying columns (3) and (4). Projected quantities are rounded.

APPENDIX B

SUPPORTING DATA FOR ANALYSIS OF UNDERGROUND STORAGE TANK SITES

Exhibit B-1: Location of Registered USTs in the United States

Region	State	Number of Active Tanks	Number of Closed Tanks	Number of Confirmed Releases	Cleanups Initiated or Completed
One	CT	21,539	16,481	1,564	2,509
	MA	20,451	15,602	4,517	6,177
	ME	12,390	7,940	1,415	2,755
	NH	5,913	10,823	1,589	2,285
	RI	6,659	7,791	859	1,412
	VT	3,058	3,566	1,374	2,056
	Subtotal	70,010	62,203	11,318	17,194
Two	NJ	29,029	34,671	6,136	8,332
	NY	44,730	44,612	13,114	21,031
	PR	7,855	2,481	464	509
	VI	305	72	21	28
	Subtotal	81,919	81,836	19,735	29,900
Three	DC	1,045	2,503	736	1,160
	DE	2,578	5,024	2,271	3,473
	MD	17,940	15,687	12,831	16,565
	PA	41,305	35,444	7,286	7,980
	VA	40,309	29,442	7,775	13,943
	WV	8,530	13,926	1,945	2,144
	Subtotal	111,707	102,026	32,844	45,265
Four	AL	21,968	20,287	8,292	13,005
	FL	41,984	74,059	25,746	7,848
	GA	49,380	15,770	6,520	8,000
	KY	20,280	19,759	6,354	11,661
	MS	11,420	17,172	4,546	8,621
	NC	42,505	52,804	18,696	29,959
	SC	18,897	22,236	4,311	2,998
	TN	27,527	25,668	8,567	14,768
	Subtotal	233,961	247,755	83,032	96,860
Five	IL	48,407	25,757	14,073	18,222
	IN	20,131	28,269	5,151	5,354
	MI	33,880	47,451	14,456	19,166
	MN	20,712	16,989	5,925	9,164
	OH	31,760	26,510	7,488	16,228
	WI	25,724	48,311	13,742	19,668
	Subtotal	180,614	193,287	60,835	87,802

Exhibit B-1: Location of Registered USTs in the United States (continued)

Region	State	Number of Active Tanks	Number of Closed Tanks	Number of Confirmed Releases	Cleanups Initiated or Completed
Six	AR	20,796	4,923	599	873
	LA	23,207	16,665	2,301	2,651
	NM	5,187	6,562	1,822	2,256
	OK	16,460	16,217	3,021	4,330
	TX	81,239	74,787	19,556	20,446
	Subtotal	146,889	119,154	27,299	30,556
Seven	IA	10,715	18,700	5,038	4,829
	KS	10,302	15,497	4,232	5,205
	MO	20,271	20,799	4,288	6,884
	NE	9,545	9,065	3,868	2,781
	Subtotal	50,833	64,061	17,426	19,699
Eight	CO	11,933	12,916	3,215	4,921
	MT	5,715	8,911	2,839	4,402
	ND	3,539	5,282	721	1,100
	SD	3,846	4,136	1,703	2,563
	UT	5,186	9,755	2,798	4,321
	WY	2,570	6,552	1,739	1,049
	Subtotal	32,789	47,552	13,015	18,356
Nine	AZ	9,489	15,488	6,157	5,991
	CA	97,623	70,886	29,824	34,370
	HI	4,053	2,917	916	816
	NV	5,836	5,963	1,839	3,136
	CQ	78	9	6	4
	GU	577	226	93	204
	SA	46	11	1	1
	Subtotal	117,702	95,500	38,836	44,522
Ten	AK	2,665	4,551	1,302	1,698
	ID	5,295	6,779	1,019	1,619
	OR	10,990	19,387	5,100	4,885
	WA	14,750	27,226	4,789	6,012
	Subtotal	33,700	57,943	12,210	14,214
Indian Lands	Subtotal	4,354	2,705	938	930
Nation-Wide	TOTAL	1,064,478	1,074,022	317,488	405,298

Source: U.S. EPA, Office of Underground Storage Tanks, Semi-Annual Activity Report, Second Half (September 30) FY 1996.

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APPENDIX C

SUPPORTING DATA FOR

ANALYSIS OF DOD SITES

Exhibit C-1: Location of DOD Sites Needing Cleanup

EPA Region	State	DOD Installations	DOD Sites	Army Sites	Navy Sites	AF Sites	DLA Sites	FUDS Sites
One	CT	7	36	3	30	2	0	1
	MA	51	158	56	14	47	0	41
	ME	25	69	0	22	22	0	25
	NH	6	18	0	0	14	0	4
	RI	15	50	3	31	0	0	16
	VT	1	1	0	0	0	0	1
	Subtotal	105	332	62	97	85	0	88
Two	NJ	34	117	44	35	8	0	30
	NY	97	269	76	8	78	0	107
	PR	13	40	0	27	1	0	12
	VI	0	0	0	0	0	0	0
	Subtotal	144	426	120	70	87	0	149
Three	DC	9	27	0	18	6	0	3
	DE	8	30	0	0	19	0	11
	MD	33	434	270	127	20	1	16
	PA	44	183	75	38	7	41	22
	VA	35	306	77	185	22	9	13
	WV	7	31	1	12	6	0	12
	Subtotal	136	1,011	423	380	80	51	77
Four	AL	17	205	166	0	28	0	11
	FL	75	390	0	211	112	0	67
	GA	23	221	149	26	36	0	10
	KY	7	66	62	2	1	0	1
	MS	26	56	0	14	19	0	23
	NC	18	175	24	121	17	0	13
	SC	21	247	29	152	55	0	11
	TN	13	175	37	57	13	65	3
	Subtotal	200	1,535	467	583	281	65	139
Five	IL	36	196	116	34	19	0	27
	IN	10	89	42	32	10	0	5
	MI	36	118	35	0	56	0	27
	MN	10	29	15	5	5	0	4
	OH	27	107	1	0	69	12	25
	WI	15	36	10	0	16	0	10
	Subtotal	134	575	219	71	175	12	98

Exhibit C-1: Location of DOD Sites Needing Cleanup (continued)

EPA Region	State	DOD Installations	DOD Sites	Army Sites	Navy Sites	AF Sites	DLA Sites	FUDS Sites
Six	AR	8	27	8	0	14	0	5
	LA	10	40	16	12	8	0	4
	NM	57	104	27	0	17	0	60
	OK	25	75	19	0	35	0	21
	TX	81	344	108	83	82	0	71
	Subtotal	181	590	178	95	156	0	161
Seven	IA	8	49	39	0	4	0	6
	KS	53	176	105	0	9	0	62
	MO	21	72	44	0	8	0	20
	NE	29	100	64	2	6	0	28
	Subtotal	111	397	252	2	27	0	116
Eight	CO	14	285	216	0	62	0	7
	MT	10	20	0	0	12	0	8
	ND	4	10	5	0	4	0	1
	SD	16	33	0	0	19	0	14
	UT	11	277	230	0	37	0	10
	WY	5	16	0	0	12	0	4
	Subtotal	60	641	451	0	146	0	44
Nine	AZ	37	172	99	10	34	0	29
	CA	220	1,851	103	916	612	64	156
	HI	50	133	15	46	43	0	29
	NV	20	56	29	2	8	0	17
	PI[a]	10[a]	19[a]	0	0	9	0	10
	GU	9	90	0	51	37	0	2
	SA	0	0	0	0	0	0	0
	Subtotal	346	2,321	246	1,025	743	64	243
Ten	AK	95	416	48	89	214	0	65
	ID	4	4	0	1	0	0	3
	OR	17	32	2	0	13	0	17
	WA	28	56	10	24	13	0	9
	Subtotal	144	508	60	114	240	0	94
Nation-Wide	TOTAL	1,561	8,336	2,478	2,437	2,020	192	1,209

Notes: PI = Pacific Islands: Johnston Atoll, Mariana Island, Midway, Palau, and Wake Island.

Source: DOD, Office of the Deputy Under Secretary (Environmental Security), Restoration Management Information System, November, 1995. Data as of September 1995.

Exhibit C-2: Definitions of DOD Site Types

Site Type	Site Description	Primary Contaminants
Underground Storage Tank	Underground storage tank sites result from the release of substances from underground storage tanks and any associated piping.	• POLs • POL sludges • Solvents • Metals
Spill Area	Spill areas are small areas where spills from drums, tanks, and other waste units have taken place.	• POLs • PCBs • Solvents • POL sludge • Metals
Landfill	Landfill sites are typically areas formerly used to dispose of both domestic and industrial hazardous waste.	• POLs • Solvents • Paint • Pesticides • Metals • Ord. compounds
Unexploded Munitions/Ordnance Area	Unexploded munitions and ordnance areas are areas that have been used for munitions and ordnance training.	• UXO • Metals • Explosive chemicals • Ord. compounds
Surface Disposal Area	Surface disposal area sites consist of small areas formerly used for disposal of solid wastes with little or no free liquids. Typical materials include rags, filters, paint cans, small capacitors, and batteries.	• POLs • Solvents • Paints • Pesticides • Metals • Acids • PCBs
Disposal Pit/Dry Well	Disposal pit/dry well sites consist of small unlined excavations and structures that were used over a period of time to dispose of small quantities of liquid wastes.	• POLs (for example, motor oil) • Acids (for example, battery acid) • Ordnance compounds • Explosive chemicals • Metals • Solvents
Storage Area	Storage areas are areas where spills and leaks occurred from stored containers or equipment.	• POLs • Solvents • POL sludge • Metals • Acid • PCBs
Contaminated Groundwater	Contaminated groundwater results from various types of releases of known or unknown origin, such as migration of leachate from disposal areas and migration of substances from contaminated surface and subsurface soils.	• Metals • POLs • Chlorinated solvents • Explosive chemicals • Non-chlorinated solvents

Exhibit C-2: Definitions of DOD Site Types

Site Type	Site Description	Primary Contaminants
Fire/Crash Training Area	Fire and crash rescue training areas consist of trenches and/or pits where flammable materials were ignited periodically for demonstrations and training exercises.	• POLs • Solvents • POL sludges • Metals
Building Demolition/ Debris Removal	Building demolition and debris removal sites consist of buildings and/or debris that are unsafe or must be removed.	• Asbestos • Construction debris • Lead paint
Surface Impoundment/ Lagoon	Surface impoundments and lagoons consist of unlined depressions, excavations, or diked areas which were used to accumulate liquid waste, waste containing free liquid, or industrial wastewaters.	• POLs • Solvents • Explosive chemicals • Industrial wastewater • Metals • Ord. compounds
Aboveground Storage Tanks	Aboveground storage tank sites result from release of substances to surrounding areas from above ground tanks, containers, and any associated piping.	• POLs (for example, heating oil, jet fuel, gasoline, and POL sludges)
Contaminated Fill	Contaminated fill areas consist of contaminated material resulting from excavations for construction, tanks, and other purposes.	• POLs • Metals • Ordnance compounds • Explosive chem. • Paint waste
Contaminated Building	Contaminated building sites result from releases within or on the outside of a structure of a substance that has been contained within the building.	• POL • Plating waste • Metals • POL sludge • Polychlorinated biphenyls (PCBs) • Asbestos • Propellants • Pesticides • Solvents • Acids
Burn Area	Burn area sites consist of pits or surface areas that were used for open-air incineration of waste.	• POLs (*e.g.*, spent motor oil, jet fuel) • Solvents (*e.g.*, spent paint thinners and degreasing agents) • Explosives • Propellants • Ordnance
Contaminated Sediments	Contaminated sediments include sediments of bodies of water that have been contaminated by surface runoff, subsurface migration, or direct discharge of contaminants.	• POLs • PCBs • Pesticides • Metals • Solvents • Explosive chem.

Exhibit C-2: Definitions of DOD Site Types (continued)

Site Type	Site Description	Primary Contaminants
Explosive/Ordnance Disposal Area	Explosive ordnance disposal areas consist of open-air areas that were used to detonate, demilitarize, bury, or dispose of explosives.	• Unexploded ordnance (UXO) • Metals • Ordnance compounds • Explosive chemicals
Waste Line	Waste lines are underground piping used to carry industrial wastes from shop facilities to a wastewater treatment plant.	• Solvents • Metals • Plating sludges • Pesticides • Explosive chemicals
Waste Treatment Plant	Wastewater treatment plant sites result from releases of substances at plants that were used to treat and dispose of domestic and/or industrial wastewater.	• POLs • Industrial wastewater • Solvents • Plating sludges • Explosive chemicals
Sewage Treatment Plant	Sewage treatment plants typically consist of a complex of tanks, piping, and sludge management areas used to treat sanitary sewage generated at an installation. The unit may use chemical or biological treatment methods. Lagoons associated with the biological treatment of sewage currently may be considered to be separate units.	• Metals • Industrial wastewater • Solvents • POLs
Petroleum, Oil, Lubricant (POL) Distribution Line	Petroleum, oil, lubricant distribution lines are used to transport POL products from storage to dispensing facilities.	• POLs (for example, heating oil, gasoline, Jet A, diesel, and other fuels) • POL sludge
Underground Storage Tank Farm	Underground storage tank farm sites result from the release of substances from multiple, typically large, underground storage tanks and associated piping which make up a tank farm complex.	• POLs • Solvents • POL sludges • Metals
Firing Range	Firing ranges consist of large areas of land used for practice firing of large artillery or mortars, or as a practice bombing range for aircraft. These areas are typically contaminated with unexploded ordnance, which may be found both on and below the ground surface.	• Metals • UXO • Ord. compounds • Explosives • Radionuclides
Soil Contaminated After Tank Removal	This unit consists of soil that has been removed during a tank removal operation and staged prior to treatment.	• POLs • POL sludge

Exhibit C-2: Definitions of DOD Site Types

Site Type	Site Description	Primary Contaminants
Storm Drain	Storm drains typically consist of a natural or man-made drain used as a runoff control structure for rainfall. The unit also may be used from runoff from other sources such as process operations. Man-made units may be concrete lined.	• POLs • Metals • POL sludge • Pesticides • Industrial wastewater • Solvents
Oil/Water Separator	Oil/water separators are typically small units that skim oil from storm water runoff. The oil/water separator consists of the unit, and any associated piping.	• POLs • Solvents • Industrial wastewater • PCBs
Maintenance Yard	Maintenance yards consist of paved or unpaved areas where vehicles and other maintenance equipment is stored and often serviced. Typically, maintenance supplies are stored at these units.	• POLs • Metals • Solvents
Low-level Radioactive Waste Area	Low-level radioactive waste areas consist of areas used to store or dispose of low-level radioactive materials of various types (for example, radium paint, and radioactive instruments and propellants).	• Low-level radioactive waste
Washrack	Washrack sites typically consist of a building designed for washing vehicles such as tanks, aircraft, and other military vehicles. This unit also may consist of a paved area where washing of vehicles occurs.	• POLs
Drainage Ditch	Drainage units typically consist of a natural or a man-made ditch used as a runoff control structure for rainfall. The unit also may be used for runoff from other sources such as process operations. Man-made units may be concrete lined.	• POLs • Explosive chemicals • Solvents • PCBs • Metals
Small Arms Range	Small arms ranges are typically located outdoors and used for target practice of small arms, usually 50 caliber or less. The unit may include a soil or sandbag berm, or hill located behind the targets to prevent bullets from travelling outside the range area.	• Metals • Ordnance compounds
Incinerator	Incinerators typically consist of a furnace and stack unit used for a variety of disposal activities including the incineration of medical waste, or an installation's dunnage. These units vary in size and may either be freestanding or part of other operations such as hospitals.	• Ash • Metals • Ordnance compounds

Exhibit C-2: Definitions of DOD Site Types (continued)

Site Type	Site Description	Primary Contaminants
Contaminated Soil Piles	This unit consists of soil that has been staged after an excavation activity.	• POLs • Sludge • Metals • Solvents • PCBs • Ordnance compounds
Mixed Waste Area	Mixed waste areas consist of areas used to store or dispose of hazardous wastes that have been mixed with or contaminated by radioisotopes.	• Solvents • Mixed waste
Pistol Range	Pistol ranges may be located indoors or outdoors and are used for target practice. Outdoor units include a soil or sandbag berm located behind the targets to prevent bullets from travelling outside the range area.	• Metals
Chemical Disposal	Chemical disposal units are areas that have been used for the disposal of chemicals, typically of an unknown type. The unit may be a burial area where bottles or packages of chemicals were placed or an area where liquids were disposed of on the soil.	• POLs • Metals • Solvents • Explosive chemicals
Pesticide Shop	Pesticide shops typically are used to store and prepare large volumes of pesticides and solvents for maintenance activities. The units may be located in a freestanding building or attached to another building. Areas near the unit may have been used for the disposal of off-specification pesticides.	• Pesticides • Metals • POLs
Industrial Discharge	Industrial discharge units consist of a pipe system used to discharge industrial effluent to the environment. The unit may discharge to a natural or man-made water body, dry creek bed or some other natural feature.	• Metals • Industrial wastewater
Surface Runoff	Surface runoff is an area with runoff from rain which may occur anywhere within a facility, particularly adjacent to industrial areas and airfield aprons.	• POLs • Metals • Solvents • Explosive chemicals
Leach Field	Leach fields typically consist of a subsurface area generally associated with septic tanks. The unit serves the purpose of biologically treating sanitary sewage, however, in cases where these units were used at industrial facilities, there also is contamination from non-biodegradable industrial contaminants.	• Metals • Solvents

Exhibit C-2: Definitions of DOD Site Types (continued)

Site Type	Site Description	Primary Contaminants
Plating Shop	Plating shops typically consist of a building or room within a building used for coating metal parts. The unit contains several tanks of solvents which are used in the plating process.	• Metals • Solvents • Acids • Industrial wastewater
Sewage Effluent Settling Pond	Sewage effluent settling ponds consist of a lagoon used for the settling of solids and/or biological treatment of sewage. The units also may be used as infiltration galleries.	• Metals • Ordnance compounds • Solvents
Dip Tank	Dip tanks are typically metal or concrete units located in coating shops that range in size from 50 to more than 500 gallons. The tanks are used to clean parts prior to treatment, or to coat parts with various materials including metals and plastics.	• POLs • Chlorinated solvents • Metals • Acids
Optical Shop	Optical shops typically consist of laboratory units located within a building. Activities include grinding lenses used in eye glasses or other optical instruments.	• Solvents

Notes: POL = Petroleum, oil, and lubricants; PCB = Polychlorinated Biphenyls; Ord. = Ordnance

Source: DOD, Office of the Deputy Under Secretary of Defense (Environmental Security), Defense Environmental Restoration Program Annual Report to Congress, for Fiscal Year 1995, Spring 1996.

Exhibit C-3: DOD Sites Needing Cleanup by Site Type

Site Type	Army	Navy	AF	DLA	FUDS	Total
Underground Storage Tanks	241	408	352	11	187	1,199
Spill Area	199	190	619	11	10	1,029
Landfill	353	255	293	5	34	940
Unexploded Munitions/Ordnance Area	53	28	17	0	398	496
Surface Disposal Area	161	356	155	3	25	700
Disposal Pit/Dry Well	185	76	201	39	34	535
Storage Area	201	298	25	32	13	569
Contaminated Groundwater	88	42	8	5	68	211
Fire/Crash Training Area	45	83	96	3	3	230
Building Demolition/Debris Removal	7	8	0	0	103	118
Surface Impoundment/Lagoon	138	63	5	9	8	223
Aboveground Storage Tanks	47	67	17	4	25	160
Contaminated Fill	27	12	5	10	63	117
Contaminated Building	114	35	1	14	7	171
Burn Area	102	40	4	7	4	157
Contaminated Sediments	53	66	10	0	15	144
Explosive/Ordnance Disposal Area	65	28	0	0	24	117
Waste Line	30	49	16	2	1	98
Waste Treatment Plant	41	26	13	0	1	81
Sewage Treatment Plant	13	0	64	1	3	81
Petroleum, Oil, Lubricant Distribution Line	12	41	18	2	2	75
Underground Storage Tank Farm	22	52	1	0	2	77
Firing Range	16	5	0	0	28	49
Soil Contaminated After Tank Removal	19	5	0	15	25	64
Storm Drain	6	7	21	3	0	37
Oil/Water Separator	28	28	6	1	0	63
Maintenance Yard	20	38	0	1	0	59
Low-level Radioactive Waste Area	4	3	12	0	2	21
Washrack	19	4	0	0	0	23
Drainage Ditch	21	15	0	2	0	38
Small Arms Range	7	3	0	0	8	18
Incinerator	21	5	0	0	0	26
Contaminated Soil Pipes	12	7	0	1	2	22

Exhibit C-3: DOD Site Types Needing Cleanup (continued)

Site Type	Army	Navy	AF	DLA	FUDS	Total
Mixed Waste Area	1	15	0	0	1	17
Pistol Range	5	7	0	2	0	14
Chemical Disposal	24	2	0	0	5	31
Pesticide Shop	8	9	0	4	0	21
Industrial Discharge	33	7	0	0	0	40
Surface Runoff	6	7	0	0	0	13
Leach Field	11	2	0	0	0	13
Plating Shop	0	9	0	0	0	9
Sewage Effluent Settling Pond	4	2	0	0	0	6
Dip Tank	1	4	0	1	0	6
Optical Shop	1	1	1	0	0	3
Other	14	29	60	4	108	215
Total	2,478	2,437	2,020	192	1,209	8,336

Source: DOD, Office of the Deputy Under Secretary of Defense (Environmental Security), Restoration Management Information System, 1996. Data as of September 1995.

Exhibit C-4: Frequency of Matrices by DOD Site Type

Site Type	No. of Sites with Data	Ground-water	Soil	Surface water	Sediment
Underground Storage Tanks	444	334	259	16	4
Spill Area	539	384	354	101	28
Landfill	491	386	305	172	38
Unexploded Munitions/Ordnance Area	14	6	11	4	1
Surface Disposal Area	347	228	251	85	17
Disposal Pit/Dry Well	334	276	253	63	27
Storage Area	181	92	152	25	10
Contaminated Groundwater	86	83	28	11	6
Fire/Crash Training Area	157	126	121	27	8
Building Demolition/Debris Removal	6	0	6	0	0
Surface Impoundment/Lagoon	93	60	56	32	15
Aboveground Storage Tanks	40	27	30	4	1
Contaminated Fill	37	22	31	8	2
Contaminated Building	37	14	32	3	8
Burn Area	78	50	53	13	9
Contaminated Sediments	49	23	33	17	9
Explosive/Ordnance Disposal Area	48	33	32	7	1
Waste Line	41	24	25	5	2
Waste Treatment Plant	25	15	15	8	2
Sewage Treatment Plant	0	0	0	0	0
Petroleum, Oil, Lubricant Distribution Line	36	29	21	2	0
Underground Storage Tank Farm	38	33	19	2	0
Other	8	7	8	0	0
Firing Range	2	2	1	1	0
Soil Contaminated After Tank Removal	10	6	7	1	0
Storm Drain	3	3	1	0	0
Oil/Water Separator	10	5	8	1	1
Maintenance Yard	0	0	0	0	0
Low-level Radioactive Waste Area	12	3	10	0	0
Washrack	9	1	8	0	0
Drainage Ditch	6	5	6	4	0
Small Arms Range	2	0	2	0	0
Incinerator	1	0	1	0	0
Contaminated Soil Piles	5	4	4	0	0

Exhibit C-4: Frequency of Matrices by DOD Site Type (continued)

Site Type	No. of Sites with Data	Ground-water	Soil	Surface water	Sediment
Mixed Waste Area	7	3	6	0	0
Pistol Range	4	2	4	0	0
Chemical Disposal	0	0	0	0	0
Pesticide Shop	3	1	3	0	0
Industrial Discharge	4	2	3	0	0
Surface Runoff	2	0	2	0	0
Leach Field	1	1	0	1	0
Plating Shop	1	0	1	0	0
Sewage Effluent Settling Pond	0	0	0	0	0
Dip Tank	1	0	1	0	0
Optical Shop	0	0	0	0	0
Other	8	7	8	0	0
Total	3,212	2,290	2,163	613	189

Note: The total count for a site type may exceed the number of sites with data for the site type, because a site may have more than one contaminated matrix.

Source: DOD, Office of the Deputy Under Secretary of Defense (Environmental Security), Restoration Management Information System, November 1995. Data as of September 1994.

Exhibit C-5: Frequency of Major Contaminant Groups by Matrix and DOD Component

DOD Component Contaminant Group	Ground-water	Soil	Surface water	Sediment	Total (All Media)
Army					
VOCs	289	59	24	5	326 (41%)
SVOCs	90	97	23	24	193 (24%)
Metals	231	343	103	69	527 (66%)
Other	209	177	42	25	341 (43%)
Fuels	25	23	0	0	40 (5%)
Explosives	114	125	49	2	185 (23%)
VOCs & SVOCs	11	8	7	2	13 (2%)
VOCs & Metals	18	12	6	2	24 (3%)
SVOCs & Metals	8	6	5	4	10 (1%)
VOCs, SVOCs, & Metals	6	5	4	2	7 (1%)
No. of Sites with Data	534	485	137	87	794
Navy					
VOCs	515	310	75	4	637 (70%)
SVOCs	317	428	61	14	573 (63%)
Metals	470	492	149	23	692 (76%)
Other	188	359	67	15	452 (49%)
Fuels	220	113	10	1	288 (31%)
Explosives	41	38	6	0	56 (6%)
VOCs & SVOCs	91	107	16	6	122 (13%)
VOCs & Metals	110	107	18	6	131 (14%)
SVOCs & Metals	97	126	21	8	144 (16%)
VOCs, SVOCs, & Metals	85	83	16	8	97 (11%)
No. of Sites with Data	648	659	166	24	916
Air Force					
VOCs	815	512	125	11	1,012 (76%)
SVOCs	288	369	111	30	575 (43%)
Metals	597	593	198	48	909 (68%)
Other	211	346	69	18	482 (36%)
Fuels	184	245	21	1	362 (27%)
Explosives	6	6	0	0	12 (1%)
VOCs & SVOCs	70	82	22	9	93 (7%)
VOCs & Metals	87	96	27	8	107 (8%)
SVOCs & Metals	55	74	22	9	77 (6%)
VOCs, SVOCs, & Metals	53	67	21	8	69 (5%)
No. of Sites with Data	1,003	901	292	63	1,331

Exhibit C-5: Frequency of Major Contaminant Groups by Matrix and DOD Component (continued)

DOD Component Contaminant Group	Ground-water	Soil	Surface water	Sediment	Total (All Media)	
FUDS						
VOCs	47	40	6	2	70	(74%)
SVOCs	12	25	1	3	34	(36%)
Metals	31	45	14	12	59	(63%)
Other	13	21	4	6	28	(30%)
Fuel	9	8	0	1	14	(15%)
Explosives	7	5	0	1	11	(12%)
VOCs & SVOCs	2	1	2	1	3	(3%)
VOCs & Metals	1	1	1	0	2	(2%)
SVOCs & Metals	1	1	1	0	2	(2%)
VOCs, SVOCs, & Metals	1	1	1	0	2	(2%)
No. of Sites with Data	61	73	18	14	94	
DLA						
VOCs	35	16	0	1	48	(62%)
SVOCs	2	15	0	0	17	(22%)
Metals	21	19	0	0	37	(48%)
Other	10	9	0	0	19	(25%)
Fuels	4	4	0	0	8	(10%)
Explosives	0	0	0	0	0	(0%)
VOCs & SVOCs	NA	NA	NA	NA	NA	NA
VOCs & Metals	NA	NA	NA	NA	NA	NA
SVOCs & Metals	NA	NA	NA	NA	NA	NA
VOCs, SVOCs, & Metals	NA	NA	NA	NA	NA	NA
No. of Sites with Data	44	45	0	1	77	
Total DOD						
VOCs	1,701	937	230	23	2,093	(65%)
SVOCs	709	934	196	71	1,392	(43%)
Metals	1,350	1,492	464	152	2,224	(69%)
Other	631	912	182	64	1,322	(41%)
Fuels	442	393	31	3	712	(22%)
Explosives	168	174	55	3	264	(8%)
VOCs & SVOCs	174	198	47	18	231	(7%)
VOCs & Metals	216	216	52	16	264	(8%)
SVOCs & Metals	161	207	49	21	233	(7%)
VOCs, SVOCs, & Metals	145	156	42	18	175	(5%)
No. of Sites with Data	**2,290**	**2,163**	**613**	**189**	**3,212**	

Notes:
- FUDS = Formerly used defense sites; DLA = Defense Logistics Agency; NA = Not available; VOC = Volatile organic compound; SVOC = Semivolatile organic compound.
- The total count for a matrix or contaminant group may exceed the number of sites with data, because a site may have more than one contaminant group or contaminated matrix.

Source: DOD, Office of the Deputy Under Secretary (Environmental Security), Restoration Management Information System, November, 1995. Data as of September 1994.

Exhibit C-6: Frequency of Major Contaminant Groups by DOD Site Type

Site Type	Total No. of Sites[a]	No. of Sites with Data	VOCs	Metals	SVOCs	Other	Fuels	Explo-sives
Underground Storage Tanks	1361	444	355	222	139	93	201	0
Spill Area	1234	539	376	318	255	177	142	26
Landfill	914	491	313	412	240	264	63	23
Unexploded Munitions/ Ordnance Area	784	14	4	12	5	9	0	5
Surface Disposal Area	748	347	221	260	182	171	45	24
Disposal Pit/Dry Well	612	334	194	273	119	143	56	86
Storage Area	608	181	94	131	112	96	28	4
Contaminated Groundwater	357	86	73	39	28	43	10	4
Fire/Crash Training Area	271	157	125	125	89	70	59	3
Building Demolition/Debris Removal	225	6	1	4	5	2	0	0
Surface Impoundment/ Lagoon	211	93	47	70	37	52	6	22
Aboveground Storage Tanks	202	40	30	24	20	12	13	0
Contaminated Fill	199	37	27	26	9	15	5	6
Contaminated Building	174	37	9	27	14	15	1	1
Burn Area	160	78	31	64	16	36	5	20
Contaminated Sediments	136	49	25	37	22	20	6	5
Explosive/Ordnance Disposal Area	130	48	15	38	17	26	1	18
Waste Line	92	41	27	29	15	22	10	3
Waste Treatment Plant	91	25	12	18	10	11	5	4
Sewage Treatment Plant	83	0	0	0	0	0	0	0
POL Distribution Line	82	36	32	17	12	5	22	0
Underground Storage Tank Farm	79	38	36	17	18	4	23	0
Firing Range	69	2	0	1	0	1	0	1
Soil Contaminated After Tank Removal	60	10	8	3	2	2	3	0

Exhibit C-6: Frequency of Major Contaminant Groups by DOD Site Type (continued)

Site Type	Total No. of Sites[a]	No. of Sites with Data	VOCs	Metals	SVOCs	Other	Fuels	Explo-sives
Storm Drain	57	3	3	1	2	1	0	0
Oil/Water Separator	52	10	7	7	5	5	5	1
Maintenance Yard	49	0	0	0	0	0	0	0
Low-level Radioactive Waste Area	33	12	8	11	0	5	1	0
Washrack	25	9	1	7	2	4	1	0
Drainage Ditch	22	6	5	5	2	4	0	3
Small Arms Range	22	2	0	2	0	0	0	0
Incinerator	19	1	0	0	0	0	0	1
Contaminated Soil Piles	17	5	3	3	2	2	1	0
Mixed Waste Area	16	7	4	4	5	3	0	0
Pistol Range	14	4	0	4	0	0	0	0
Chemical Disposal	11	0	0	0	0	0	0	0
Pesticide Shop	10	3	1	2	1	2	0	0
Industrial Discharge	8	4	3	4	1	2	0	0
Surface Runoff	5	2	0	1	1	1	0	0
Leach Field	4	1	0	1	1	0	0	0
Plating Shop	4	1	1	1	1	1	0	0
Sewage Effluent Settling Pond	3	0	0	0	0	0	0	0
Dip Tank	2	1	0	0	1	0	0	0
Optical Shop	1	0	0	0	0	0	0	0
Other	78	8	2	4	2	3	0	4
Total	9,331	3,212	2,093	2,224	1,392	1,322	712	264

Notes:
[a] Number of sites needing remediation; data were available for 3,212 of the sites needing remediation.
- POL = Petroleum, oil, lubricant
- The total count for a site type may exceed the number of sites with data for the site type, because a site may have more than one contaminant group.

Source: DOD, Office of the Deputy Under Secretary of Defense (Environmental Security), Restoration Management Information System, November 1995. Data as of September 1994.

Exhibit C-7: Frequency of Contaminant Subgroup by Matrix
Percent of Sites with Data

Contaminant	Groundwater	Soil	Surface Water	Sediment
Metals	58.86	60.77	75.69	80.42
Halogenated VOCs	56.55	22.80	8.87	5.29
Nonhalogenated VOCs	44.06	28.22	20.39	8.99
Toxic Elements	19.39	34.54	23.82	30.16
Nonhalogenated SVOCs	24.67	26.47	25.77	22.22
BTEX	19.30	16.03	5.06	2.65
PAHs	5.98	15.99	3.92	15.34
Pesticides/Herbicides	5.41	15.42	7.34	16.93
Explosives/Propellants	7.34	7.10	8.97	1.59
Halogenated SVOCs	6.68	4.65	1.96	2.65
Other	7.42	2.65	5.71	3.70
PCBs	1.48	7.10	1.47	6.88
Inorganic Cyanides	3.19	3.10	2.94	1.06
Solvents	1.05	0.12	0.00	0.00
Radioactive Metals	0.13	0.57	0.00	0.00
Dioxins/Furans	0.09	0.08	0.16	0.00
Organic Corrosives	0.09	0.20	0.00	0.00
Inorganic Corrosives	0.04	0.00	0.00	0.00
Organic Cyanides	0.00	0.04	0.00	0.00

Notes:
- VOC = Volatile organic compound; SVOC = Semivolatile organic compound; BTEX = Benzene, toluene, ethylbenzene, xylene; PAH = Polynuclear Aromatic Hydrocarbons; PCB = Polychlorinated biphenyls.
- Data were available for 3,212 sites.

Source: DOD, Office of the Deputy Under Secretary of Defense (Environmental Security) Restoration Management Information System (RMIS), November 1995. Data as of September 1994.

APPENDIX D

ADDITIONAL DATA ON

DEPARTMENT OF ENERGY SITES

Exhibit D-1: DOE Installations and Other Locations Where Remedial Action is Ongoing or Completed[1]

State	Installation/Site	Program[2]	Status[3]	No. of Operable Units[3,4]	Estimated Budget FY 1997 (millions)[3]	Estimated Life-Cycle Cost (millions)[3]
AK	Project Chariot	ER	RA complete			
AZ	Monument Valley Site	ER/UMTRA	RA complete (surface)			
	Tuba City Site	ER/UMTRA	RA complete (surface)			
CA	Energy Technology Engineering Center	ER (including D&D)	RA, D&D ongoing	16[5]	$4.2[5]	$131.0[5]
	Lawrence Livermore Laboratory	ER (including D&D)	RA ongoing	11	$22.5	$639.0
	Rockwell International	ER (including D&D)	RA, D&D ongoing	[6]		
	Sandia National Laboratory - Livermore	ER	RA ongoing	4	$1.9	$13.5
	University of California	ER/FUSRAP	RA complete			
CO	Durango Site	ER/UMTRA	RA complete (surface)			
	Grand Junction Mill Tailing Site	ER/UMTRA	RA ongoing (surface)	1	$12.8	$73.3
	Grand Junction Projects Office Site	ER (including D&D)	RA ongoing	1	$10.3	$466.9
	Gunnison	ER/UMTRA	RA ongoing (surface)	1	$0.9	$12.3
	Maybell	ER/UMTRA	RA ongoing (surface)	1	$4.3	$22.3
	Naturita	ER/UMTRA	RA ongoing	1	$13.4	$43.0
	Old North Continent (Slick Rock)	ER/UMTRA	RA ongoing (surface)	1	$9.1[7]	$32.9[7]
	Rifle Mill (Old and New)	ER/UMTRA	RA ongoing (surface)	2	$1.4	$20.3
	Union Carbide (Slick Rock)	ER/UMTRA	RA ongoing (surface)	2	[8]	[8]

Exhibit D-1: DOE Installations and Other Locations Where Remedial Action is Ongoing or Completed (continued)[1]

State	Installation/Site	Program[2]	Status[3]	No. of Operable Units[3,4]	Estimated Budget FY 1997 (millions)[3]	Estimated Life-Cycle Cost (millions)[3]
CT	Combustion Engineering	ER/FUSRAP	RA ongoing	1	$43.7	$233.9
	Seymour Specialty Wire	ER/FUSRAP	RA complete			
ID	Idaho National Engineering Laboratory	ER (including D&D) on NPL	D&D, RA ongoing	106	$112.8	$3,049.1
	Lowman Site	ER/UMTRA	RA complete			
IL	Fermi National Accelerator Laboratory	No Environmental Restoration activities planned				
	Granite City Steel	ER/FUSRAP	RA complete			
	National Guard Armory	ER/FUSRAP	RA complete			
	University of Chicago	ER/FUSRAP	RA complete			
KY	Maxey Flats	ER on NPL	DOE is funding a portion of this cleanup as a Potentially Responsible Party; cleanup is being carried out by the State of Kentucky under a ROD issued by EPA in 1991.			
MA	Ventron Corporation	ER/FUSRAP	RA ongoing	1	NA	NA
MI	General Motors	ER/FUSRAP	RA completed			
MO	Kansas City Plant	ER (including D&D)	RA ongoing	13	$3.5	$28.1
	Latty Avenue Properties (includes Hazelwood Interim Storage Site and Futura Coatings)	ER/FUSRAP on NPL	RA ongoing	2	[9]	[10]
	St. Louis Airport Site Vicinity Properties	ER/FUSRAP on NPL	RA ongoing	1	[9]	[10]
	St. Louis Downtown Site	ER/FUSRAP	RA ongoing	1	[9]	[10]
	Weldon Spring Site	ER (including D&D) on NPL	RA ongoing	8	$66.0	$447.9
MS	Salmon Test Site	ER	RA ongoing	2	$2.9[11]	$7.7[11]
NE	Hallam Nuclear Power Facility	ER (D&D only)	D&D complete; S&M ongoing			

Exhibit D-1: DOE Installations and Other Locations Where Remedial Action is Ongoing or Completed (continued)[1]

State	Installation/Site	Program[2]	Status[3]	No. of Operable Units[3,4]	Estimated Budget FY 1997 (millions)[3]	Estimated Life-Cycle Cost (millions)[3]
NJ	Kellex/Pierpont	ER/FUSRAP	RA complete			
	Middlesex Municipal Landfill	ER/FUSRAP	RA complete			
	Middlesex Sampling Plant	ER/FUSRAP	RA ongoing	1	$2.8	$24.8
NM	Acid/Pueblo Canyon	ER/FUSRAP	RA complete			
	Ambrosia Lake	ER/UMTRA	RA ongoing (surface)	1	$0.2	$1.2
	Bayo Canyon	ER/FUSRAP	RA complete			
	Chupadera Mesa	ER/FUSRAP	RA complete			
	Inhalation Toxicology Research Institute	ER	RA ongoing	4	$0.395	$2.2
	Los Alamos National Laboratory	ER (including D&D)	D&D, RA ongoing	6	$53.2	$623.7
	Pagano Salvage	ER	RA complete			
	Shiprock Site	ER/UMTRA	RA complete (surface)			
	South Valley Superfund Site	ER on NPL	DOE does not manage the cleanup project at this site; it is responsible for reimbursing General Electric, which currently owns the site, for cleanup costs. Soil and groundwater remedies already have been chosen.			
	Waste Isolation Pilot Plant	No environmental restoration, waste management only				
NY	Baker-Williams Warehouse	ER/FUSRAP	RA complete			
	Colonie Interim Storage	ER/FUSRAP	RA ongoing	1	NA	NA
	Niagara Falls Storage	ER/FUSRAP	RA complete			
	Niagara Falls Vicinity Properties	ER/FUSRAP	RA complete			
	West Valley Demonstration Project	Site of DOE vitrification process demonstration to be conducted from 1996 through 1998. DOE will be responsible only for cleanup of facilities used in the demonstration; State of New York owns site.				

Exhibit D-1: DOE Installations and Other Locations Where Remedial Action is Ongoing or Completed (continued)[1]

State	Installation/Site	Program[2]	Status[3]	No. of Operable Units[3,4]	Estimated Budget FY 1997 (millions)[3]	Estimated Life-Cycle Cost (millions)[3]
OH	Alba Craft	ER/FUSRAP	RA complete			
	Associated Aircraft and Tool	ER/FUSRAP	RA ongoing	1	NA	NA
	Baker Brothers	ER/FUSRAP	RA complete			
	Battelle Columbus Laboratories	ER (including D&D)	D&D ongoing	16	$4.0	$101.1
	Fernald Site	ER on NPL	RA, D&D ongoing	11	$260.3	$2,523.7
	HHM Safe Company	ER/FUSRAP	RA complete			
	Piqua Nuclear Power Facility	ER (D&D only)	S/M ongoing	1	0	$0.3
	Portsmouth Gaseous Diffusion Plant	ER (including D&D)	RA, D&D ongoing	30	$45.9	$3,959.7
OR	Albany Metallurgical Research Center	ER/FUSRAP	RA complete			
	Lakeview Site	ER/UMTRA	RA complete (surface)			
PA	Aliquippa Forge	ER/FUSRAP	RA complete			
	Canonsburg Site	ER/UMTRA	RA complete (surface)			
	C.H. Schnoor	ER/FUSRAP	RA complete			
	Shippingport Atomic Power Station	ER	RA complete			
SC	Savannah River Site	ER (including D&D) on NPL	RA ongoing	92	$111.7	$12,687.0
TN	Elza Gate	ER/FUSRAP	RA complete			
	Oak Ridge Associated Universities	ER on NPL	RA ongoing	2	$0.0	$24.0
TX	Falls City Site	ER/UMTRA	RA complete (surface)			
UT	Green River Site	ER/UMTRA	RA complete (surface)			
	Mexican Hat Site	ER/UMTRA	RA complete (surface)			
	Monticello Remedial Action Project	ER on NPL (2 sites)	RA ongoing	3	$21.2	$109.9
	Salt Lake City Site	ER/UMTRA	RA complete (surface)			

Exhibit D-1: DOE Installations and Other Locations Where Remedial Action is Ongoing or Completed (continued)[1]

State	Installation/Site	Program[2]	Status[3]	No. of Operable Units[3,4]	Estimated Budget FY 1997 (millions)[3]	Estimated Life-Cycle Cost (millions)[3]
WA	Hanford Site	ER (including D&D) on NPL (4 sites)	RA ongoing	78	$138.8	$8,349.2
WY	Riverton Site	ER/UMTRA	RA complete (surface)			
	Spook Site	ER/UMTRA	RA complete (surface)			

ER = Environmental Restoration
UMTRA = Uranium Mill Tailing Remedial Action
C/A = Characterization and assessment
D&D = Decontamination and Decommissioning
RA = Remedial Action
NPL = National Priorities List
IA = Interim Action
S/M = Surveillance and monitoring
FUSRAP = Formerly Utilized Sites Remedial Action Program

Notes:

1 This table includes installations and other locations where remedial action is in progress or has been compeleted for some or all operable units. Some installations and other locations included here also may appear in Exhibit A-1, because characterization and assessment still may be in progress at some operable units. These installations are included on both tables, because they continue to represent opportunities for vendors of remedial technologies.

2 U.S. Department of Energy, "The 1996 Baseline Environmental Report," DOE/EM-0290, June 1996.

3 U.S. Department of Energy, "The 1996 Baseline Environmental Report," DOE/EM-0290, June 1996, and data as of June 1996 from DOE's "1996 Baseline Environmental Report" Database and other internal DOE databases provided by the Systems Management Division, Office of Program Integration, Office of Environmental Restoration, and interviews with selected site operations staff at DOE Headquarters. Actual Congressional appropriations for FY 1997 may differ from the amounts printed here. Data on operable units and life-cycle costs come from several different sources, which are continuously being revised by DOE staff as conditions at specific installations and other locations change and as new sites are identified. In addition, these data were extracted from these sources at different times. Therefore, although these data provide an indication of the approximate level of effort needed at a given location, their sum may not accurately reflect the program total.

4 An "operable unit" consists of one or more "sites" (individual areas of contamination). DOE aggregates sites with similar characteristics or sources into operable units to facilitate remedy selection and operations for all its remediation projects, whether they are conducted under CERCLA, RCRA, or other authorities.

5 Includes both Energy Technology Engineering Center and Rockwell International site.

6 See Energy Technology Engineering Center entry.

7 Includes Old North Continent (Slick Rock) and Union Carbide (Slick Rock) sites.

8 See Old North Continent (Slick Rock).

9 Total estimated FY97 budget for all Missouri FUSRAP sites is $10.4 million. Site-by-site estimates are not available.

10 Total estimated life-cycle cost for all Missouri FUSRAP sites is $243.8 million. Site-by-site estimates are not available.

11 Work at Amchitka Island (AK), Project Rio Blanco and Project Rulison (CO), Salmon Test Site (MS), Project Gassbuggy and Gnome-Coach Site (NM), and the Central Nevada, Shoal, and Tonopah Test Sites (NV) is managed by and funded through DOE's Nevada Operations Office.

Exhibit D-2: Contaminants and Contaminated Media Volumes To Be Remediated at DOE Installations Where Characterization and Assessment Are Ongoing[1]

State	Installation/Site	Examples of Contaminants of Concern[2,3]	Estimated Soil/Sediment Volume To Be Addressed (Cu. Yds.)[4]	Estimated Ground-water Volume To Be Remediated (Cu. Yds.)[4]	Estimated Rubble/Debris Volume To Be Remediated (Cu. Yds.)[4]
AK	Amchitka Island	Organic compounds, hydrocarbons, radionuclides, beryllium, lead	9,000	104,900	5,320
AZ	Monument Valley	Cadmium, chromium, molybdenum, net gross alpha, nitrate, radium-226/228, selenium, uranium (ground water)	Complete	Undetermined	NA
	Tuba City	Net gross alpha, nitrate, selenium, uranium (ground water)	Complete	Undetermined	NA
CA	Energy Technology Engineering Center	Radioactive and chemical waste (soil and buildings); solvents, tritium, alpha and beta radioactivity, radium (ground water)	Not reported	Not reported	Not reported
	General Atomics	Low-level radioactive waste, low-level mixed waste, asbestos, lead	Undetermined	Undetermined	Undetermined
	General Electric/ Vallecitos Nuclear Center	Low-level radioactive waste and transuranic waste	NA	NA	20
	Geothermal Test Facility	Salts and minerals (sediments and debris); arsenic (soil and debris); asbestos (building materials)	11,960	NA	Not reported
	Laboratory for Energy-Related Health Research	Nitrates, chromium, chloroform, tritium, carbon (ground water); low-level radioactive waste (soil); low-level radioactive waste, asbestos, chemical and biological waste (buildings and facilities)	810	Undetermined	520

Exhibit D-2: Contaminants and Contaminated Media Volumes To Be Remediated at DOE Installations Where Characterization and Assessment Are Ongoing (continued)[1]

State	Installation/Site	Examples of Contaminants of Concern[2,3]	Estimated Soil/Sediment Volume To Be Addressed (Cu. Yds.)[4]	Estimated Ground-water Volume To Be Remediated (Cu. Yds.)[4]	Estimated Rubble/Debris Volume To Be Remediated (Cu. Yds.)[4]
CA (con-tinued)	Lawrence Berkeley Laboratory	Chlorinated hydrocarbons, solvents, tritium, motor fuels (ground water); radioactive and mixed waste (soil and buildings)	50	181,700	12,200
	Lawrence Livermore Laboratory	VOCs, fuel hydrocarbons, depleted uranium, PCBs, high explosives (soil); tritium, chlorinated hydrocarbons, TCE (ground water); radioactive and hazardous waste, asbestos (buildings)	2,307,000	1,753,000	Not reported
	Oxnard	PCBs, tetrachloroethane, fuel products (soil)	Undetermined	Undetermined	Undetermined
	Salton Sea Test Base	Radioactive and chemical waste	Undetermined	Undetermined	Undetermined
	Stanford Linear Accelerator Center	PCBs, petroleum hyrocarbon, lead (soil); VOCs, TCE (ground water)	111,100	2,614,380	980
CO	Durango	Arsenic, cadmium, lead, molybdenum, net gross alpha, selenium, uranium (ground water)	Complete	Undetermined	NA
	Grand Junction Mill Tailing Site	Radon, heavy metals, radium, thorium (soil); molybdenum, net gross alpha, selenium, uranium (ground water)	45,440 (RA ongoing)	117,380	3,550
	Gunnison	Cadmium, uranium (ground water)	345,485 (RA ongoing)	Undetermined	NA
	Maybell	Arsenic, cadmium, molybdenum, nitrate, radium-226/228, selenium, uranium (ground water)	2,800,000 (RA ongoing)	Undetermined	NA

Exhibit D-2: Contaminants and Contaminated Media Volumes To Be Remediated at DOE Installations Where Characterization and Assessment Are Ongoing (continued)[1]

State	Installation/Site	Examples of Contaminants of Concern[2,3]	Estimated Soil/Sediment Volume To Be Addressed (Cu. Yds.)[4]	Estimated Ground-water Volume To Be Remediated (Cu. Yds.)[4]	Estimated Rubble/Debris Volume To Be Remediated (Cu. Yds.)[4]
CO (con-tinued)	Naturita	Arsenic, molybdenum, net gross alpha, radium-226/228, selenium, uranium (ground water)	704,000 (RA ongoing)	Undetermined	NA
	Old North Continent (Slick Rock)	Radon, heavy metals, radium, thorium (soil); selenium, uranium (ground water)	Not reported	Undetermined	NA
	Project Rio Blanco	Organic compounds, hydrocarbons, radionuclides, beryllium, lead	6,000[5]	Undetermined	Undetermined
	Project Rulison	Organic compounds, hydrocarbons, radionuclides, beryllium, lead	[6]	Undetermined	Undetermined
	Rifle Mill (New)	Radon, heavy metals, radium, thorium (soil); arsenic, barium, cadmium, chromium, lead, molybdenum, net gross alpha, nitrate, radium-226/228, selenium, uranium (ground water)	2,000,000	Undetermined	NA
	Rifle Mill (Old)	Radon, heavy metals, radium, thorium (soil); arsenic, barium, cadmium, chromium, lead, molybdenum, net gross alpha, radium 226/228, selenium, uranium (ground water)	259,000	Undetermined	NA
	Rocky Flats	Plutonium, americium, uranium, VOCs, PAHs, beryllium (soils); nitrates, metals, solvents (ground water); radionuclides, metals, VOCs, PCBs (surface water)	414,900	1,550,000	Undetermined
	Union Carbide (Slick Rock)	Radon, heavy metals, radium, thorium (soil); cadmium, molybdenum, net gross alpha, nitrate, radium226/228, selenium, uranium (ground water)	Not reported	Undetermined	NA
FL	Pinellas Plant	VOCs	10	91,500	30

Exhibit D-2: Contaminants and Contaminated Media Volumes To Be Remediated at DOE Installations Where Characterization and Assessment Are Ongoing (continued)[1]

State	Installation/Site	Examples of Contaminants of Concern[2,3]	Estimated Soil/Sediment Volume To Be Addressed (Cu. Yds.)[4]	Estimated Ground-water Volume To Be Remediated (Cu. Yds.)[4]	Estimated Rubble/Debris Volume To Be Remediated (Cu. Yds.)[4]
FL	Pinellas Plant	VOCs	10	91,500	30
HI	Kauai Test Facility	Chemical waste	930	7,400	Undetermined
IA	Ames Laboratory	Uranium, thorium, tritium, mercury, thallium, potassium, lithium, diesel fuels, kerosene	1,270	30	150
ID	Argonne National Laboratory-West	Uranium, thorium, tritium, heavy metals, PCBs, organic corrosives, dioxins/furans, sodium	750	Not reported	200
	Idaho National Engineering Laboratory	Heavy metals, PCBs, acids, asbestos, solvents, low-level radioactive waste, trans- uranic waste	851,720	989,540	33,380
IL	Argonne National Laboratory-East	Radionuclides, VOCs, SVOCs, PAHs, PCBs, arsenic, chromium, pesticides, aromatic hydrocarbons, chlorinated benzenes, heavy metals, lead (soil, ground water, and sediments); cobalt^{60}, iron, nickel, lead, tritium, uranium$^{235/238}$, beryllium, cadmium, plutonium^{239}, americium^{241}, mixed fission products (reactors and reactor facilities)	125,630	434,750	685,420
	Madison	Uranium	10	NA	NA
	Site A/Plot M, Palos Forest Preserve	VOCs, SVOCs, heavy metals, radioactive waste	6,540	Undetermined	Undetermined
KY	Paducah Gaseous Diffusion Plant	Petroleum hydrocarbons, PCBs, uranium, technetium^{99}, mercury (soil and sediments); TCE, technetium^{99} (ground water)	756,850	89,781,060	37,650

Exhibit D-2: Contaminants and Contaminated Media Volumes To Be Remediated at DOE Installations Where Characterization and Assessment Are Ongoing (continued)[1]

State	Installation/Site	Examples of Contaminants of Concern[2,3]	Estimated Soil/Sediment Volume To Be Addressed (Cu. Yds.)[4]	Estimated Ground-water Volume To Be Remediated (Cu. Yds.)[4]	Estimated Rubble/Debris Volume To Be Remediated (Cu. Yds.)[4]
MA	Chapman Valve	Uranium	Not reported	NA	Not reported
	Shpack Landfill	Uranium residues, radium	9,370	NA	NA
MD	W.R. Grace & Company	Thorium	Not reported	NA	Not reported
MO	Kansas City Plant	PCBs, VOCs, metals, solvents, petroleum hydrocarbons	32,230	110,290	3,110
	St. Louis Airport Site	Uranium processing residues	250,000	NA	NA
	Weldon Spring Site	Low-level radioactive, chemical, and mixed wastes	321,940	650,200	163,090
NJ	DuPont & Company	Uranium	8,270	NA	[7]
	Maywood Chemical Works	Thorium tailings	395,000	NA	NA
	New Brunswick Site	Radium, uranium	4,500	NA	NA
	Princeton Plasma Physics Laboratory	Petroleum hydrocarbons, solvents	Not reported	Not reported	Not reported
	Wayne	Thorium, thorium tailings	109,000	NA	[7]

Exhibit D-2: Contaminants and Contaminated Media Volumes To Be Remediated at DOE Installations Where Characterization and Assessment Are Ongoing (continued)[1]

State	Installation/Site	Examples of Contaminants of Concern[2,3]	Estimated Soil/Sediment Volume To Be Addressed (Cu. Yds.)[4]	Estimated Ground-water Volume To Be Remediated (Cu. Yds.)[4]	Estimated Rubble/Debris Volume To Be Remediated (Cu. Yds.)[4]
NM	Ambrosia Lake	Radon, heavy metals, radium, thorium (soil); chromium, molybdenum, net gross aplha, nitrate, radium[226/228], selenium, uranium (ground water)	2,000,000 (RA ongoing)	Undetermined	NA
	Gassbuggy Site	Organic compounds, hydrocarbons, radionuclides, beryllium, lead	6,000[8]	Undetermined	Undetermined
	Gnome Coach Site	Organic compounds, hydrocarbons, radionuclides, beryllium, lead	[9]	Undetermined	Undetermined
	Los Alamos National Laboratory	Radionuclides, VOCs, SVOCs, heavy metals, high explosives, PCBs, asbestos, pesticides, herbicides (soil); tritium, cesium, strontium (ground water)	12,694,000	13,770	Not Reported
	Sandia National Laboratory-Albuquerque	PCBs, radionuclides, metals, petroleum hydrocarbons, high explosives, VOCs, SVOCs	772,500	40	24,800
	Shiprock	Net gross aplha, nitrate, radium[226/228], selenium, uranium (ground water)	Complete	Undetermined	NA
NV	Central Nevada Test Site	Organic compounds, hydrocarbons, beryllium, lead, plutonium, tritium	6,000[10]	Undetermined	Undetermined
	Nevada Test Site	Organic compounds, hydrocarbons, beryllium, lead, plutonium, tritium	18,931,550	104,900	5,320
	Shoal Test Site	Organic compounds, hydrocarbons, beryllium, lead, plutonium, tritium	[11]	Undetermined	Undetermined
	Tonopah Test Range	Organic compounds, hydrocarbons, beryllium, lead, plutonium, tritium	[11]	Undetermined	Undetermined

Exhibit D-2: Contaminants and Contaminated Media Volumes To Be Remediated at DOE Installations Where Characterization and Assessment Are Ongoing (continued)[1]

State	Installation/Site	Examples of Contaminants of Concern[2,3]	Estimated Soil/Sediment Volume To Be Addressed (Cu. Yds.)[4]	Estimated Ground-water Volume To Be Remediated (Cu. Yds.)[4]	Estimated Rubble/Debris Volume To Be Remediated (Cu. Yds.)[4]
NY	Ashland Oil CO.#1	Uranium ore tailings	Not reported	NA	NA
	Ashland Oil Co.#2	Uranium ore tailings	52,100	NA	NA
	Bliss & Laughlin	Low-level radioactive waste, uranium (trace)	Not reported	NA	NA
	Brookhaven National Laboratory	Uranium, plutonium, cesium$^{134/137}$, tritium, strontium^{90}, cobalt^{60}, sodium^{22}, radium^{226}, metals, organics	38,930	56,993,590	520
	Linde Air Products	Uranium ore tailings	70,000	NA	NA
	Seaway Industrial Park	Uranium ore tailings	Not reported	NA	NA
	Separation Process Research Unit	Plutonium, stontium^{90}, cesium^{137}	Undetermined	NA	Undetermined
OH	B and T Metals	Uranium	NA	NA	1,000
	Fernald Site	Uranium, thorium, oils, reactive chemicals, organic compounds	1,236,650	512,500,000	302,250
	Luckey	Beryllium, uranium (traces)	64,000	NA	NA
	Mound Plant	VOCs, petroleum hydrocarbons, tritium, plutonium, thorium (soil); tritium (ground water)	200,990	890,690	36,100
	Portsmouth Gaseous Diffusion Plant	Low-concentration radionuclides, chlorinated solvents, PCBs, heavy metals	32,280	741,230	71,160
	RMI Site	Uranium, TCE, technitium	35,520	620	5,830
OR	Lakeview Site	Arsenic, cadmium (ground water)	Complete	Undetermined	NA
PA	Canonsburg Site	Uranium	Complete	Undetermined	NA

Exhibit D-2: Contaminants and Contaminated Media Volumes To Be Remediated at DOE Installations Where Characterization and Assessment Are Ongoing (continued)[1]

State	Installation/Site	Examples of Contaminants of Concern[2,3]	Estimated Soil/Sediment Volume To Be Addresseda (Cu. Yds.)[4]	Estimated Ground-water Volume To Be Remediated (Cu. Yds.)[4]	Estimated Rubble/Debris Volume To Be Remediated (Cu. Yds.)[4]
PR	Center for Environmental Research	Asbestos, PCBs	Not reported	Not reported	Not reported
SC	Savanah River Site	TCE, PCE, aluminum, zinc, arsenic, cadmium, chromium, lithium, mercury, lead, strontium^{90}, cesium$^{137/139}$, cobalt^{60}, tritium, thorium	11,276,500	406,809,230	714,000
TN	Oak Ridge K-25 Site	Asbestos, petroleum hydrocarbons, PCBs, radionuclides (principally uranium), mixed waste	4,900	1,249,440	109,560
	Oak Ridge National Laboratory	Strontium^{90}, cesium^{137}, cobalt^{60}, tritium, PCBs, heavy metals, mixed waste	92,870	90,330	60,920
	Oak Ridge Reservation Offsite	Radionuclides (cesium^{137}, cobalt^{60}, tritium, strontium^{90}), mercury, lead, arsenic, selenium, chromium, PCBs, dioxin, chlordane, polychlorinated hydrocarbons	136,960	10	Not reported
	Oak Ridge Y-12 Plant	Radionuclides (depleted uranium and uranium^{235}), nitrates, organic solvents, PCBs, beryllium compounds, asbestos, mercury, cadmium	464,910	4,689,070	119,750
TX	Falls City Site	Molybdenum, uranium (ground water)	Complete	Undetermined	NA
	Pantex Plant	Organic solvents, high explosives, heavy metals	5,080	30	Not reported
UT	Green River Site	Arsenic, cadmium, chromium, lead, molybdenum, net gross alpha, nitrate, radium$^{226/228}$, selenium, uranium (ground water)	Complete	Undetermined	NA
	Mexican Hat Site	Chromium, molybdenum, net gross alpha, nitrate, radium$^{226/228}$, selenium, uranium (ground water)	Complete	Undetermined	NA

Exhibit D-2: Contaminants and Contaminated Media Volumes To Be Remediated at DOE Installations Where Characterization and Assessment Are Ongoing (continued)[1]

State	Installation/Site	Examples of Contaminants of Concern[2,3]	Estimated Soil/Sediment Volume To Be Addressed (Cu. Yds.)[4]	Estimated Ground-water Volume To Be Remediated (Cu. Yds.)[4]	Estimated Rubble/Debris Volume To Be Remediated (Cu. Yds.)[4]
UT (continued)	Monticello Remedial Action Project	Radium, uranium, thorium, polonium, radon	2,922,460	NA	[12]
	Salt Lake City Site	Molybdenum, selenium, uranium (ground water)	Complete	Undetermined	NA
WA	Hanford Site	Tritium, cobalt, strontium, cesium, technitium, plutonium, uranium, carbon tetrachloride, nitrates, iodine, chromium, mixed waste, transuranic waste	83,840,000	26,000,000	Not reported
WY	Riverton Site	Molybdenum, net gross alpha, radium[226/228], selenium, uranium (ground water)	Complete	Undetermined	NA
	Spook Site	Chromium, nitrate, radium[226/228], selenium, uranium (ground water)	Complete	Undetermined	NA

Notes:

NA = Not Applicable

1 Installations and other locations included in this table are the same as those listed in Exhibit 7-2 in the text of the Chapter.

2 U.S. Department of Energy, “Estimating the Cold War Mortgage: The 1995 Baseline Environmental Report,” DOE/EM-0230, March 1995; DOE/EM-40 Contaminated Media/Waste Database as of March 3, 1995; and U.S. Department of Energy, UMTRA Project Office, “Draft Program-matic Environmental Impact Statement for the Uranium Mill Tailings Remedial Action Ground Water Project,” DOE/EIS-0198, April 1995.

3 When specific contaminant types were not available from the references cited in endnote 2, available waste class information has been provided to give an indication of the types of contaminants that may be present.

4 U.S. Department of Energy, “Estimating the Cold War Mortgage: The 1995 Baseline Environmental Report,” DOE/EM-0230, March 1995, and DOE/EM-40 Contaminated Media/Waste Database as of March 3, 1995. Volume estimates have been rounded for inclusion in this table. Not all of the contaminated soil volume shown will be remediated—treated or disposed of—because a portion of the volume at some locations is below the proposed cleanup level for that location.

Exhibit D-2: Contaminants and Contaminated Media Volumes To Be Remediated at DOE Installations Where Characterization and Assessment Are Ongoing (continued)[1]

Notes (continued):

[5] Includes estimated volumes for Project Rio Blanco and Project Rulison.

[6] See Project Rio Blanco.

[7] Included in Estimates Soil/Sediment Volume shown for this site.

[8] Includes estimated volumes for Gassbuggy Site and Gnome-Coach Site.

[9] See Gassbuggy Site.

[10] Includes estimated volumes for Central Nevada Test Site, Shoal Test Site, and Tonopah Test Range.

[11] See Central Nevada Test Site.

[12] Included in Estimated Soil/Sediment Volume shown for this site.

APPENDIX E

FEDERAL AND STATE AGENCY PROGRAMS

ENVIRONMENTAL PROTECTION AGENCY

Regional Offices

U.S. EPA - Region 1
One Congress Street
Boston, Massachusetts 02203-0001
617-565-3420

U.S. EPA - Region 2
290 Broadway
New York, New York 10007-1866
212-637-3000

U.S. EPA - Region 3
841 Chestnut Street
Philadelphia, Pennsylvania 19107
215-566-5000

U.S. EPA - Region 4
100 Alabama Street, SW
Atlanta, Georgia 30303
404-562-8357

U.S. EPA - Region 5
77 West Jackson Boulevard
Chicago, Illinois 60604-3507
312-353-2000

U.S. EPA - Region 6
1445 Ross Avenue
12th Floor, Suite 1200
Dallas, Texas 75202-2733
214-665-6444

U.S. EPA - Region 7
726 Minnesota Avenue
Kansas City, Kansas 66101
913-551-7000

U.S. EPA - Region 8
999 18th Street, Suite 500
Denver, Colorado 80202-2466
303-312-6312

U.S. EPA - Region 9
75 Hawthorne Street
San Francisco, California 94105
415-744-1305

U.S. EPA - Region 10
1200 Sixth Avenue
Seattle, Washington 98101
206-553-1200

Remedial Action Contractors (RACs)

Region 1

Brown & Root Environmental, Inc.
55 Jonspin Road
Willmington, MA 01887
Contact: George Gardner
508-658-7899

Metcalf and Eddy, Inc.
30 Harvard Mill Square
Wakefield, MA 01880
Contact: Neville Chung
617-224-6385

Region 2

The RAC Procurement for this region is on-going.

Region 3

Brown & Root Environmental, Inc.
993 Old Eagle School Road, Suite 415
Wayne PA 1987-1710
Contact: Meg Price
610-971-0900

The RAC Procurement for this region is on-going.

Region 4

The RAC Procurement for this region is in the planning process

Region 5

CH_2M Hill, Inc.
411 E. Wisconsin Ave., Suite 1600
P.O. Box 2090
Milwaukee, WI 53201

Region 6

PRC/EMI Corporation
1 Dallas Center, Suite 600
350 N. Paul St.
Dallas TX 75201
Contact: Bill Miner
214-754-8765

CH_2M Hill, Inc.
5339 Alpha Road, Suite 300
Dallas TX 75240
Contact: Kent Robibson
214-980-2188

Region 7

Black and Veatch Waste Science Inc.
4717 Grand Avenue, Suite 500
P.O. Box 30240
Kansas City, MO 64112
Contact: Thomas Buechler
913-339-2900

Sverdrup Environmental, Inc.
13723 Riverport Drive
Maryland Heights, MO 63043
Contact: Arl Altman
314-436-7700

Region 8

CDM Federal programs Corp.
1626 Cole Blvd., Suite 100
Golden, CO 80401
Contact: Michael Malloy
303-232-0131

Region 9

The RAC Procurement is in the planning process.

Region 10

The RAC Procurement is in the planning process.

ARCS Contractors

Region 1

Arthur D. Little, Inc.
Acorn Park
Cambridge, MA 02140-2390
Contact: Ms. Renee Wong
617-864-5770

CDM Federal Programs Corp.
98 N. Washington St., Suite 200
Boston, MA 02114
Contact: Mr. Fred Babin
617-742-2659

HNUS Corp.
187 Ballard Vale St.
Wilmington, MA 01887
Contact: George Gardner
508-658-7889

Metcalf and Eddy, Inc.
10 Harvard Mill Square
Wakefield, MA 01880
Contact: William J. Farino
617-246-5200

Roy F. Weston, Inc.
1 Vande Graffe Dr.
Burlington, MA 01803
Contact: Rick Keller
617-229-2050

TRC Companies, Inc.
Boot Mills South
Foot of John Street
Lowell, MA 01852
508-970-5600

Region 2

CDM Federal Programs Corp.
40 Rector St.
New York, NY 10006
Contact: Charles W. Robinson
212-693-0370

EBASCO Services, Inc.
160 Chubb Ave.
Lyndhurst, NJ 07071
Contact: Mr. Dev. R. Sachdev
201-460-6434

ICF Kaiser Technology, Inc.
379 Thornall St., 5th floor
Edison, NJ 08837-0001
Contact: William Colvin
201-603- 3755
John Bachmann, 212-264-2702

Malcolm Pirnie, Inc.
2 Corporate Park Dr., Box 751
White Plains, NY 10602
Contact: Ralph Sarnelli
914-694-2100

Roy F. Weston, Inc.
355 Main St.
Armonk, NY 10504
Contact: Thomas Stevenson
913-273-9840

TAMS
655 Third Ave.
New York, NY 10067
Contact: Brian Styler
212-867-1777

Region 3

Black and Veatch, Inc.
Public Ledger Building, Suite 272
Independence Square
Philadelphia, PA 19106
Contact: Steve Hooper
215-627-1443

CH_2M Hill, Mid-Atlantic Office
P.O. Box 4400
Reston, VA 22090
Contact: Debbie Reif
703-471-1441

Ecology & Environment, Inc.
1528 Walnut St., Suite 1603
Philadelphia, PA 19102
Contact: Mr. Joseph Pearson
215-875-7370

NUS Corp.
One Devon Square, Suite 222
724 W. Lancaster Ave.
Wayne, PA 19087
Contact: Meg Price
215-971-0900

Tetra Tech, Inc.
10306 Eaton Plaza, Suite 340
Fairfax, VA 22030
Contact: Steve Pollak
703-385-6000

Region 4

Black & Veatch, Inc.
Perimeter Center West, Suite 212
Atlanta, GA 30338
Contact: Kendall M. Jacob
404-392-9227

CDM Federal Programs Corp.
2100 River Edge Parkway, Suite 400
Atlanta, GA 30328
Contact: Richard C. Johnson
404-952-8643
Abe Dunning, 404-952-7393

Bechtel Environmental, Inc.
P.O. Box 350
800 Oak Ridge Turnpike
Oak Ridge, TN 37830
Contact: G. Phillip Crotwell
615-482-0440

EBASCO Services, Inc.
145 Technology Park
Norcross, GA 30092-2979
Contact: David Knapp
404-662-2378

Roy F. Weston, Inc.
6021 Live Oak Parkway
Norcross, GA 30093
Contact: Michael Foulke
404-448-0644

Region 5

Black and Veatch Architects and Engineers
230 West Monroe, Suite 2250
Chicago, IL 60606
Contact: William Bruce
312-346-3775

CH_2M Hill, Inc.
310 West Wisconsin Avenue
P.O. Box 2090
Milwaukee, WI 53201
Contact: John T. Fleissner
414-272-2426

Donohue and Associates
111 North Canal St., Suite 305
Chicago, IL 60606
Contact: Roman Gau
312-902-7100

Ecology & Environment
111 West Jackson Blvd.
Chicago, IL 60604
Contact: Tom Yeates
312-663-9415

PRC Corporation
233 N. Michigan Ave., Suite 1621
Chicago, IL 60601
Contact: Majid Chaudhry
312-856-8700

Roy F. Weston, Inc.
3 Hawthorne Parkway, Suite 400
Vernon Hills, IL 60061
Contact: John W. Thorsen
708-918-4000

WW Engineering and Science
5555 Glenwood Hills Parkway, S.E.
P.O. Box 874
Grand Rapids, MI 49508-0874
Contact: Robert Phillips
616-940-4263 / 616-942-9600

Regions 6, 7, and 8

CDM Federal Programs Corp.
7 Pine Ridge Plaza
8215 Melrose Dr., Suite 100
Lenexa, KS 66214
Contact: Michael Malloy
913-492-8181

CH_2M Hill Central, Inc.
6060 South Willow Drive
Englewood, CO 80111
Contact: Don Ulrich
303-771-0900

Fluor Daniel, Inc.
12790 Merit Drive, Suite 200
Dallas, TX 75251
Contact: Mark DeLorimer
214-450-4100

Jacobs Engineering Group, Inc.
251 South Lake Ave.
Pasadena, CA 91101-3603
Contact: Steve Houser
913-492-9218

Morrison Knudsen
7100 E. Belleview Avenue, Suite 300
Englewood, CO 80111
Contact: Ed Baker
303-793-5000

Roy F. Weston, Inc.
5599 San Felipe, Suite 700
Houston, TX 77056
Contact: John DiFilippo
713-621-1620

Sverdrup Corp.
801 North Eleventh St.
St. Louis, MO 63101
Contact: Arl Altman
314-436-7600

URS Consultants, Inc.
5251 DTC Parkway, Suite 800
Englewood, CO 80111
Contact: John Coats
303-796-9700

Regions 9 and 10

Bechtel Environmental, Inc.
P.O. Box 3965
50 Beale St.
San Francisco, CA 94119
Contact: Peter R. Nunn
415-768-2797

CH_2M Hill
6425 Christie Ave., Suite 500
Emeryville, CA 94608
Contact: Stephen Hahn
415-652-2426

Ecology & Environment
101 Yesler Way, Suite 600
Seattle, WA 98104
Contact: Ronald Karpowitz
206-624-9537

ICF Technology, Inc
160 Spear St., Suite 1380
San Francisco, CA 94105-1535
Contact: Earle Krivanic
415-957-0110

Roy F. Weston, Inc.
201 Elliot Ave. West, Suite 500
Seattle, WA 98119
Contact: Frank Monahan
206-286-6000

URS Consultants, Inc.
2710 Gateway Oaks Drive, Suite 250
Sacramento, CA 95834
Contact: Gary Jandgian
916-929-2346

DEPARTMENT OF DEFENSE

U.S. Air Force

Air Combat Command
HQ ACC/CEV
Langley AFB, VA 23665-5001
Col. John Mogge
804-764-2801

Air Force Reserve
HQ AFRES/CEPV
Robins AFB, GA 31098-6001
Mr. Robert Akridge
912-327-1072

Air Training Command
HQ ATC/DEV
Randolph AFB, TX 7815-5001
Col. Richard Kochanek
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APPENDIX F

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APPENDIX G

DEFINITIONS OF INNOVATIVE TECHNOLOGIES

SELECTED FOR NPL SITE CLEANUPS

INNOVATIVE TECHNOLOGIES SELECTED FOR NPL SITE CLEANUPS

Soil Control Technologies

***Ex Situ* Bioremediation**	This technology uses microorganisms to degrade organic contaminants in excavated soil, sludge, and solids. The microorganisms break down the contaminants by using them as a food source. The end products are typically CO_2 and H_2O. *Ex situ* bioremediation includes slurry-phase bioremediation, in which the soils are mixed in water to form a slurry, and solid-phase bioremediation, in which the soils are placed in an cell or building and tilled with added water and nutrients. Land farming and composting are types of solid-phase bioremediation.
***In Situ* Soil Bioremediation**	With *in situ* bioremediation, an oxygen source and, sometimes, nutrients, are pumped under pressure into the soil through wells, or they are spread on the surface for infiltration to the contaminated material. Bioventing is a common form of *in situ* bioremediation. Bioventing uses extraction wells to circulated air with or without pumping air into the ground.
Contained Recovery of Oily Wastes (CROW™)	This process displaces oily wastes with steam and hot water. The contaminated oils are swept into a more permeable area and are pumped out of the soil.
Cyanide Oxidation	Organic cyanides are oxidized to form less hazardous compounds though chemical reactions.
Dechlorination	Dechlorination is a chemical reaction which removes or replaces chlorine atoms contained in hazardous compounds, rendering them less hazardous.
Hot Air Injection	With hot air injection, heated air is injected and circulated through the subsurface. The heated air volatizes volatile organic compounds so they can be extracted and captured for further treatment or recycling.
***In Situ* Flushing**	For *in situ* flushing, large volumes of water at times supplemented with treatment compounds, are introduced to the soil, waste, or groundwater to flush hazardous contaminants from a site. Injected water must be isolated effectively within the aquifer and recovered.
Physical Separation	Removes contaminants from a medium in order to reduce the volume of material requiring treatment.
Phytoremediation	Phytoremediation involves the cultivation of specialized plants that are capable of taking up specific soil contaminants into their roots or foliage. Uptake of contaminants by the plants reduces concentrations of contaminants in the soil. Periodic harvesting of the plants may be necessary.

Plasma High Temperature Metals Recovery
This technology is a thermal treatment process that purges contaminants from solids and soils as metal fumes and organic vapors. The organic vapors can be burned as fuel and the metal fumes can be recovered and recycled.

Soil Vapor Extraction (SVE)
This technology removes volatile organic compounds from the soil through the use of vapor extraction wells, sometimes combined with air injection wells, to strip and flush the contaminants into the air stream for further treatment.

Soil Washing
Soil washing is used for two purposes. First, the mechanical action and water (sometimes with additives) physically remove the contaminants from the soil particles. Second, the agitation of the soil particles allows the more highly contaminated fine particles to separate from the larger ones, thus reducing the volume of material requiring treatment.

Solvent Extraction
Solvent extraction operates on the principle that, in the correct solvent, organic contaminants can be solubilized preferentially and removed from the waste. The solvent to be used will vary, depending on the waste type.

Thermal Desorption
For thermal desorption, the waste is heated in a controlled environment to cause organic compounds to volatilize from the waste. The operating temperature for thermal desorption is less than 1000°F (550°C). The volatilized contaminants will usually require further control or treatment.

Vitrification
Vitrification melts contaminated soil in place at temperatures of approximately 3000°F (1600°C). Metals are encapsulated in the glass-like structure of the melted silicate compounds. Organics may be treated by combustion.

Groundwater Treatment Technologies

Air Sparging
Air sparging involves injecting air or oxygen into the aquifer to strip or flush volatile contaminants as the air bubbles up through the groundwater and is captured by a vapor extraction system. The entire system acts as an *in situ* air stripper. Stripped or volatized contaminants usually will be removed through soil vapor extraction wells and usually require further treatment.

***In Situ* Groundwater Bioremediation**
With *in situ* bioremediation, which is often combined with air sparging, nutrients or an oxygen source (such as air) are pumped under pressure into the aquifer through wells to enhance biodegradation of contaminants in the groundwater.

Dual-Phase Extraction

Dual-phase extraction removes contaminants simultaneously from both the saturated and the unsaturated zone soils *in situ*. This new technology applies soil vapor extraction techniques to contaminants trapped in saturated zone soils, which are more difficult to treat than are those in the unsaturated zone. In some instances, this result may be achieved by sparging the groundwater section of a well that penetrates the groundwater table. Other methods also may be employed.

***In Situ* Oxidation**

This technology oxidizes contaminants that are dissolved in groundwater, converting them into insoluble compounds.

Passive or Permeable Treatment Walls

Passive treatment walls act like chemical treatment zones. Contaminated groundwater comes into contact with the wall, which is permeable, and a chemical reaction takes place. Limestone treatment zones increase the pH, which effectively immobilizes dissolved metals in the saturated zone. Another type of passive treatment wall contains iron filings that dechlorinate compounds.

Surfactant Flushing

Surfactant flushing of non-aqueous phase liquids (NAPL) increases the solubility and mobility of the contaminants in water, so that the NAPL can be biodegraded more easily in the aquifer or recovered for treatment aboveground via a pump-and-treat system.

APPENDIX H

ACRONYMS

Acronyms

AFBC	Air Force Base Conversion Agency
ANPRM	Advanced Notice of Proposed Rulemaking
ARCS	Alternative Remedial Contracting Strategy
ASTSWMO	Association of State and Territorial Solid Waste Management Officials
ATTIC	Alternative Treatment Technology Information Center
BFSS	Bioremediation in the Field Search System
BLM	Bureau of Land Management
BRAC	Base Realignment and Closure
BCP	BRAC Cleanup Plan
BCT	BRAC Cleanup Team
BTEX	Benzene, Toluene, Ethylbenzene, Xylene
CA	Cooperative Agreement
CAMU	RCRA Corrective Action Management Unit
CBO	Congressional Budget Office
CERFA	Community Environmental Response Facilitation Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (Superfund)
CERCLIS	Comprehensive Environmental Response, Compensation, and Liability Information System
CFR	Code of Federal Regulations
CMI	RCRA Corrective Measures Implementation
CMS	RCRA Corrective Measures Study
CORA	Cost of Remedial Action Computer Model
CRDA	Cooperative Research and Development Agreement [DOE]
D&D	Decontamination and Decommissioning
DERA	Defense Environmental Restoration Account
DERP	Defense Environmental Restoration Program
DERPMIS	Defense Environmental Restoration Program Management Information System
DLA	Defense Logistics Agency
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOI	U.S. Department of Interior
DOJ	U.S. Department of Justice
DOT	U.S. Department of Transportation
DSMOA	Defense and State Memorandum of Agreement
EBS	Environmental Baseline Survey
EC	Enterprise Community
EPA	U.S. Environmental Protection Agency
ERCS	Emergency Remedial Contracting Strategy
ERMC	Environmental Restoration Management Contractor [DOE]
ESTCP	Environmental Security Technology Certification Program
EZ	Empowerment Zone
FR	Federal Register
FUDS	Formerly Used Defense Sites
FUSRAP	Formerly Utilized Sites Remedial Action Program
FY	Fiscal Year
GAO	U.S. Government Accounting Office

Acronyms (continued)

GENSUR	National Survey of Hazardous Waste Generators
GWRTAC	Groundwater Remediation Technologies Analysis Center
HRS	Superfund Hazard Ranking System
HSWA	Hazardous and Solid Waste Amendments of 1984
HWIR-Media	Hazardous Waste Identification Rule - Media
HUD	U.S. Department of Housing and Urban Development
IAG	Interagency Agreement
IRP	Defense Installation Restoration Program
LDR	RCRA Land Disposal Restrictions
LTTD	Low Temperature Thermal Desorption
MUDSS	Mobile Underwater Debris Survey System
NAPL	Nonaqueous Phase Liquid
NASA	National Aeronautics and Space Administration
NAVFAC	Navy Facilities Engineering Command
NCAPS	National Corrective Action Priority Ranking System
NCEPI	National Center for Environmental Publications and Information
NCP	National Oil and Hazardous Substances Contingency Plan
NETAC	National Environmental Technologies Applications Center
NTIS	National Technical Information Service
NPL	Superfund National Priorities List of Hazardous Waste Sites
O&M	Operation and Maintenance
OU	Operable Unit
ORD	Office of Research and Development
OSW	Office of Solid Waste
OSWER	Office of Solid Waste and Emergency Response
OTA	Office of Technology Assessment
PA	Preliminary Site Assessment
PAH	Polynuclear Aromatic Hydrocarbons
PCB	Polychlorinated Biphenyls
PCE	Perchloroethylene
PRDA	Program Research and Development Announcement [DOE]
PEIS	Programmatic Environmental Impact Statement [DOE]
POL	Petroleum, Oil, and Lubricants
POTW	Publicly Owned [wastewater] Treatment Works
PRP	Potentially Responsible Party
RA	Remedial Action
RAB	Restoration Advisory Board
RAC	Remedial Action Contractor
RACS	Remedial Action Contracting Strategy
RCRA	Resource Conservation and Recovery Act of 1976
RCRIS	Resource Conservation and Recovery ACT Information System National Oversight Database
RD	Remedial Design
RD&D	Research, Development, and Demonstration
RFA	RCRA Facility Assessment
RFI	RCRA Facility Investigation

Acronyms (continued)

RFP	Request for Proposals
RI/FS	Remedial Investigation/Feasibility Study
RIA	Regulatory Impact Analysis
RIS	RCRA Implementation Study
RMIS	DOD's Restoration Management Information System
ROD	Record of Decision
RP	Responsible Party
RPM	Remedial Project Managers
RTC	Resolution Trust Corporation
RTDF	Remediation Technologies Development Forum
NTIS	National Technology Information System
RU	RCRA Regulated Unit
SACM	Superfund Accelerated Cleanup Model
SARA	Superfund Amendments and Reauthorization Act of 1986
SBA	Small Business Administration
SBIR	Small Business Innovative Research Program
SERDP	Strategic Environmental Research and Development Program
SI	Site Inspection
SITE	Superfund Innovative Technology Evaluation Program
SVE	Soil Vapor Extraction
SVOC	Semivolatile Organic Compound
SWMU	Solid Waste Management Unit
TCE	Trichloroethylene
TIO	Technology Innovation Office
TPS	Third Party Site [DOD]
TSD	Treatment, Storage, or Disposal
TSDF	Treatment, Storage, or Disposal Facility
TSDR	Treatment, Storage, Disposal, or Recycling Facility
UIC	Underground Injection Control
UMTRA	Uranium Mill Tailings Remedial Action Project
USACE	U.S. Army Corps of Engineers
USAEC	U.S. Army Environmental Center
USATHAMA	U.S. Army Toxics and Hazardous Materials Agency
USDA	U.S. Department of Agriculture
UST	Underground Storage Tank
VISITT	Vendor Information System on Innovative Treatment Technologies
VOC	Volatile Organic Compound
WPB	War Production Board