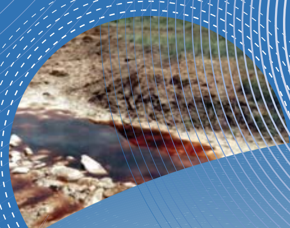
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Treatment Technologies for Site Cleanup:

Annual Status Report

TWELFTH EDITION



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Treatment Technologies for Site Cleanup: Annual Status Report (Twelfth Edition)

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Notice

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A portable document format (PDF) version of the ASR is available for viewing or downloading from the Hazardous Waste Cleanup Information (CLU-IN) Web site at *http://clu-in.org/asr*. Printed copies of the ASR can also be ordered through that web address, subject to availability.

The data for the ASR are available in a searchable online database (the ASR Search System) at *http://cfpub.epa.gov/asr/*.

List of Acronyms

ASR	Annual Status Report
BTEX	Benzene, toluene, ethylbenzene, and xylene
CC	Construction completion
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CERCLIS	Comprehensive Environmental Response, Compensation, and Liability Information System
CFR	Code of Federal Regulations
CLU-IN	EPA's CLeanUp INformation system
DCE	Dichloroethene
DNAPL	Dense nonaqueous phase liquid
DRE	Destruction and removal efficiency
EOU	Excess, obsolete, or unserviceable
EPA	U.S. Environmental Protection Agency
ESD	Explanation of significant differences
FRTR	Federal Remediation Technologies Roundtable
FY	Fiscal year
LNAPL	Light nonaqueous phase liquid
MNA	Monitored natural attenuation
MSW	Municipal solid waste
NA/NFA	No action/no further action
NAPL	Nonaqueous phase liquid
NPL	National Priorities List
NSCEP	National Service Center for Environmental Publications
OB	Open burn
OD	Open detonation
OSC	On-Scene Coordinator
OSRTI	Office of Superfund Remediation and Technology Innovation
OSWER	Office of Solid Waste and Emergency Response
OU	Operable unit
P&T	Pump and treat
PAH	Polycyclic aromatic hydrocarbons
PCB	Polychlorinated biphenyls
PCE	Tetrachloroethene
PCOR	Preliminary close-out report
PDF	Portable document format
PRB	Permeable reactive barrier
RA	Remedial action
RCRA	Resource Conservation and Recovery Act
ROD	Record of Decision
RPM	Remedial Project Manager
RSE	Remediation System Evaluation
S/S	Solidification/stabilization
SARA	Superfund Amendments and Reauthorization Act
SVE	Soil vapor extraction
SVOC	Semivolatile organic compound
TCA	Trichloroethane
TCE	Trichloroethene
UV	Ultraviolet
VC	Vinyl chloride
VEB	Vertical engineered barrier
VOC	Volatile organic compound

Executive Summary

The Twelfth Edition of *Treatment Technologies for Site Cleanup: Annual Status Report* (ASR) documents the status, achievements, and trends associated with treatment technologies at National Priorities List (NPL) sites for remedy decisions between 1982 and 2005. Information collected and analyzed for this report helps document the progress and contributions of technologies implemented at NPL sites. In addition to presenting information about remedy decisions based solely on records of decision (ROD), this report provides data about projects that relate to their operational status and treatment accomplishments. The report includes information about:

- **Treatment technologies for source control**: *In situ* and *ex situ* treatment technologies for sources of contamination (such as soil, sludge, sediment, other solid matrix wastes, and nonaqueous phase liquids [NAPL]).
- **Treatment technologies and other remedies for groundwater:** *In situ* and *ex situ* (pump and treat [P&T]) groundwater treatment technologies and monitored natural attenuation (MNA) remedies for groundwater.
- **On-site containment remedies:** Vertical engineered barriers (VEB), caps, and liners used to prevent the migration of contaminants or contaminated media.

This edition of the ASR provides:

- Information about 192 treatment technologies selected from fiscal year (FY) 2002 to 2005 ("new" for the ASR Twelfth Edition)
- Updates to more than 1,200 projects from 1982 to 2002
- A total of 1,915 treatment technologies and 57 groundwater VEBs are included with updated information
- Analysis of 133 on-site containment projects ("new" analysis for the ASR Twelfth Edition)

The data contained in the report were gathered from the Comprehensive Environmental Response, Compensation, and Liability Act Information System (CERCLIS) for FY 1982 to 2005 (as documented as of October 2006), from site-specific decision documents, and online U.S. Environmental Protection Agency (EPA) sources.

Major Findings

Use of Treatment Remedies at NPL Sites

The Superfund Amendments and Reauthorization Act of 1986 (SARA) expressed a preference for permanent remedies (that is, treatment) over containment or removal and disposal in the remediation of Superfund sites. As of September 2005, 1,536 sites had been listed on the NPL. Of those, 307 sites had been deleted, leaving 1,229 sites on the NPL. An additional 54 sites were proposed for listing at that time.

- At nearly two-thirds of NPL sites (63 percent), source control treatment, groundwater treatment, or both, have been implemented or are planned as a remedy for some portion of the site.
- More than a quarter of the sites (28 percent) selected treatment for both source control and groundwater.
- The selected remedies do not include treatment for 24 percent of sites.
- No ROD has been issued for 13 percent of all NPL sites.

Some 56 percent (1,677) of all RODs analyzed for the ASR (2,976) contained provisions for treatment of source media or groundwater. EPA currently tracks the status of 1,915 projects for application of treatment technologies at Superfund sites, including *in situ* and *ex situ* treatment projects for both source control and groundwater. These applications include:

- 515 *ex situ* source control treatment projects (27 percent of all projects)
- 421 *in situ* source control treatment projects (22 percent)
- 725 P&T projects (38 percent)
- 213 *in situ* groundwater treatment projects (11 percent)
- 41 *in situ* source control and *in situ* groundwater treatment projects (2 percent)

Use of Treatment for Source Control

A total of 977 projects were planned or implemented for the 1,104 source control treatment RODs and ROD amendments. Those projects include a wide range of *in situ* and *ex situ* technologies used to address many types of contaminants, and represent various stages of design and implementation. Trends and general observations include:

- The selection of *in situ* treatment for source control continues to increase. *In situ* source control treatment projects represented 60 percent of source treatment projects from FY 2002 to 2005. Cumulatively, from FY 1982 through 2005, *in situ* source control projects make up 47 percent of the projects.
- From FY 2002 to 2005, projects that used *in situ* technologies of multi-phase extraction and chemical treatment are being selected at an increasing rate compared with soil vapor extraction (SVE) projects that are not being selected as frequently as in past years.
- Historically, incineration projects have represented a high percentage of *ex situ* source treatment projects (29 percent reported in the eleventh edition of the ASR for FY 1982 to 2005). During the period from FY 2002 to 2005, incineration represented only 6 percent of *ex situ* treatment projects.
- In FY 2004, the percentage of projects that selected innovative technologies reached 47 percent, nearly equaling the percentage for established technologies. This trend continued in FY 2005, with partial data indicating 48 percent of projects selected innovative technologies.
- Nearly 80 percent of *ex situ* source control projects are completed and 10 percent are operational. Approximately 40 percent of *in situ* source control projects are completed, while another 40 percent are operational.

Use of Treatment for Groundwater

Of the RODs that select groundwater treatment, 18 percent (195) used *in situ* treatment remedies, whereas more than 90 percent (958) used P&T remedies. A total of 254 *in situ* treatment projects and 725 P&T projects are planned or have been implemented from those RODs. Trends and general observations about groundwater treatment RODs and projects include:

- RODs that select *in situ* groundwater treatment have been generally increasing, from none in FY 1982 through 1986 to a high of 31 percent in FY 2005.
- RODs that select P&T alone have decreased from about 80 percent before FY 1992 to an average of 20 percent over the last 5 years (FY 2001 through 2005).
- RODs that select MNA experienced a decline from FY 1999 to 2002, coinciding with publication of EPA guidance on the use of MNA in 1999. Since FY 2002, RODs that select MNA have been increasing, with almost half of all groundwater RODs selecting MNA in FY 2005.
- The most common *in situ* technologies include air sparging, bioremediation, chemical treatment, permeable reactive barriers (PRB), and multi-phase extraction. Cumulatively, air sparging represents almost 30 percent of all *in situ* groundwater treatment projects and bioremediation represents 27 percent.
- *In situ* bioremediation and chemical treatment have increased significantly in recent years, with approximately 70 to 80 percent of these projects selected in the past six years.
- More than 70 percent of P&T projects selected are currently operational. Another 10 percent have been shut down. Eighteen percent of *in situ* groundwater projects have been completed, and nearly 50 percent continue to operate.

Project Completion at NPL Sites

A total of 1,915 treatment remedies have been planned or implemented at NPL sites. Of these treatment remedies:

- 687 projects (36 percent) have been completed or shut down
- 857 projects (45 percent) are operational
- 371 projects (19 percent) are being designed or constructed

Trends and general observations about completed projects include:

- Approximately 60 percent of all source control projects are completed.
- Most of the completed projects are *ex situ* source control treatments (57 percent) that usually involve excavation of contaminated soil and application of an aggressive treatment technology in a controlled environment. Nearly all incineration projects have been completed. Approximately 80 percent of the solidification/stabilization (S/S) and thermal desorption projects have been completed.
- *In situ* treatments are applied to contaminated media in place, without excavation. These projects typically require longer treatment times because they take place in a less controlled environment, which may limit the treatment rate. *In situ* treatment technologies represent

31 percent of completed projects, with 170 of those 216 projects being *in situ* source control treatment only (with no groundwater treatment).

- More *in situ* source control projects have been completed than *in situ* groundwater projects. For instance, approximately 65 percent of *in situ* S/S projects and 45 percent of *in situ* SVE projects have been completed. In contrast, less than 30 percent of air sparging for *in situ* groundwater treatment have been completed.
- P&T projects, which represent the largest number of treatment projects (725), typically require long treatment times and represent only 11 percent of all completed and shut down projects.
- Ten percent of P&T projects have been completed or shut down.

Section 1: Introduction

In 1980, Congress enacted the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, or Superfund) to address the dangers of abandoned or uncontrolled hazardous waste sites. CERCLA provides the U.S. Environmental Protection Agency (EPA) and other federal agencies the authority to respond to a release or a substantial threat of a release of a hazardous substance into the environment, or a release or substantial threat of a release of "any pollutant or contaminant, which may present an immediate and substantial danger to public health or welfare."

Since the inception of the Superfund program, EPA has responded to thousands of actual or potential releases of hazardous substances through short-term or emergency removal actions and longer-term cleanup efforts known as remedial actions. These remedial actions, undertaken to provide more permanent solutions to protect human health and safety, may require years to design, implement, and complete.

Although remedial options may include a variety of possible remedies, ranging from containment of wastes to treatment to institutional controls, the Superfund Amendments and Reauthorization Act of 1986 (SARA) expressed a preference for permanent remedies (that is, treatment) over containment or removal and disposal in remediation of Superfund sites. EPA currently tracks the status of projects where treatment technologies are applied at National Priorities List (NPL) sites to collect and analyze information about the progress and contributions of technologies that have been implemented. This report documents the status, achievements, and trends associated with treatment technologies at NPL sites with remedy decisions from fiscal year (FY) 1982 through 2005.

Reporting on the Status of Treatment Technologies

The Twelfth Edition of Treatment Technologies for Site Cleanup: Annual Status Report (ASR) documents treatment technology applications for soil, other solid wastes, liquid wastes, and groundwater at NPL sites. The report includes information about:

Box 1. New in the Twelfth Edition

- Information about 192 treatment technologies selected from FY 2002 to 2005 ("new" for the ASR Twelfth Edition).
- Updates to more than 1,200 treatment technologies selected from FY 1982 to 2002.
- A total of 1,915 treatment technologies and 57 groundwater vertical engineered barriers (VEBs) are included with updated information.
- Analysis of 133 on-site containment projects ("new" for the ASR Twelfth Edition).

- Treatment Technologies for Source Control - *In situ* and *ex situ* treatment technologies for sources of contamination (such as soil, sludge, sediment, other solid matrix wastes, and nonaqueous phase liquids [NAPL]).
- Treatment Technologies and Other Remedies for Groundwater - *In situ* and *ex situ* (pump and treat [P&T]) groundwater treatment technologies and monitored natural attenuation (MNA) remedies for groundwater.
- Containment Remedies - Vertical engineered barriers (VEB), caps, and liners used to prevent the migration of contaminants or contaminated media.

The Twelfth Edition of the ASR uses information from the ASR Eleventh Edition (EPA 542-R-03-009), published by EPA in February 2004, and updated data from the following sources:

- FY 2002 decision documents (e.g., records of decision [ROD], ROD amendments, and Explanations of Significant Differences [ESD]). Data includes the estimated 30 percent of decision documents that were not included in the ASR Eleventh Edition.
- FY 2003 decision documents.
- FY 2004 decision documents.
- FY 2005 decision documents available as of October 2006 (an estimated 76 percent of the total signed decision documents).
- Other sources of information, including 5-year review reports, preliminary close-out reports (PCOR), and online regional site summaries.

Information about technologies and sites identified in this report was obtained, in part, from the CERCLA Information System (CERCLIS) as of October 2006. Some data may differ from information found in the CERCLIS database as a result of review of individual decision documents, site summaries, or other sources obtained while preparing this report.

Treatment Technologies Included in this Report

Remedies selected for NPL sites are documented in RODs and ROD amendments. Throughout the ASR, the term "RODs" is generally used inclusively to mean both RODs and ROD amendments. Many RODs for remedial actions address the source of contamination, such as soil, sludge, sediments, and solid-matrix wastes; these "source control" RODs select "source control remedies." A groundwater remedial action is also known as "a non-source control action." These actions are described in the report as "groundwater remedies." The graphic at the right illustrates a remedial site with source media contamination and groundwater contamination. A ROD may include both "source control" and "groundwater" components. Appendix F to this document is a detailed description of the methodology used to classify RODs, including detailed definitions of "source control remedies," "groundwater remedies," and other remedy types. Box 3 provides a summary of the remedy types presented in Appendix F.

Box 2. *In Situ* and *Ex Situ* Treatment

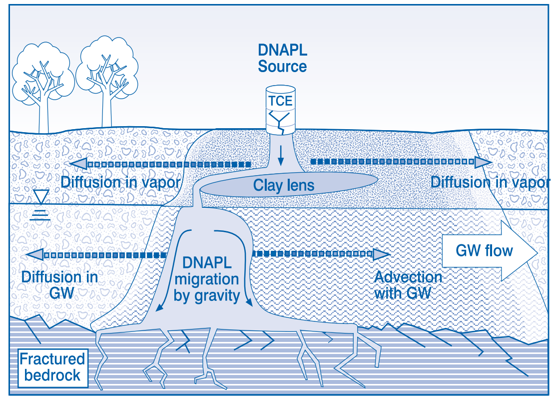
In situ: In its original place; unmoved, unexcavated; remaining at the site or in the subsurface.

In situ treatment technologies treat or remove the contaminant from source media without excavation or removal of the source media, or from groundwater without extracting, pumping, or otherwise removing the groundwater from the aquifer.

Ex situ: Moved, excavated, or removed from the site or subsurface.

Implementation of ex situ remedies requires excavation or removal of the contaminated source media or extraction of groundwater from an aquifer before treatment may occur above ground.

Site with Source Media and Groundwater Contamination



The term "treatment technology" means any unit operation or series of unit operations that alters the composition of a hazardous substance or pollutant or contaminant through chemical, biological, or physical means so as to reduce toxicity, mobility, or volume of the contaminated materials being treated. Treatment technologies are an alternative to land disposal of hazardous wastes without treatment (March 8, 1990 Federal Register [55 FR 8819], see Title 40 Code of Federal Regulations [CFR] Part 300.5, "Definitions").

Information on cost and performance is often available for treatment technologies that are considered "established." The most frequently used established technologies are on- and off-site incineration, solidification/stabilization (S/S), soil vapor extraction (SVE), and thermal desorption for source control, and P&T technologies for groundwater. Treatment of groundwater after it has been pumped to the surface usually involves traditional water treatment; as such, groundwater P&T remedies are considered established technologies.

Innovative technologies are alternative treatment technologies with a limited number of applications and limited data on cost and performance. Often, these technologies are established in other fields, such as chemical manufacturing. In such cases, it is the application of a technology or process at a waste site (to soils, sediments, sludge, and solid-matrix waste such as mining slag, or groundwater) that is innovative, and not the technology itself. Innovative technologies for source control are discussed in Section 2. Innovative technologies for *in situ* treatment of groundwater are discussed in Section 3.

Box 3. Summary of Source Control and Groundwater Remedy Types

Source Control Remedy Types*

Source Control Treatment

- Treatment of a contaminant source *in situ* or *ex situ*.
- Can include any of the source control treatment technologies described in this report, such as chemical treatment and thermal desorption.

Source Control Containment

- Containment of a contaminant source.
- Can include the use of caps, liners, covers, and landfilling, both on and off site.

Source Control Other

- Other remedies for contaminant sources.
- Can include institutional controls, monitoring, and population relocation.

Groundwater Remedy Types*

***In Situ* Treatment**

- Treatment of groundwater in place without extracting it from an aquifer.
- Can include any of the *in situ* groundwater treatment technologies identified in this report, such as air sparging and permeable reactive barriers.

Pump and Treat (P&T)

- Extraction of groundwater from an aquifer and treatment aboveground.
- Groundwater usually is extracted by pumping from a well or trench.
- Treatment can include any of the P&T technologies described in this report, such as air stripping and ion exchange.

Monitored Natural Attenuation (MNA)

- The reliance on natural attenuation processes (within the context of a carefully controlled and monitored approach to site cleanup) to achieve site-specific remediation objectives on a schedule that is reasonable compared with other alternatives.
- Natural attenuation processes include a variety of physical, chemical, and biological processes.

Groundwater Containment

- Containment of groundwater through a vertical, engineered, subsurface, impermeable barrier.
- Containment of groundwater through a hydraulic barrier created by pumping.

Groundwater Other

- Groundwater remedies that do not fall into the categories of groundwater *in situ* treatment, P&T, MNA, or containment remedies.
- Can include a variety of remedies, such as water use restrictions and alternative water supply.

* See Appendix F for further definitions of Source Control and Groundwater Remedies.

In addition to the remedy types identified in Box 3 and the classifications of remedies discussed in Appendix F, specific treatment technologies are discussed throughout this report. Appendix C defines 17 types of source control (primarily soil) treatment technologies, 9 types of *in situ* groundwater treatment technologies, 8 types of groundwater P&T technologies, and 3 on-site containment technologies.

Framework for Discussion of Treatment Technology Data

From FY 1982 through 2005 (including an estimated 76 percent of FY 2005 decision documents), 2,976 RODs and ROD amendments were signed. Multiple RODs may be prepared for some sites to address different areas of the site known as operable units (OU) and different media within a site. In addition, each OU may require a number of RODs to address different media or contaminants, or ROD amendments to revise the selected remedy. Box 4 identifies the numbers of RODs and ROD amendments issued for NPL sites. On average, 2.3 RODs are signed for each NPL site. While a majority of sites (53 percent of 1,309 sites for which ROD data was available) have a single ROD, and 95 percent have 5 or fewer RODs and ROD amendments, some sites may have a significant number of RODs and ROD amendments. The majority of these sites are very large and complex federal facilities (e.g., Savannah River [68 RODs and ROD amendments], Oak Ridge Reservation [29], Idaho National Engineering Lab [25], Naval Air Engineering Center [25] and Cecil Field [24]).

Box 4. NPL Sites and RODs

Number of Sites	Number of RODs and Amendments Per Site
697	1
360	2
111	3
46	4
33	5
12	6
7	7
5	8
8	9
25	10-18
4	24-29
1	68

Box 5. Evolution of Treatment Technologies

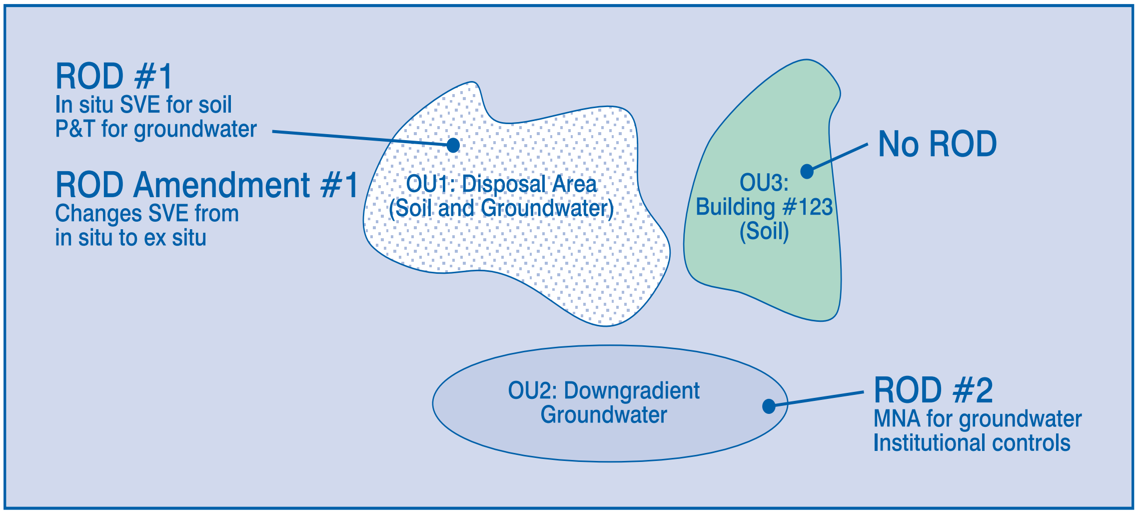
Driven by the need for more effective, less costly approaches (i.e., “smarter solutions”) to clean up contaminated sites, new remediation technologies are developed and deployed on a continual basis. Since the inception of the Superfund program, several treatment technologies have evolved from “innovative” bench- and pilot-scale demonstrations to commonly used “established” technologies. As technologies mature, their applications become better defined and cost and performance are documented, enabling them to become established. With the ongoing use of these technologies, new needs are identified and new technologies emerge, continuing the cycle.

For example, in the early 1980s, SVE was considered innovative and was used infrequently. Since then, SVE has become an established technology, representing 26 percent of the total source control treatment projects planned or implemented at NPL sites from 1982 to 2005. However, data in the ASR Twelfth Edition now indicate that projects using innovative *in situ* technologies like multi-phase extraction and chemical treatment are being selected at an increased rate relative to SVE over the period from 2002 to 2005.

Each ROD or ROD amendment issued for a site or OU may result in one or more projects consisting of treatment, contaminant, or another remedy. Alternatively, multiple RODs and ROD amendments may be issued for a single project over the duration of its operation. As such, the ratio of RODs and ROD amendments to projects varies. The graphic on the following page illustrates an example of a remedial approach at a site with multiple OUs, RODs, and projects.

The remedy selected in a ROD may not be the remedy that is actually implemented at a site. For example, a different remedy may be used when a treatment technology that was selected in a ROD based on bench-scale treatability testing proves ineffective in pilot-scale tests conducted during the design phase. Likewise, additional contamination may be discovered at the site during the

Example Remedial Approach at a Site



implementation of a remedy, which may warrant a change in the remedy. Furthermore, a particular remedy may have been included in a ROD only as a contingent remedy, but future site investigations reveal that implementation of the contingent remedy was not necessary. The changes usually are documented in an ESD or ROD amendment when significant and fundamental changes are made to remedies selected in the ROD.

Given the preference established by SARA for permanent remedies (that is, treatment) over containment or disposal in remediation of NPL sites, EPA currently tracks the status and accomplishments of projects for the application of treatment technologies at NPL sites, including *in situ* and *ex situ* treatments for both source media and groundwater. Some 56 percent of all RODs analyzed for the ASR contained provisions for treatment.

For this report, as with the previous ASR Eleventh Edition, EPA reviews and analyzes data from CERCLIS and site documents and compiles information about remedies selected in RODs and the projects subsequently implemented at NPL sites. It should be noted that data have been included for a limited number of sites for which RODs have been signed, but which have not been listed on the NPL. Box 6 summarizes the format for presenting data in this report. ROD-level figures and site-level figures may present remedy selection data in two ways, depending on the objective of the figure, because a ROD or a site may have multiple remedies. For some figures, RODs (or sites) that selected multiple remedies are counted in each category of remedy type as appropriate. For example, a single ROD that selects two remedy types is listed in each applicable category. For other figures, a hierarchy is used to classify a ROD (or site) into a single category of remedy types. This hierarchy has been established to represent the data consistent with the preferred remedial approach (treatment over containment or other remedies). Notes on individual figures and tables indicate whether or not a hierarchy was used. Additionally, although data have been collected since 1982, some figures do not include earlier years to minimize their size and simplify their format, or because little information was available

Project-level data portray information about actual treatment projects (remedies) planned or under way at NPL sites. These data are based on the specific technology (such as bioremediation or chemical treatment) selected or being implemented for a site. (See the definitions of specific treatment technologies in Appendix C.) Each individual treatment system is considered its own project. For example, where two air sparging systems (or two separate P&T systems) are treating separate plumes at a site, the site would contribute two separate air sparging projects (or two P&T projects). Project-level data are not only based on RODs, amendments, or ESDs, but also on 5-year review reports, PCORs, and site summaries. In addition to the technology implemented, project-level data include information about the status of the project, the media and contaminants treated, and other information. Projects are updated based on the technology actually implemented at a site (or OU). For instance, the treatment associated with a project is updated accordingly if a technology changes from one treatment technology to another. Project data may change until the project is completed or project managers decide that the technology will not be used. Site-level data combines project-level data and ROD data for all remedies at a particular site.

Box 6. Reporting of ROD and Project Data in the ASR

ROD Data:

ROD data (remedy selection data) are reported:
- By media (source control or groundwater), or
- Grouped using a hierarchy (each ROD being listed once) under the categories of treatment, containment, and other.

ROD data for source control are reported:
- With each of the remedies selected in a ROD classified under a specific remedy type* (with more than one remedy identified if appropriate), or
- With all remedies selected by a single ROD grouped using a hierarchy (each ROD being listed only once) under the categories of treatment, containment, and other.

ROD data for groundwater are reported:
- With each of the remedies selected in a ROD classified under a specific remedy type* (with more than one remedy identified if appropriate), or
- With all remedies selected by a single ROD grouped using a hierarchy (each ROD being listed only once) under the categories of treatment, MNA, containment, and other.

Project Data:

Project data portrays information about actual projects planned or underway at NPL sites.

Each remedy is considered a single project, for which technology, status, contaminant, and other information is provided.

Site Data:

These data combine ROD data and project-level data for all remedies at a particular site.

Site data are reported:

- With each of the remedies selected for a site classified under a specific remedy type* (with more than one remedy identified if appropriate), or
- With all remedies selected for a site grouped using a hierarchy (each remedy being listed only once) under the categories of treatment, MNA, containment, and other. These groupings may be subdivided according to media (source control and groundwater).

*See Box 3 and Appendix F for additional information about remedy types.

Organization of the ASR Twelfth Edition

The ASR Twelfth Edition consists of the following major sections:

- Executive Summary - Summarizes the major findings of the report.
- Section 1: Introduction - Provides an introduction to the ASR, the types of data contained in the report, and the framework used for reporting data.
- Section 2: Overview of Data - Presents an overview of the remedies selected in decision documents and status of projects planned or underway at NPL sites.
- Section 3: Treatment Technologies for Source Control - Reports data and trends associated with remedy decisions and projects to address contaminated source media.
- Section 4: Treatment Technologies for Groundwater - Reports data and trends associated with remedy decisions and projects to address contaminated groundwater.
- Section 5: Report Focus Area - On-Site Containment Remedies - Provides data and analysis for a limited sample of on-site containment remedies.
- Section 6: References and Sources of Additional Information - Identifies references for data used in the development of the ASR and sources of additional data. Note: Section 6 contains references to online sources of ASR data and ASR appendices not included in the print version of the report.

Section 2: Overview of Data

As of September 2005, 1,536 sites had been listed on the NPL. Of those, 307 sites had been deleted, leaving 1,229 sites on the NPL. An additional 54 sites were proposed for listing at that time. Updated information on site listings and deletions is available at *http://www.epa.gov/superfund*.

Figure 1 provides a summary of the number of NPL sites (both current and deleted) by type of remedial action. The types of remedies planned or under way at each site were identified and the sites were classified based on the most recent information about the implementation status of the remedies. At nearly two-thirds of NPL sites (63 percent), source control treatment, groundwater treatment, or both, have been implemented or are planned as a remedy for some portion of the site. More than a quarter of the sites (28 percent) selected treatment for both source control and groundwater. The selected remedies do not include treatment for 24 percent of sites. No ROD has been issued for 13 percent of all NPL sites.

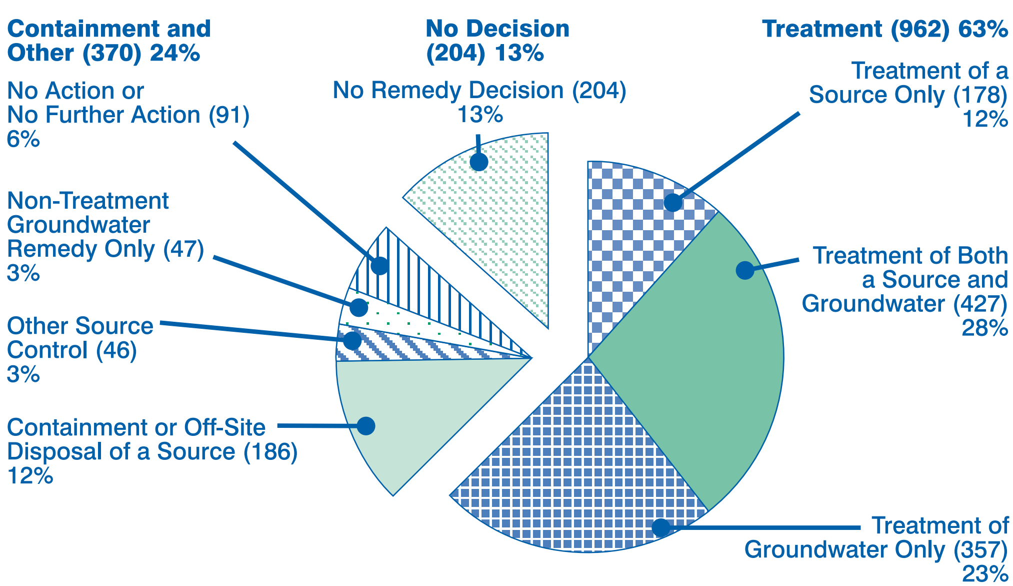
For the 1,536 sites that were listed on the NPL from 1982 through 2005:

- 2,976 RODs and ROD amendments were signed
- 1,915 treatment projects have been implemented or are planned

As discussed in the Introduction, each ROD and ROD amendment, and the remedies they selected, have been classified by the remedy types identified in Appendix F. The following text presents a brief overview of remedies selected in RODs and the status of projects undertaken.

Figure 1: Actual Remedy Types at Sites on the NPL (FY 1982 - 2005)*

Total Number of Sites = 1,536



Treatment remedies are planned or implemented at 63 percent of NPL sites.

**Includes final or deleted NPL sites as of September 2005. Also includes information from an estimated 74 percent of FY 2005 records of decision and amendments available as of October 2006 and project data available in CERCLIS as of October 2006.*

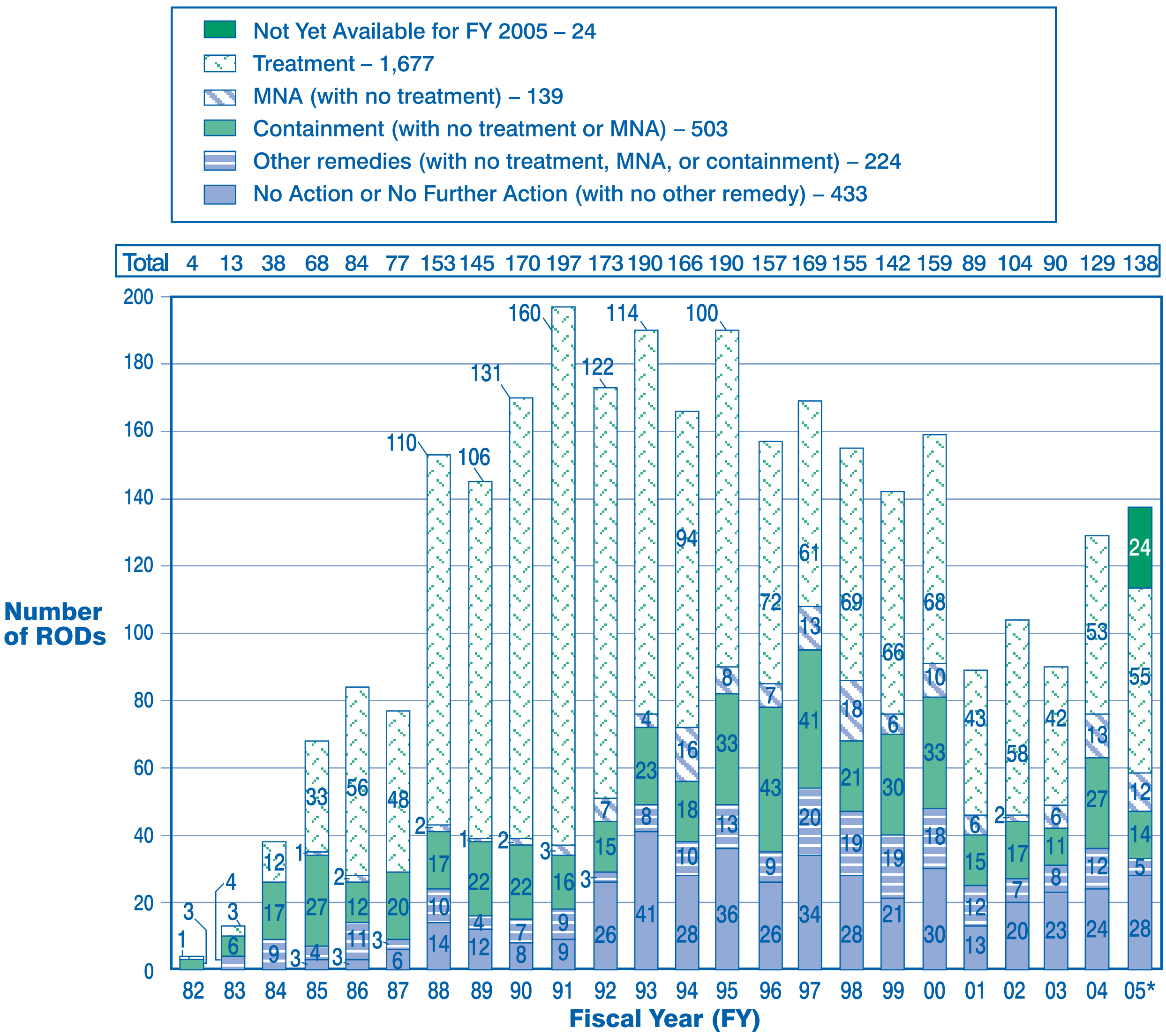
Each NPL site is listed only once using the following hierarchy: treatment, containment, and other. Sites with treatment remedies may also include containment and other non-treatment remedies. Sites with containment/disposal may include other non-treatment remedies. Other source control (described in Appendix F) includes institutional controls and other non-treatment/non-containment remedies. Non-treatment groundwater remedies include MNA, containment, and other remedies defined in Appendix F.

Sources: 1, 2, 3, 4, 7. Data sources are listed in Section 6.

Remedies Selected in RODs

Superfund remedy decisions are documented in RODs. ROD amendments are used to document changes to remedies that occur after a ROD has been signed. Figure 2 presents remedy decisions from FY 1982 to 2005. During that period, 2,976 RODs and ROD amendments were signed documenting groundwater and source control remedies (as well as no action and no further action). Since FY 1991, the number of RODs signed per year generally decreased. Recent years indicate that the trend may be leveling off or beginning to increase.

Figure 2: Remedies Selected in RODs
(FY 1982 - 2005)*
Total Number of RODs = 2,976



The number of RODs signed each year peaked at 197 in FY 1991, 11 years after CERCLA was enacted.

MNA = Monitored natural attenuation
ROD = Record of Decision (Note: Data include ROD amendments)
**Includes information from an estimated 74 percent of FY 2005 RODs and amendments available as of October 2006. The following hierarchy was used for this figure to count RODs only once: treatment, MNA, containment, other non-treatment remedies, and no action/no further action.*
Sources: 3, 4, 7. Data sources are listed in Section 6.

Using the previously described hierarchy for classifying remedies selected, the 2,976 RODs and ROD amendments signed between FY 1982 and 2005 may be classified as:

- Treatment remedies - 1,677 (56 percent)
- MNA for groundwater (with no treatment) - 139 (5 percent)
- Containment remedies (without treatment) - 503 (17 percent)
- Other remedies such as institutional controls or monitoring (with no treatment, MNA, or containment) - 224 (7 percent)
- No action or no further action (with no treatment, MNA, containment, or other remedy) - 433 (15 percent)

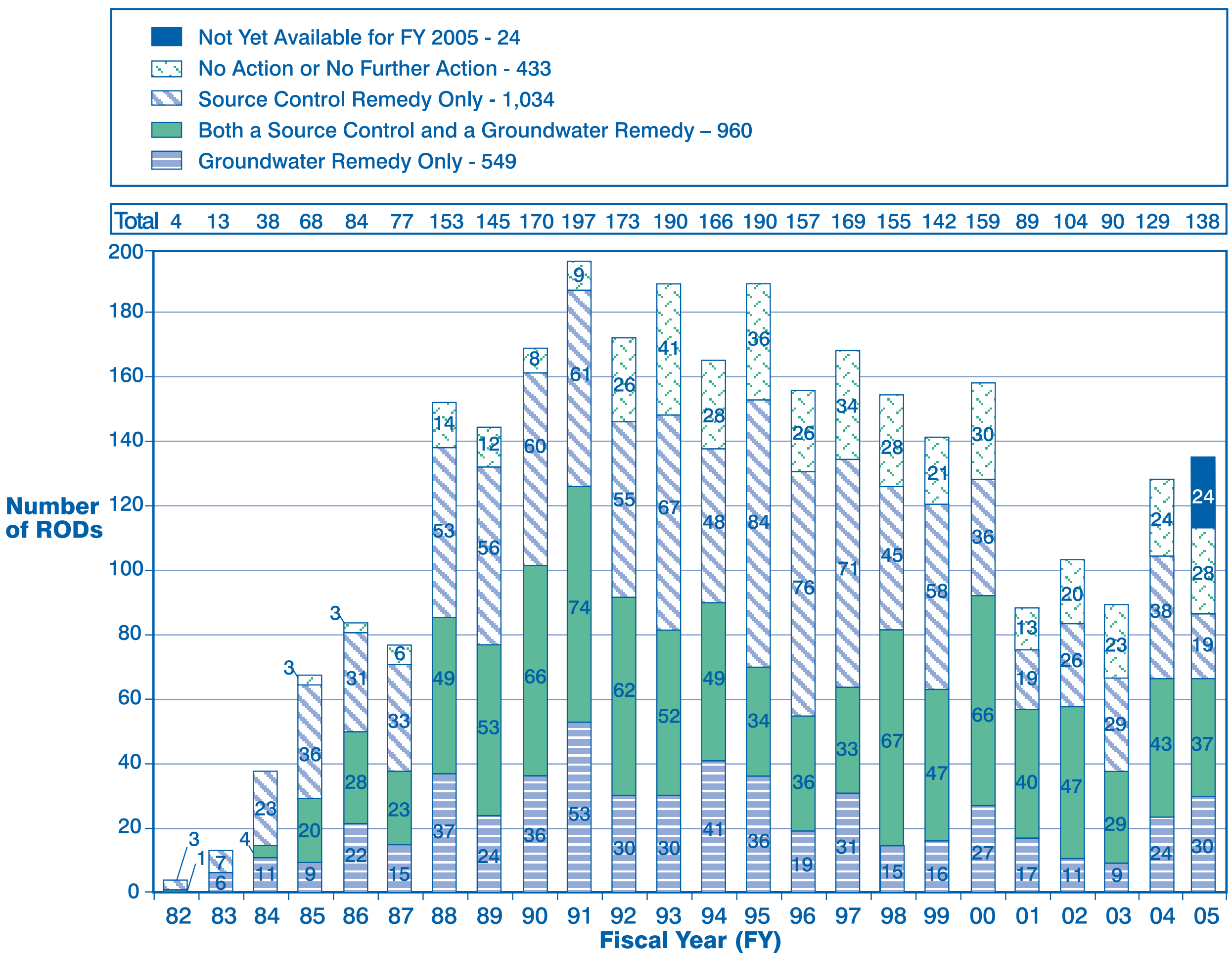
RODs may include a single remedy to address source control or groundwater or may contain multiple remedies for both sources and groundwater within a single OU, for multiple OUs, or across the entire site.

Figure 3 shows the number of RODs for each fiscal year that selected:

- Only source control remedies
- Both groundwater and source control remedies
- Only groundwater remedies
- No action or no further action remedies

Figure 3: Media Addressed in RODs (FY 1982 - 2005)*

Total Number of RODs = 2,976



In most years since FY 1998, many RODs include remedies that address both source control and groundwater media.

ROD = Record of Decision (Note: Data include ROD amendments)
**Includes information from an estimated 74 percent of FY 2005 RODs available as of October 2006. RODs are counted only once in this figure as appropriate.*
Sources: 3, 4, 7. Data sources are listed in Section 6.

Status of Superfund Remediation Projects

Information collected and analyzed for this report helps document the progress and contributions of technologies implemented at NPL sites. In addition to presenting information about remedy decisions based on RODs and ROD amendments, this report provides project-related data concerning operational status and treatment applications. This section presents a brief overview of the progress of treatment technologies at Superfund remedial action sites. Box 7 explains how the status of a project is classified.

Some 56 percent (1,677) of the 2,976 RODs analyzed for the ASR contained provisions for treatment of source media or groundwater. EPA currently tracks the status of 1,915 treatment projects at NPL sites, including *in situ* and *ex situ* treatment projects for both source control and groundwater. These applications include:

- 515 *ex situ* source control treatment projects (27 percent of all projects)
- 421 *in situ* source control treatment projects (22 percent)

> **Box 7. Classifying the Status of Projects**
>
> The Superfund cleanup process begins with Site Discovery followed by NPL Listing, Remedial Investigation/Feasibility Study, ROD, Remedial Design/Remedial Action, Construction Completion, and NPL Deletion. These stages are based on the site as a whole, not individual actions (or projects) at the site. In contrast, the ASR evaluates projects individually based on the following classifications. After a remedy is selected in a ROD, the project begins in the "predesign/design" phase where the project team is formed and the design of the remedy is developed. Additional data may be collected and bench-scale or pilot-scale testing may also be conducted during this phase, if necessary. The next phase is called "design complete/being installed" and continues through installation until construction is complete. The third phase includes the "operational" phase where the technology is operating and treatment is being conducted. The final phase, "completion," occurs when operations are ceased and the treatment system is shut down.

- 725 P&T projects (38 percent)
- 213 *in situ* groundwater treatment projects (11 percent)
- 41 *in situ* source control and *in situ* groundwater treatment projects (2 percent)

Figure 4 presents data about 687 completed treatment projects by media (i.e., projects where treatment is no longer under way). The term "completed" does not necessarily indicate that treatment goals have been achieved. Although most source control treatment projects that are completed have achieved their treatment goals, groundwater projects may have been completed or shut down because of issues with the treatment technology. These issues can include technical problems with the equipment, continuing sources of contamination, or may result because concentrations have been reduced significantly but not to the point of cleanup goals. It may therefore be more appropriate to describe these projects as "shut down" rather than "completed" in this report. Appendix G lists the 73 P&T projects that are shut down and the reasons that were identified for making the decision. EPA is currently gathering additional data to better understand, across the Superfund program, the decisions that result in the shutdown of P&T systems. In many cases, this decision appears to be driven by a "treatment train" approach, where P&T is supplemented by a different remedy such as *in situ* treatment or MNA.

For the 1,915 treatment projects:

- 687 projects (36 percent) have been completed or shut down
- 857 projects (45 percent) are operational
- 371 projects (19 percent) are being designed or constructed

> **Box 8. Definition of a Completed Project**
>
> Project completion and construction completion (CC) are different terms used in defining progress in Superfund. The first refers to a specific project (for example, a soil vapor extraction system that has been shut down after cleanup levels have been achieved), whereas CC refers to construction of all remedies for an entire site (all remedial construction at the site has been completed). Note that project completion does not always indicate that all cleanup goals have been achieved, as projects may sometimes be shut down for other reasons.

Most of the completed projects are *ex situ* source control treatments (57 percent). *Ex situ* source control projects usually involve excavation of contaminated soil and application of an aggressive treatment technology in a controlled environment. Therefore, this type of remedy typically requires a shorter amount of time to complete. Additional information on source control projects is presented in Section 3.

In situ treatments are applied to contaminated media in place, without excavation. These projects typically require longer treatment times because they take place in a less controlled environment, which may limit the treatment rate. *In situ* treatment technologies represent approximately 31 percent of completed projects, with 170 of those 216 projects addressing *in situ* source control treatment only (with no groundwater treatment).

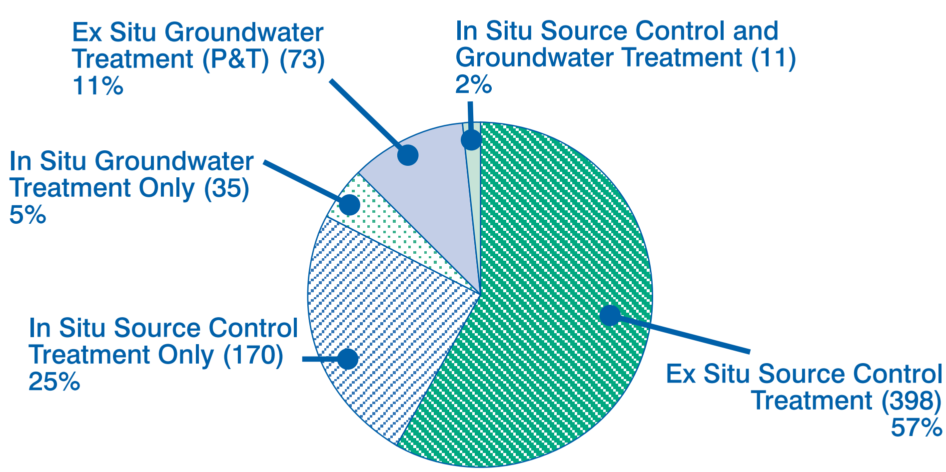
P&T projects, which represent the largest number of treatment projects (725), also typically require long treatment times, and in fact represent only 11 percent of all completed and shut down projects. The application of P&T is often limited by environmental factors, including the rate contaminated groundwater can be extracted from an aquifer and the presence of continuing sources of groundwater contamination such as DNAPLs. Additional information on groundwater projects is provided in Section 4.

Figure 5 shows the number of completed and shut down projects for the most commonly used technologies for *ex situ* source control, *in situ* source control, *in situ* groundwater, and P&T. Nearly all incineration projects have been completed. Additionally, nearly 80 percent of the S/S (*ex situ*) and thermal desorption projects have been completed.

Approximately 64 percent of S/S projects *(in situ)* and 43 percent of SVE projects have been completed. Fewer *in situ* groundwater projects have been completed compared to source control projects. However, these technologies tend to be innovative and have been selected in more recent RODs. Ten percent of P&T projects have been shut down.

Figure 4: Completed Treatment Projects by Remedy Type (FY 1982 - 2005)*

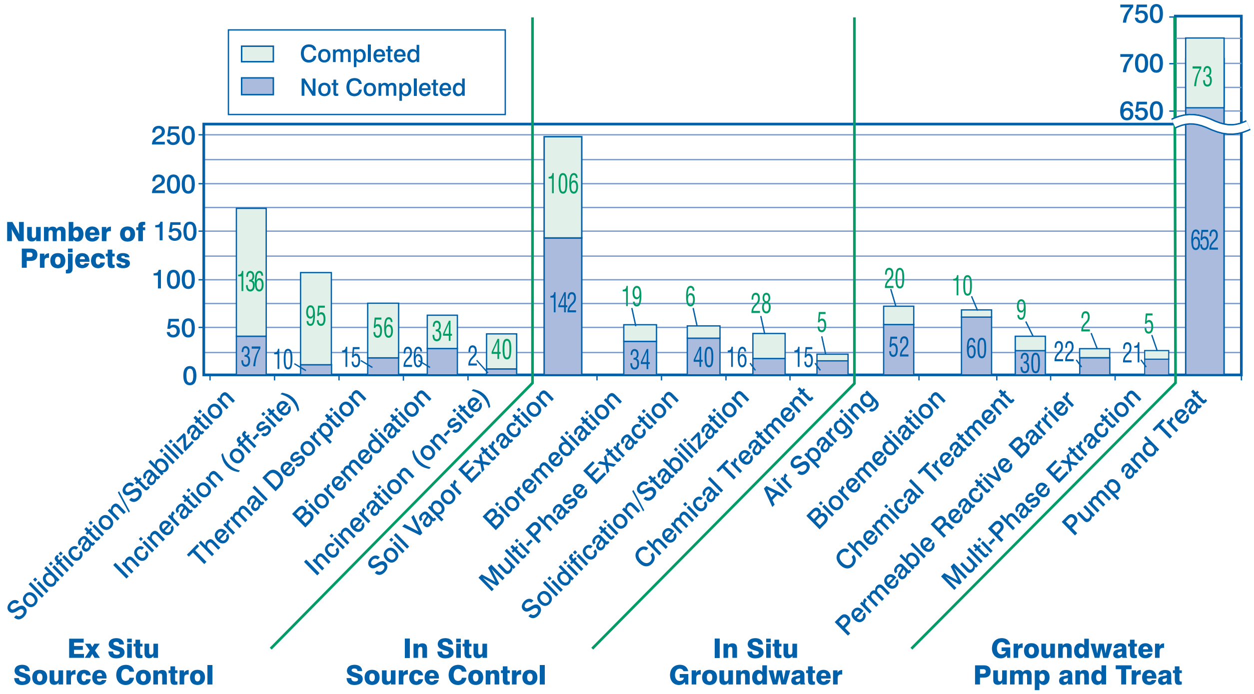
Total Projects Completed = 687



Nearly one-third of completed treatment projects are in situ technologies.

**Includes information from an estimated 74 percent of FY 2005 records of decision and amendments available as of October 2006 and project data available in CERCLIS as of October 2006. Completed does not always indicate that cleanup goals have been met.*
Sources: 3, 4, 7. Data sources are listed in Section 6.

Figure 5: Projects Completed for the Most Common Technologies (FY 1982 - 2005)*



Most ex situ treatment projects have been completed; in situ treatment and pump and treat projects tend to have longer operation times.

**Includes information from an estimated 74 percent of FY 2005 records of decision and amendments available as of October 2006 and project data available in CERCLIS as of October 2006. Completed does not always indicate that cleanup goals have been met. Only the most common technologies are included in this figure (representing 644 of the 687 total completed treatment projects).*
Sources: 3, 4, 7. Data sources are listed in Section 6.

Section 3: Treatment Technologies for Source Control

Source control remedies address soil, sediment, sludge, solid-matrix wastes, or NAPL (in other words, the source of contamination) and do not address groundwater directly. Source control remedies can be delineated by the general type of remedy specified: (1) source control treatment that is either *in situ* or *ex situ*, (2) source control containment that uses caps or liners, or (3) other actions (such as population relocation or institutional controls). Box 9 delineates source control remedies by remedy type and provides a description for each category.

Box 9. Source Control Remedy Types

Source Control Treatment

- Treatment of a contaminant source *in situ* or *ex situ*.
- Includes any of the source control treatment technologies described in this report, such as chemical treatment and thermal desorption.

Source Control Containment

- Containment of a contaminant source.
- Includes the use of caps, liners, covers, and landfilling both on and off site.

Source Control Other

- Other remedies for contaminant sources.
- Includes institutional controls, monitoring, and population relocation.

Beyond categorization by remedy type, source control treatment projects may be classified as 1 of 17 specific technologies. Definitions for these remedies are presented in Appendix C. Specific key words in decision documents determine the remedy classification into 1 of the 17 technologies. Key words used to classify source control treatment remedies are listed in Appendix F. Some of these technologies may also be used in other applications, such as to treat contaminated groundwater. Technology definitions are based on the Remediation Technologies Screening Matrix and Reference Guide, Version 4.0, which can be viewed at the Federal Remediation Technologies Roundtable (FRTR) Web site at http://www.frtr.gov.

Of the 1,104 source control treatment RODs, a total of 977 projects were planned or implemented at 605 sites. Tables 1 and 2 provide breakdowns of the source control remedies by sites and RODs, respectively. The following section of this report discusses the latest data and historical trends associated with these RODs and source control treatment projects.

Table 1. Actual Source Control Remedy Types at NPL Sites (FY 1982 - 2005)*

Total Number of Sites with a Source Control Remedy = 1,055

Remedy Type	Number of Sites
Treatment of a Source	605
Containment or Off-Site Disposal of a Source	632
Other Source Control	682

**Includes final or deleted NPL sites as of September 2005. Also includes information from an estimated 74 percent of FY 2005 records of decision and amendments available as of October 2006 and project data available in CERCLIS as of October 2006.*
No hierarchy is used for this table; sites may be included in more than one category.
Sources: 1, 2, 3, 4, 7. Data sources are listed in Section 6.

Download file containing source data for Table 1.

Table 2. RODs Selecting Source Control Remedies (FY 1982 - 2005)*

Total Number of RODs with a Source Control Remedy = 1,994

Remedy Type	Number of RODs
Treatment of a Source	1,104
Containment or Off-Site Disposal of a Source	953
Other Source Control	507

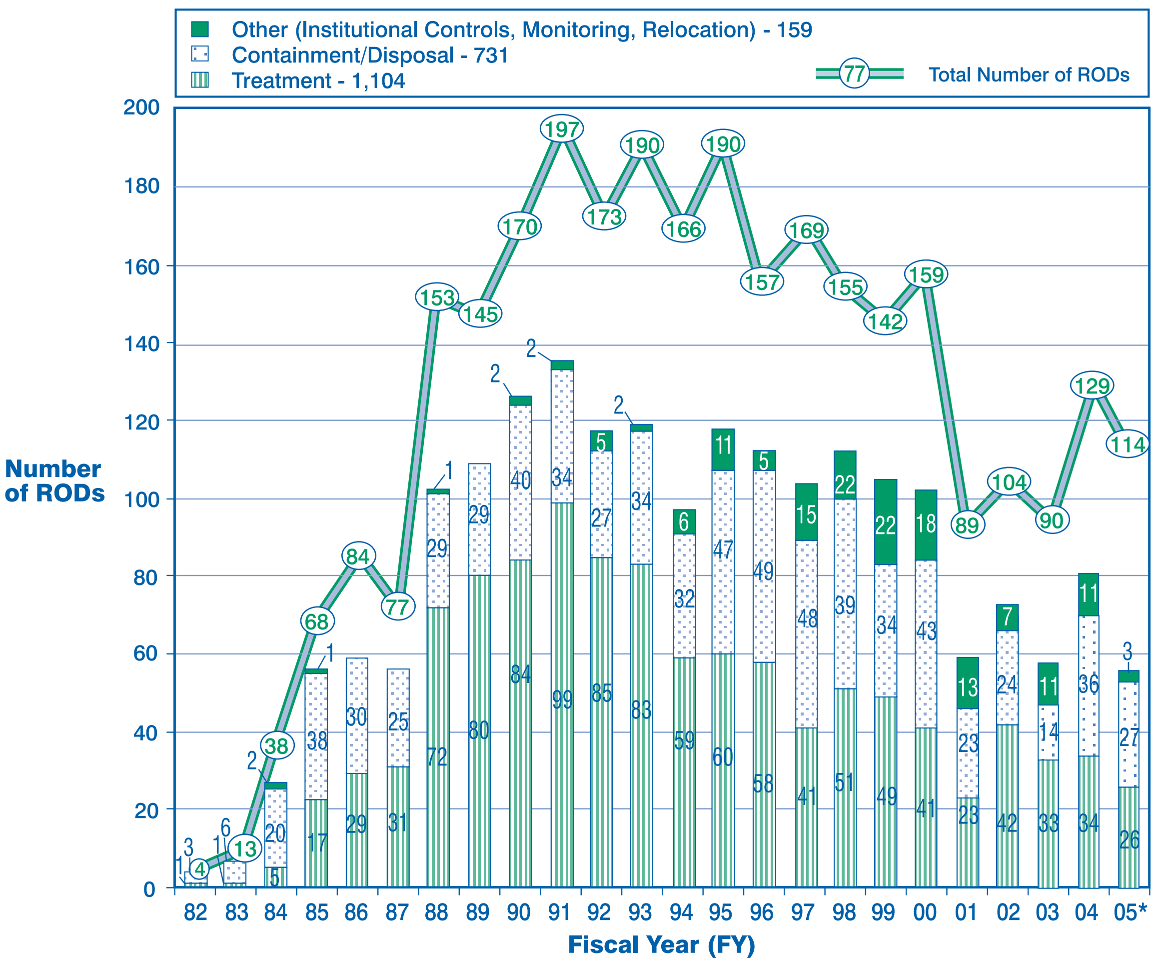
ROD = Record of Decision (Note: Date include ROD amendments)
**Includes information from an estimated 74 percent of FY 2005 RODs and amendments available as of October 2006.*
No hierarchy is used for this table; RODs and amendments may be counted in more than one category.
Sources: 3, 4, 7. Data sources are listed in Section 6.

The following subsections provide information about (1) the selection of source control remedies and (2) technologies, status, and contaminants treated for source control treatment projects.

Source Control RODs

Of the 2,976 RODs and amendments signed between FY 1982 and 2005, 67 percent (1,994) addressed the source of contamination. Figure 6 delineates source control RODs, showing annual totals for treatment, containment and disposal, and other categories. The trends exhibited for all source control remedies and source control treatment generally track with the trends for RODs overall, with the number of source treatment RODs ranging from 23 to 42 annually over the last 5 years. Figure 7 shows the percentage of source control RODs of each type for each fiscal year. For Figures 6 and 7, each ROD, which may select multiple remedies, is assigned a single remedy type based on the classification hierarchy discussed in the Introduction (i.e., source control treatment, source control containment, and other). For example, RODs that select treatment are considered "source control treatment RODs" even though they may also have selected additional remedies including containment or other remedies. "Source control containment" includes those using containment but no treatment. Containment RODs may also have selected other non-treatment source control remedies. Other source

Figure 6: Source Control RODs
(FY 1982 - 2005)*
Total Number of RODs = 1,994

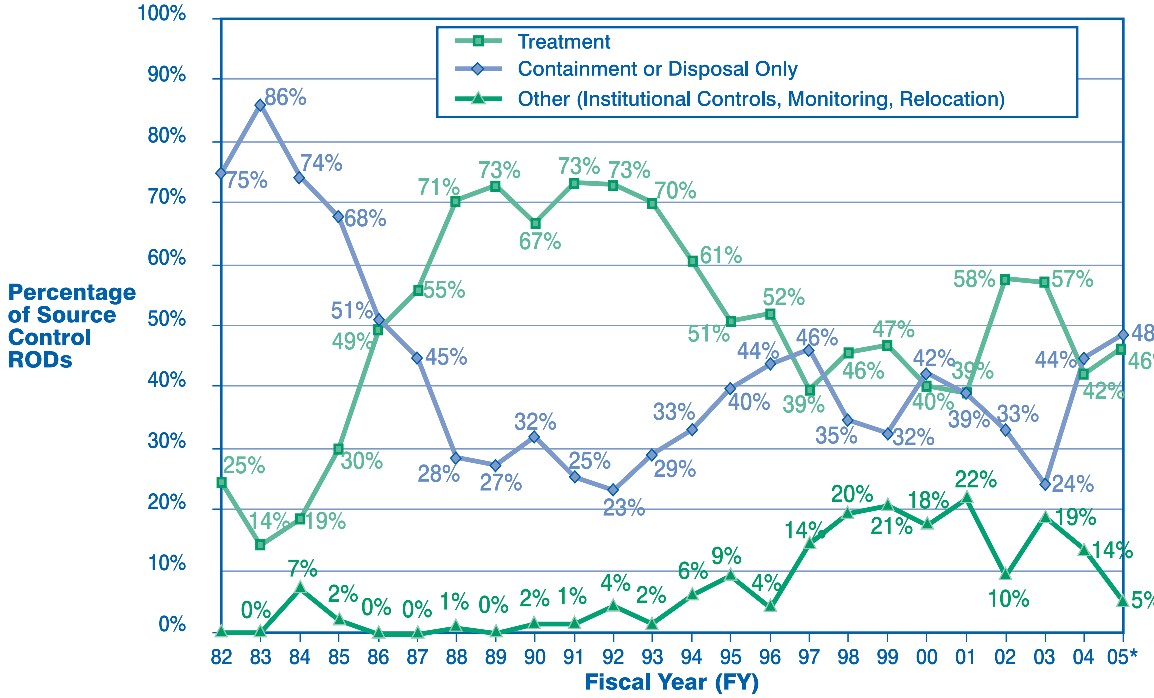


For most years, the majority of source control RODs selected treatment.

ROD = Record of Decision (Note: Data include ROD amendments)
**Includes information from an estimated 74 percent of FY 2005 RODs available as of October 2006. RODs are only counted once in this figure using the following hierarchy: source control treatment, source control containment or disposal with no treatment, then source control other remedies only.*
Sources: 3, 4, 7. Data sources are listed in Section 6.

Figure 7: Trends in Types of Source Control RODs (FY 1982 - 2005)*

Total Number of RODs = 1,994



Since 1986, the percentage of source control RODs selecting treatment usually has been greater than those for containment/disposal without treatment; however, the gap appears to be closing.

ROD = Record of Decision (Note: Data include ROD amendments)
**Includes information from an estimated 74 percent of FY 2005 RODs available as of October 2006.*
RODs are only counted once in this figure using the following hierarchy: source control treatment, source control containment or disposal with no treatment, then source control other only.
Sources: 3, 4, 7. Data sources are listed in Section 6.

control remedies (such as institutional controls, relocation, and others) are the only remedy type represented in the other column.

As shown in Figure 7, from FY 1987 to 2003 (with the exception of FY 1997 and 2000), the percentage of RODs including a source control treatment remedy has equaled or exceeded the percentage of RODs with source control containment (and no treatment). Over the last two years, the percentage of source control containment RODs has slightly exceeded those with some treatment. Cumulatively:

- 55 percent of source control RODs use some form of "treatment"
- 37 percent are "containment or disposal" RODs that do not include "treatment"
- 8 percent are "other source remedy" and use remedies such as institutional controls, monitoring, or population relocation (with no treatment or containment)

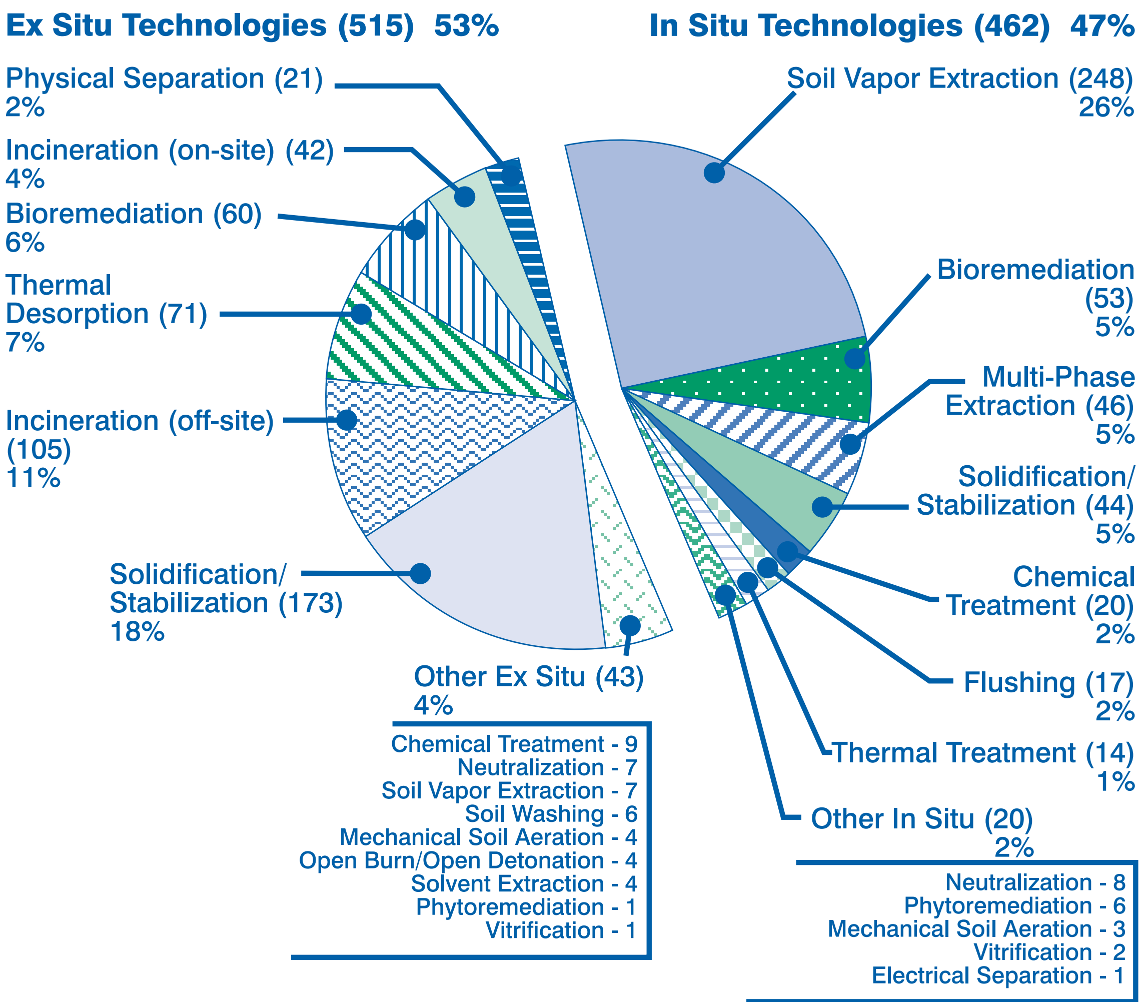
From FY 2002 to 2005, the percentage of each type of source control remedy has remained consistent with the cumulative percentages, with approximate values of 51 percent treatment, 37 percent containment, and 12 percent other. The percentage of source control treatment RODs was generally higher from FY 1988 through 1996, ranging from 51 percent to 73 percent, while the percentages of containment and other source control remedies were generally lower.

Source Control Treatment Projects

From FY 1982 through 2005, 977 treatment projects were selected for source control. Figure 8 provides a cumulative overview of these treatment technologies.

Figure 8: Source Control Treatment Projects (FY 1982 - 2005)*

Total Number of Projects = 977



Cumulatively, more than half of source control treatment projects have been ex situ, although the single most common treatment technology has been in situ soil vapor extraction.

**Includes information from an estimated 74 percent of FY 2005 records of decision and amendments available as of October 2006 and project data available in CERCLIS as of October 2006.*
Sources: 3, 4, 7. Data sources are listed in Section 6.

In Situ Versus *Ex Situ* Technologies

In situ treatment technologies for source control treat or remove the contaminated medium without excavating, pumping, or otherwise moving the contaminated medium to the surface. Implementation of *ex situ* technologies requires excavation, dredging, or other processes to remove the contaminated medium before treatment either on site or off site.

As Figure 8 indicates, the most common *in situ* technologies, together making up 85 percent of all *in situ* source control treatment projects, are:

- SVE (248 projects, 26 percent of all source control treatment projects)
- Bioremediation (53 projects, 5 percent)
- Multi-phase extraction (46 projects, 5 percent)
- S/S (44 projects, 5 percent)

The most common *ex situ* technologies, representing 88 percent of all *ex situ* source control treatment projects, are:

- S/S - 173 projects (18 percent)
- Incineration, both on and off site - 147 projects (15 percent)
- Thermal desorption - 71 projects (7 percent)
- Bioremediation - 60 projects (6 percent)

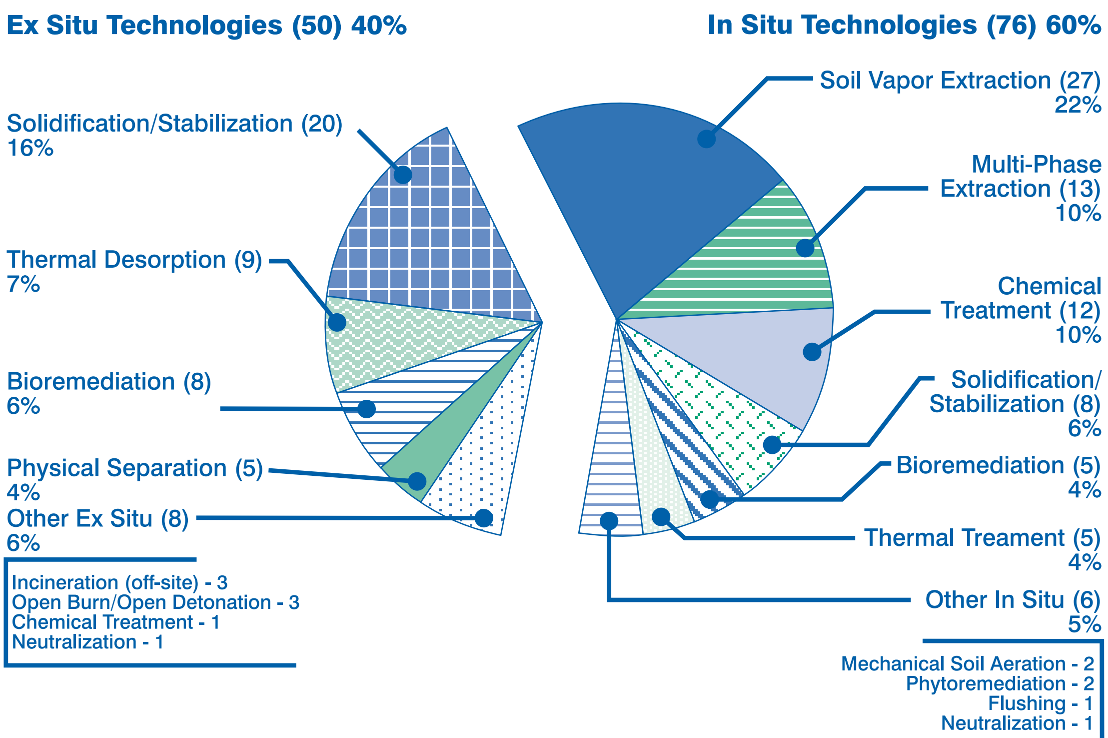
More recently, 126 source control treatment projects have been selected from FY 2002 to 2005. As shown in Figure 9, S/S (both *in situ* and *ex situ*), *in situ* SVE, and bioremediation (both *in situ* and *ex situ*) are still the technologies most frequently selected. Multi-phase extraction has been selected more frequently recently, with a third of the total number of projects (13 of 46) selected in the last 4 years. Selection of *in situ* chemical treatment has also increased, with more than half of the projects (12 of 20) being selected during the period from FY 2002 to 2005. Some of the more common established technologies, including incineration (off-site) and thermal desorption, were selected less frequently.

As shown in Figure 10, *in situ* source control treatment technologies display a gradual increase as a percentage of all treatment technology projects between FY 1985 and 2005. The figure does not include FY 1982 through 1984 because too few RODs were signed during those years to develop accurate information about trends in remedy selection. A 5-year moving average of the percentage of *in situ* treatment technologies has nearly doubled from 33 percent (FY 1985 to 1989) to 64 percent (FY 2001 to 2005). The following factors may play a role in this upward trend:

- Because *in situ* technologies require no excavation, risk from exposure to contaminated media is reduced, compared with levels of risk associated with *ex situ* technologies that require excavation.

Figure 9: Source Control Treatment Projects (FY 2002 - 2005)*

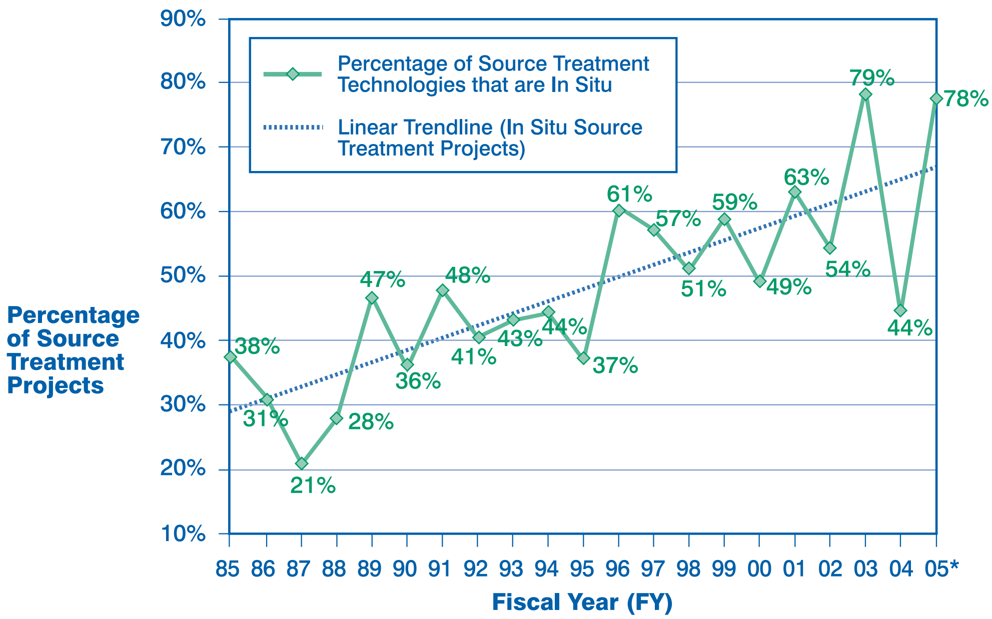
Total Number of Projects = 126



In recent years, more than half of the selected treatment technologies for source control have been in situ. Soil vapor extraction continues to be the most commonly selected in situ remedy, now followed by multi-phase extraction and chemical treatment.

**Includes information from an estimated 74 percent of FY 2005 records of decision and amendments available as of October 2006 and project data available in CERCLIS as of October 2006.*
Sources: 3, 4, 7. Data sources are listed in Section 6.

Figure 10: In Situ Technologies for Source Media (FY 1985 - 2005)*



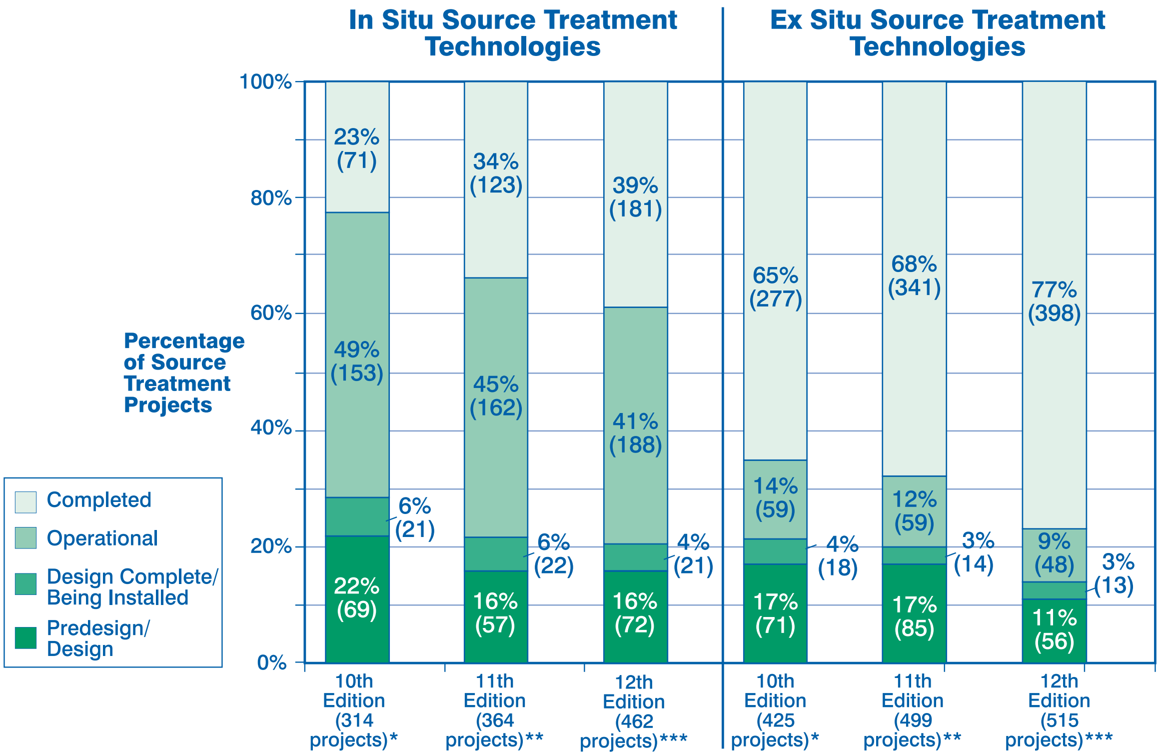
On average, the number of in situ treatment projects has gradually increased. In situ remedies can reduce potential risks from waste because there is no excavation, and can be more cost effective than ex situ technologies.

**Includes information from an estimated 74 percent of FY 2005 records of decision and amendments available as of October 2006 and project data available in CERCLIS as of October 2006.*
Sources: 3, 4, 7. Data sources are listed in Section 6.

Box 10. *In Situ* Chemical Treatment at Eastland Woolen Mill, Maine

In situ chemical treatment is being used to treat soil, DNAPL, and groundwater contamination at the Eastland Woolen Mill site in Maine. This site served as a textile mill from 1909 to 1996 and related activities led to chlorobenzene (mono, di, tri, and tetra) contamination in soil, groundwater, and nearby surface water. DNAPL has also been observed at the site. A non-time critical removal action (NTCRA) was conducted between 1999 and 2003. This action removed all soil contamination above the water table and most soil contamination, including the DNAPL, below the water table, and resulted in decreasing groundwater contamination levels. However, since contamination would remain in a few areas that were inaccessible to excavation, a ROD was signed in 2002, which selected *in situ* chemical treatment to reduce the mass of contamination in the soil and bedrock fractures to achieve groundwater restoration. Based on pilot studies that were conducted as part of the NTCRA, iron-catalyzed sodium persulfate was determined to be the optimal oxidant for use at this site. The *in situ* chemical treatment system was constructed in September 2006 and is currently operational. Following chemical oxidation, bioremediation may be conducted if cleanup levels are not achieved. A ROD Amendment was issued in 2006, which eliminated two components of the original ROD (P&T to limit the migration of contaminated groundwater and *in situ* flushing), because it was determined these actions were no longer necessary following the success of the removal action.

Figure 11: Status of In Situ and Ex Situ Source Treatment Projects - Comparison Between Tenth, Eleventh and Twelfth Editions of the ASR (FY 1982 - 2005)***



The percentage of projects at the end of the Superfund pipeline, those completed, has increased while the percentage of projects at the beginning of the pipeline, in predesign/design,has decreased.

ROD = Record of Decision (Note: Data include ROD amendments)
**Includes information from RODs through FY 1999 available as of summer 2000.*
***Includes information from an estimated 70 percent of FY 2002 RODs available as of March 2003.*
****Includes information from an estimated 74 percent of FY 2005 RODs available as of October 2006 and project data available in CERCLIS as of October 2006.*
Sources: 3, 4, 7. Data sources are listed in Section 6.

- *In situ* technologies are often more cost-effective at large sites where excavation and materials handling for *ex situ* technologies can be expensive.
- As *in situ* treatment technologies are used more frequently, site managers, regulators, and other remediation professionals are coming to accept them as a reliable technology.

Status of Source Control Treatment Projects

Figure 11 shows the status of *in situ* and *ex situ* source control treatment projects, comparing the projects in the Tenth Edition of the ASR (data collected through FY 1999) and the Eleventh Edition (data collected through March 2003) with the Twelfth Edition (data collected through October 2006). Based on the data in Figure 11, in this 3-year period:

- The number of completed *in situ* source control projects increased from 123 to 181 (a 47 percent increase), while completed *ex situ* source control projects increased from 341 to 398 (a 17 percent increase).
- *In situ* source control projects completed since the Eleventh Edition included 33 SVE, 10 bioremediation, 6 S/S, 6 multi-phase extraction, 4 chemical treatment, 3 neutralization, 2 flushing, 1 thermal treatment, 1 phytoremediation, and 1 electrical separation project.
- *Ex situ* source control projects completed since the Eleventh Edition included 20 S/S, 7 bioremediation, 7 incineration (off-site), 7 physical separation, 4 thermal desorption, 2 solvent extraction, and 1 soil washing project.

Table 3. Status of Source Treatment Projects by Technology (FY 1982 - 2005)*

Technology	Predesign/ Design	Design Complete/ Being Installed	Operational	Completed	Total
In Situ					
Soil Vapor Extraction	23	9	110	106	248
Bioremediation	8	1	25	19	53
Multi-Phase Extraction	8	2	30	6	46
Solidification/Stabilization	13	1	2	28	44
Chemical Treatment	9	3	3	5	20
Flushing	1	2	9	5	17
Thermal Treatment	5	2	3	4	14
Neutralization	0	1	3	4	8
Phytoremediation	2	0	3	1	6
Mechanical Soil Aeration	2	0	0	1	3
Vitrification	1	0	0	1	2
Electrical Separation	0	0	0	1	1
Total	**72**	**21**	**188**	**181**	**462**
Percentage of In Situ Technologies	16%	5%	41%	39%	—
Percentage of All Source Treatment Technologies	**7%**	**2%**	**19%**	**19%**	**47%**
Ex Situ					
Solidification/Stabilization	23	4	10	136	173
Incineration (off-site)	4	0	6	95	105
Thermal Desorption	10	1	4	56	71
Bioremediation	9	1	16	34	60
Incineration (on-site)	0	1	1	40	42
Physical Separation	3	2	6	10	21
Chemical Treatment	0	1	1	7	9
Neutralization	1	0	1	5	7
Soil Vapor Extraction	0	1	2	4	7
Soil Washing	2	0	1	3	6
Mechanical Soil Aeration	0	1	0	3	4
Open Burn/Open Detonation	2	1	0	1	4
Solvent Extraction	1	0	0	3	4
Phytoremediation	0	0	0	1	1
Vitrification	1	0	0	0	1
Total	**56**	**13**	**48**	**398**	**515**
Percentage of Ex Situ Technologies	11%	3%	9%	77%	—
Percentage of All Source Treatment Technologies	**6%**	**1%**	**5%**	**41%**	**53%**

** Includes information from an estimated 74 percent of FY 2005 records of decision and amendments available as of October 2006 and project data available in CERCLIS as of October 2006.*

Sources: 3, 4, 7. Data sources are listed in Section 6.

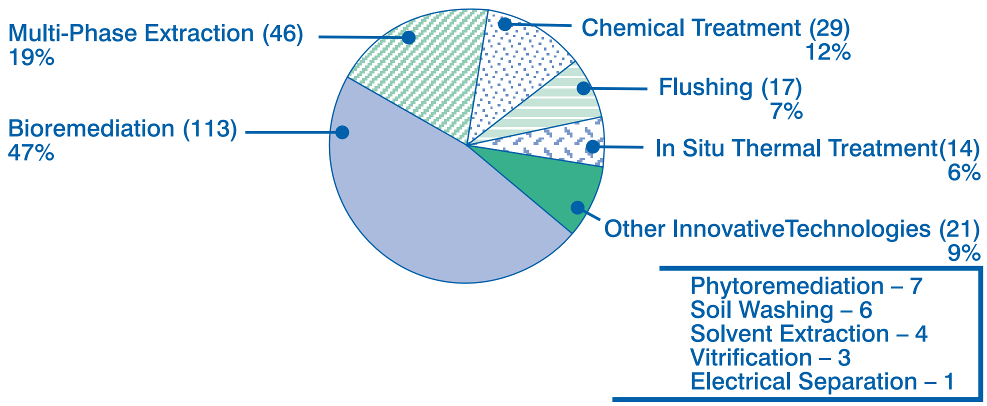
Download file containing source data for Table 3.

Please note that a comparison of the numbers in Figure 11 may not be consistent with the ASR Eleventh and Twelfth Editions because of projects that were reclassified during the collection and analysis of data for the most recent edition.

Table 3 provides a summary of project status for each technology type. Of the most commonly selected (20 or more selected projects), the highest percentage of completed projects of *in situ* technologies was for S/S, while the highest completion percentage for *ex situ* technologies involved incineration (on site). The completion percentages for these technologies, along with incineration (off site), S/S (*ex situ*), and thermal desorption, are high (above 75 percent) because they often can be completed within months, in contrast to *in situ* technologies such as SVE, which may require years to complete remediation. In general, *ex situ* projects, which can be implemented more quickly than *in situ* projects, represent a greater percentage of completed projects.

Figure 12: Innovative Applications of Source Treatment Technologies (FY 1982 - 2005)*

Total Number of Projects = 240



Bioremediation remains the most common innovative technology for source control treatment, making up nearly half of all innovative technologies. In recent years, multi-phase extraction and chemical treatment projects have been increasing (see Figure 9).

**Includes information from an estimated 74 percent of FY 2005 records of decision and amendments available as of October 2006 and project data available in CERCLIS as of October 2006.*
Sources: 3, 4, 7. Data sources are listed in Section 6.

Innovative Applications

Innovative technologies are defined as alternative treatment technologies that have a limited number of applications and limited data on cost and performance. Innovative technologies have the potential for providing more cost-effective and reliable alternatives for cleanup, or may offer a solution to an environmental problem historically considered impossible to treat.

For example, DNAPLs historically have been difficult to treat because of their physical and chemical properties (relatively low solubility, high specific gravity, and tendency to remain sorbed to organic materials in an aquifer). They tend to sink in the subsurface and continue to release dissolved contaminants to surrounding media. In addition, DNAPLs may not contact soil vapor, and therefore are not effectively treated by technologies that extract and treat soil vapor, such as *in situ* SVE. However, innovative technologies such as *in situ* thermal treatment or *in situ* flushing have been found to effectively treat DNAPLs. In other cases, an innovative technology may be less expensive than an established technology. It may be expensive to treat soils deep below the ground surface by incineration because of the amount of excavation required to reach the soil. However, an *in situ* chemical oxidation process may work effectively at that depth, while avoiding the cost of excavation to reach the source zone. Other reasons for selecting innovative technologies can include a reduction in exposure of workers to contaminated media; and community concern about off-site releases of contaminants, noise, or odor.

Figure 12 depicts the number and types of innovative technologies used for source control treatment. Innovative treatment technologies currently account for 25 percent of all source treatment technologies compared with the Eleventh Edition of the ASR, where innovative technologies made up only 21 percent. As with the Eleventh Edition, bioremediation still contributes nearly one half of the innovative applications (113 projects, 47 percent). Multi-phase extraction accounts for nearly 20 percent of innovative technologies. This is a significant increase in applications compared with the Eleventh Edition, up from 8 applications to 46. However, of the 38 projects added since the Eleventh Edition, only 8 projects were newly selected between FY 2002 and 2005. The remaining 30 projects were selected prior to FY 2002 and were either reclassified because of a revision in the categorization of this technology or identified as a result of a more refined analysis conducted for this edition of the report.

As shown in Figure 12, some innovative technologies, such as solvent extraction, vitrification, and electrical separation, have been applied few times at NPL sites. A low number of applications of a technology does not necessarily indicate its lack of effectiveness. In some cases, the technology may have only recently become available and has not had time to become widely accepted and used at NPL sites. In other cases, the technology may be designed for specific types of applications, such as certain contaminants or media. For example, energy costs for vitrification typically are higher than for other technologies. However, vitrification is often capable of destroying hazardous chemicals in addition to immobilizing radioactive contaminants when radioactive contaminants are mixed with other hazardous chemicals. The contaminants treated for one of the three vitrification applications included a mixture of radioactive and other contaminants.

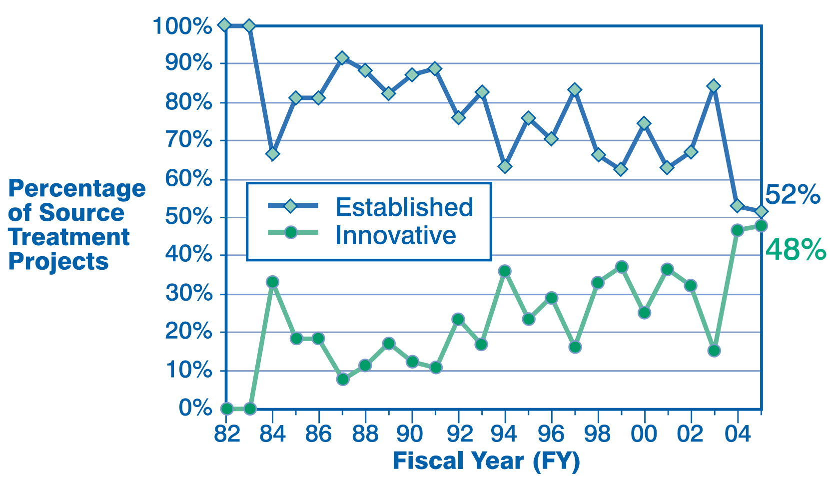
Figure 13 depicts the percentage of projects selected for innovative and established technologies for source control by fiscal year. The figure shows that although established technologies historically have been the most frequently used, the frequency of their use when compared with innovative technologies has been gradually decreasing since the early 1990s. The use of innovative technologies has generally increased during that time, with the percentage of projects that used innovative technologies becoming nearly equal to the percentage for established technologies for the first time in 2004. This trend has continued into FY 2005.

Box 11. Innovative Technologies Selected from FY 2002 through 2005

- Bioremediation – 13 projects
- Chemical treatment – 13 projects
- Multi-phase extraction – 13 projects
- In situ thermal treatment – 5 projects
- Phytoremediation – 2 projects
- Flushing – 1 project

The FRTR case studies Web site *(http://www.frtr.gov/costperf.htm)* provides detailed information on the cost and performance of both innovative and established technologies applied at NPL sites. As of October 2006, the FRTR included 383 case studies covering a wide range of treatment technologies that are available for viewing on line or for downloading from the FRTR

Figure 13: Established and Innovative Source Treatment Projects (FY 1982 - 2005)*



Recently, the percentage of projects using innovative treatment has become nearly equal to those using more established treatment approaches.

**Includes information from an estimated 74 percent of FY 2005 records of decision and amendments available as of October 2006 and project data available in CERCLIS as of October 2006.*
Sources: 3, 4, 7. Data sources are listed in Section 6.

Web site. The case studies were developed by EPA, the U.S. Department of Defense, the U.S. Department of Energy, the U.S. Department of the Interior, and the National Aeronautics and Space Administration for Superfund and non-Superfund sites. They present available cost and performance information for full-scale remediation efforts and large-scale demonstration projects. They also provide information about site background and setting, contaminants and media treated, technology, cost and performance, and points of contact for the technology application. Additional information on innovative technologies can be found at EPA's Hazardous Waste Cleanup Information (CLU-IN) Technology Focus area (*http://www.clu-in.org/techfocus/*), which bundles information for particular technologies that may be used in a variety of applications.

Contaminants Addressed

Nine major groups of contaminants targeted by specific technologies were analyzed for this report, as summarized in Table 4. Compounds were categorized (with the exceptions noted in Table 4) as:

- Volatile organic compounds (VOC) – either halogenated or non-halogenated
- Semivolatile organic compounds (SVOC) – either halogenated or non-halogenated
- Polycyclic aromatic hydrocarbons (PAH)
- Benzene, toluene, ethylbenzene, and xylene (BTEX)
- Polychlorinated biphenyls (PCB)
- Organic pesticides/herbicides
- Metals and metalloids

Table 4. Contaminants Treated by Source Treatment Projects (FY 1982 - 2005)*

Technology	Total number of projects[a]	Polycyclic aromatic hydrocarbons (PAHs)	Other nonhalogenated semivolatile organic compounds[b]	Benzene-toluene-ethylbenzene-xylene (BTEX)	Other nonhalogenated volatile organic compounds[c]	Organic pesticides and herbicides	Other halogenated semivolatile organic compounds[d]	Halogenated volatile organic compounds	Polychlorinated biphenyls	Metals and metalloids
Bioremediation	113	37	51	33	33	24	17	22	2	5
Chemical Treatment	29	1	2	3	4	1	4	12	4	13
Multi-Phase Extraction	46	9	3	11	6	4	8	18	1	1
Electrical Separation	1	0	0	0	0	0	0	1	0	0
Flushing	17	3	5	5	5	1	3	11	0	5
Incineration	147	27	41	33	23	36	34	52	36	6
Mechanical Soil Aeration	7	0	0	3	1	0	1	7	0	0
Neutralization	15	2	0	0	0	0	0	0	0	6
Open Burn/ Open Detonation	4	0	1	0	0	0	0	0	0	0
Physical Separation	21	4	2	1	0	3	0	0	4	5
Phytoremediation	7	1	2	2	2	1	1	4	0	4
Soil Vapor Extraction	255	15	31	107	51	3	33	217	1	0
Soil Washing	6	1	1	0	0	2	0	0	1	2
Solidification/ Stabilization	217	17	18	13	13	16	7	20	35	180
Solvent Extraction	4	2	1	0	1	1	0	2	2	1
Thermal Desorption	71	21	17	24	15	8	12	33	16	0
In Situ Thermal Treatment	14	5	0	2	0	3	3	8	0	0
Vitrification	3	0	0	1	1	0	1	3	2	1
Total Projects	**977**	**145**	**175**	**238**	**155**	**103**	**124**	**410**	**104**	**229**

The contaminants most often addressed by source control treatment are halogenated VOCs followed by BTEX and metals.

[a] *Each project may treat more than one contaminant group.*
[b] *Does not include PAHs.*
[c] *Does not include BTEX.*
[d] *Does not include organic pesticides and herbicides.*
** Includes information from an estimated 74 percent of FY 2005 records of decision and amendments available as of October 2006 and project data available in CERCLIS as of October 2006.*

Sources: 3, 4, 7. Data sources are listed in Section 6.

It should be noted that projects are listed in Table 4 multiple times, once for each contaminant type (resulting in a total number of projects that is greater than the actual number of projects). Overall, 42 percent of the source control treatment projects address halogenated VOCs; while 24 percent address BTEX; and 23 percent address metals and metalloids.

The selection of treatment technologies for a site often depends on the physical and chemical properties of the contaminants. For example, VOCs are amenable to treatment by certain technologies, such as SVE or thermal desporption, because of their volatility. Conversely, metals, which are not volatile and do not degrade, are not usually amenable to treatment by those technologies. S/S is most often used for treatment of these contaminants because metals form insoluble compounds when combined with appropriate additives, such as Portland cement. Some of the more common uses of technologies for contaminant groups are identified below.

- Halogenated VOCs, BTEX, and other non-halogenated VOCs are treated most often by SVE.
- Non-halogenated SVOCs and PAHs are treated most often by bioremediation.
- PCBs, organic pesticides and herbicides, and halogenated SVOCs are treated most often by incineration.
- Metals are treated almost exclusively by S/S. An interesting exception is the use of bioremediation in five projects to treat metals. Three of these projects are in the predesign or design phase. The other two are operational *ex situ* projects.

EPA has developed the CLU-IN Contaminant Focus area (*http://www.clu-in.org/contaminantfocus/*), which bundles information associated with cleanup of individual contaminants and contaminant groups. This information is presented in categories that include Overview, Policy and Guidance, Chemistry and Behavior, Environmental Occurrence, Toxicology, Detection and Site Characterization, Treatment Technologies, Conferences and Seminars, and Other Resources. Contaminant Focus will be continuously updated with information from federal cleanup programs, state sources, universities, nonprofit organizations, peer-reviewed publications, and public-private partnerships. New contaminants will be added on a periodic basis.

Remedy Changes

As discussed earlier, remedies selected at NPL sites are documented in a ROD, and changes to the original remedies can be either formally documented or executed through clauses in the original ROD. Remedies most often change during the pre-design or design phase of a project when new information about site characteristics is discovered or when treatability studies for the selected technologies are completed. Remedies also may change throughout the implementation and operation of the remedy. Source control treatment remedies have been changed to non-treatment remedies at approximately 130 sites. These remedies are most often changed to excavation with off-site disposal (and no treatment), containment, or institutional controls. The most commonly cited reason for changing source control treatment to another remedy was that further site investigation revealed that the concentration or extent of contamination was less than expected. Other frequently cited reasons included rising groundwater levels that made soil treatment impracticable, community concerns about on-site remedies, and high costs. The Superfund program allows EPA and state regulators the flexibility to modify remedies as site conditions change. The ASR tracks 977 source control treatment projects, not including the 130 that have been changed to non-treatment remedies. Based on a total of 1,107 source control treatment remedies (977 active plus 130 changed), 12 percent have been changed.

In 94 instances, one source control treatment technology was replaced with a different treatment technology. Table 5 provides information about the most frequently changed treatment technologies and the technologies that replaced them, as indicated by cumulative data from FY 1982 to 2005. The source control treatment technologies that were most frequently changed to another treatment technology were incineration, bioremediation, and thermal desorption. These technologies are the second, fourth, and third most frequently selected *ex situ* treatment technologies, respectively (see Figure 8). The most common technologies selected to replace incineration, bioremediation, and thermal desorption were thermal desorption (replacing incineration and bioremediation), S/S, SVE, and incineration (replacing bioremediation and thermal desorption).

Previous editions of the ASR included an appendix (Appendix D) that listed all the technology changes, additions, and deletions since the previous edition of the ASR. Because the appendix has expanded over time, it is now available online at *http://clu-in.org/asr*. For additional information about remedy updates, see *Updating Remedy Decisions at Superfund sites – Summary Report FY 2004 and FY 2005*, February 2007 (EPA 540-R-06-074).

Table 5. Most Commonly Changed Source Contol Technologies (FY 1982 - 2005)*

New Treatment Technology	Technology Initially Selected			
	Incineration	Bioremediation	Thermal Desorption	Total
Thermal Desorption	9	4	-	13
Solidification/Stabilization	7	3	1	11
Soil Vapor Extraction	3	2	5	10
Incineration	-	5	5	10
Bioremediation	5	-	0	5
Chemical Treatment	1	0	1	2
Pump and Treat	0	2	0	2
Solvent Extraction	1	0	0	1
Air Sparging	0	1	0	1
Soil Washing	0	0	1	1
Physical Separation	0	0	1	1
In Situ Thermal Treatment	0	1	0	1
Total Number of Remedy Revisions	**26**	**18**	**14**	**58**

The most commonly changed source control technologies are incineration, bioremediation, and thermal desorption. Thermal desorption also is the most frequently used "replacement" technology.

**Includes information from an estimated 74 percent of FY 2005 records of decision and amendments available as of October 2006 and project data available in CERCLIS as of October 2006.*
Sources: 3, 4, 7. Data sources are listed in Section 6.

Conclusion

A total of 977 projects were initiated from the 1,104 source control treatment RODs. Those projects consist of a wide range of *in situ* and *ex situ* technologies at various stages in design and implementation, being used to address a broad spectrum of contaminants. Although annual fluctuations occur, some trends and general observations can be noted:

- The selection of *in situ* source control projects continues to increase. *In situ* source control treatment projects represented 60 percent of source treatment projects from FY 2002 to 2005. Cumulatively, from FY 1982 through 2005, *in situ* source control projects made up nearly 50 percent of the projects.
- From FY 2002 to 2005, *in situ* technologies of multi-phase extraction and chemical treatment are being selected at an increasing rate compared with SVE, which is not being selected as frequently as in previous years.
- Historically, incineration projects have represented a high percentage of *ex situ* source treatment projects (29 percent reported in the eleventh edition of the ASR for FY 1982 to 2002). During the period from FY 2002 to 2005, incineration represented only 6 percent of *ex situ* treatment projects.
- In FY 2004, the percentage of projects that selected innovative technologies reached 47 percent, nearly equaling the percentage for established technologies. This trend continued in FY 2005, with available data indicating 48 percent of projects selected innovative technologies.

Section 4: Treatment Technologies for Groundwater

Groundwater remedies are delineated by the type of remedy specified: (1) *in situ* treatment, (2) extraction of groundwater followed by aboveground treatment (P&T), (3) MNA, (4) containment using subsurface VEBs, or (5) other actions (such as alternative drinking water supplies or drilling prohibitions). Box 12 delineates groundwater remedies by type and provides a description for each category. Remedies for source media (such as soil, sediment, solids, and NAPL), discussed in a previous section, fall into similar categories.

Beyond categorization by remedy type, groundwater treatment projects may be classified as 1 of 17 specific technologies. Definitions for these remedies are presented in Appendix C. Specific key words in decision documents determine classification into 1 of the 17 technologies (9 *in situ* technologies and 8 P&T technologies). Key words used to classify groundwater treatment remedies are listed in Appendix F. Definitions are based on the Remediation Technologies Screening Matrix and Reference Guide, Version 4.0, which can be viewed at the FRTR Web site at http://www.frtr.gov.

This section focuses on updated information for *in situ* and *ex situ* (P&T) groundwater treatment by documenting the status, achievements, and trends associated with applications of these treatment technologies at NPL sites from 1982 to 2005. The following subsections provide information about (1) the selection of groundwater remedies, (2) the technologies and status of *in situ* groundwater treatment projects, and (3) the status of P&T projects and the most frequently treated contaminants.

Groundwater Remedy Decisions

Groundwater remedies have been implemented or are currently planned at 1,072 sites, nearly 70 percent of sites on the NPL. As shown in Table 6, P&T remedies have been implemented or are planned at 728 of the sites. More than one type of groundwater remedy has been implemented at many sites. These sites are counted in Table 6 once for each type of groundwater remedy. Approximately 900 sites with groundwater remedies also have source control remedies.

When different types of groundwater remedies are applied to the same contaminant plume, they may be used to treat different parts of the plume. For example, an *in situ* groundwater treatment technology may be used for areas that are difficult to treat using P&T, such as hot spots, NAPL source zones, tight clays, fractured rock, and areas with heterogeneous hydrogeology. P&T, in turn, may be used to control migration of the plume and

Box 12. Groundwater Remedy Types

***In Situ* Treatment**
- Treatment of groundwater in place without extracting it from an aquifer.
- Includes any of the *in situ* groundwater treatment technologies described in this report, such as air sparging and permeable reactive barriers.

Pump and Treat (P&T)
- Extraction of groundwater from an aquifer and treatment aboveground.
- Groundwater usually is extracted by pumping groundwater from a well or trench.
- Treatment can include any of the P&T technologies described in this report, such as air stripping and ion exchange.

Monitored Natural Attenuation (MNA)
- The reliance on natural attenuation processes (within the context of a carefully controlled and monitored approach to site cleanup) to achieve site-specific remediation objectives within a time frame that is reasonable compared to other alternatives.
- Natural attenuation includes a variety of physical, chemical, and biological processes.

Groundwater Containment
- Containment of groundwater through a vertical, engineered, subsurface, impermeable barrier, or;
- Containment of groundwater through a hydraulic barrier created by pumping.

Groundwater Other
- Groundwater remedies that do not fall into the categories above.
- Can include a variety of remedies, such as restrictions on water use.

Table 6. Actual Groundwater Remedy Types at NPL Sites (FY 1982 - 2005)*

Total Number of Sites with a Groundwater Remedy = 1,072

Remedy Type	Number of Sites
Groundwater Pump and Treat	728
In Situ Treatment of Groundwater	228
MNA of Groundwater	239
Other Groundwater	854

MNA = Monitored natural attenuation
**Includes final or deleted NPL sites as of September 2005. Also includes information from an estimated 74 percent of FY 2005 records of decision and amendments available as of October 2006 and project data available in CERCLIS as of October 2006.*
No hierarchy is used for this table; sites may be included in more than one category.
Other groundwater includes sites with groundwater containment using vertical engineered barriers, as well as other groundwater remedies.
Sources: 1, 2, 3, 4, 7. Data sources are listed in Section 6.

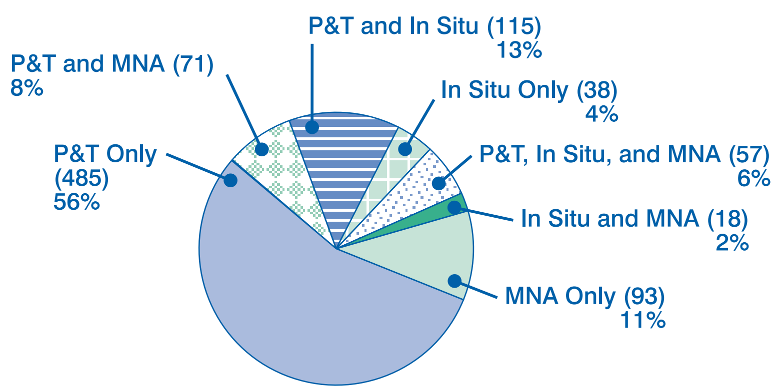
Download file containing source data for Table 6.

remediate other areas of the plume where contaminant concentrations are lower. Similarly, MNA may be used to treat areas of the plume where contaminant concentrations are relatively low but that still remain above remediation goals. However, remediation may not have occurred in the same aquifer or groundwater plume for sites where several types of groundwater remediation were used, such as a P&T system and *in situ* treatment.

An indication of possible multiple groundwater remedies working "jointly" can be seen in Figure 14, which shows the selection of P&T, *in situ* treatment, and MNA for groundwater, both alone and in combination with each other. (Note: groundwater containment using VEBs and other groundwater remedies are not included in this figure.) The most common combinations are P&T and *in situ* treatment (115 sites) and P&T with MNA (71 sites). Three types of groundwater remedies were used for 57 of the 877 sites. Some form of groundwater treatment was included at most sites where one of these remedies was selected. P&T or *in situ* treatment was included in the selected remedy at 89 percent (784) of the sites,

Figure 14: NPL Sites with P&T, In Situ Treatment, or MNA Selected as Part of a Groundwater Remedy (FY 1982 - 2005)*

Total Number of Sites= 877



Pump and treat is the sole groundwater treatment remedy at more than half of NPL sites, though many of these sites also have a source control remedy or non-treatment groundwater remedy (see Box 13).

MNA = Monitored natural attenuation
P&T = Pump and treat
**Includes final or deleted NPL sites as of September 2005. Also includes information from an estimated 74 percent of FY 2005 records of decision and amendments available as of October 2006 and project data available in CERCLIS as of October 2006. Sites are counted only once in this figure as appropriate.*
Sources: 1, 2, 3, 4, 7. Data sources are listed in Section 6.

while only MNA was selected for 11 percent (93) of the sites. The remedy at many of the sites shown in Figure 14 also includes source control treatment. For example, source control treatment is part of the remedy at 45 percent of the 485 sites with P&T only. Source control treatment is also part of the remedy at 41 percent of the 93 sites with MNA only, though this information is not displayed in Figure 14.

Although other groundwater remedies, such as monitoring and institutional controls, are not the focus of this report, analysis indicates they have been selected in about 95 percent of RODs in recent years at NPL sites. These remedies, although they are protective, typically do not directly reduce contaminant concentrations or decrease contaminant mobility and are therefore not considered treatment. Table 7 shows the number of sites where these other groundwater remedies have been selected. By far, the most common other groundwater remedy is monitoring, which has been selected at 727 sites (68 percent of sites with a groundwater remedy) followed by institutional controls, which has been selected at 437 sites (41 percent of sites with a groundwater remedy).

RODs That Select Groundwater Treatment

More than 1,500 RODs included at least one groundwater remedy. Table 8 shows the number of RODs that selected these remedies. P&T was selected most frequently (958 RODs), while containment using VEBs was selected the least (60 RODs). Each ROD may be counted in more than one category.

Table 7. Sites with Groundwater Other Remedies (FY 1982 - 2005)*

Total Number of Sites with Groundwater Other Remedies = 786

Remedy Type	Number of Sites
Engineering Control	45
Groundwater Monitoring	727
Institutional Control	437
Water Supply Remedies	106

**Includes final or deleted NPL sites as of September 2005. Also includes information from an estimated 74 percent of FY 2005 records of decision and amendments available as of October 2006.*
No hierarchy is used for this table; sites may be included in more than one category.
Sources: 1, 2, 7. Data sources are listed in Section 6.

Box 13. Sites with both Pump and Treat and Source Control Treatment Remedies

At 45 percent of sites with P&T (and no *in situ* groundwater treatment or MNA), source control treatment has also been selected. One example is ABC One Hour Cleaners in North Carolina. This site is an active dry cleaning facility where chlorinated solvents have contaminated both soil and groundwater. RODs were signed for groundwater (OU 1) in 1993 and soils (OU 2) in 1994. Remediation currently is being conducted using P&T for groundwater and SVE for soils. In this case, although different media are being treated, both technologies are addressing the same contaminants at the same area of the site. At other sites with P&T and source control treatment, it is possible that these technologies are being used to address different contaminants or different areas of the site.

Table 8. RODs Selecting Groundwater Remedies (FY 1982 - 2005)*

Total Number of RODs with a Groundwater Remedy = 1,509

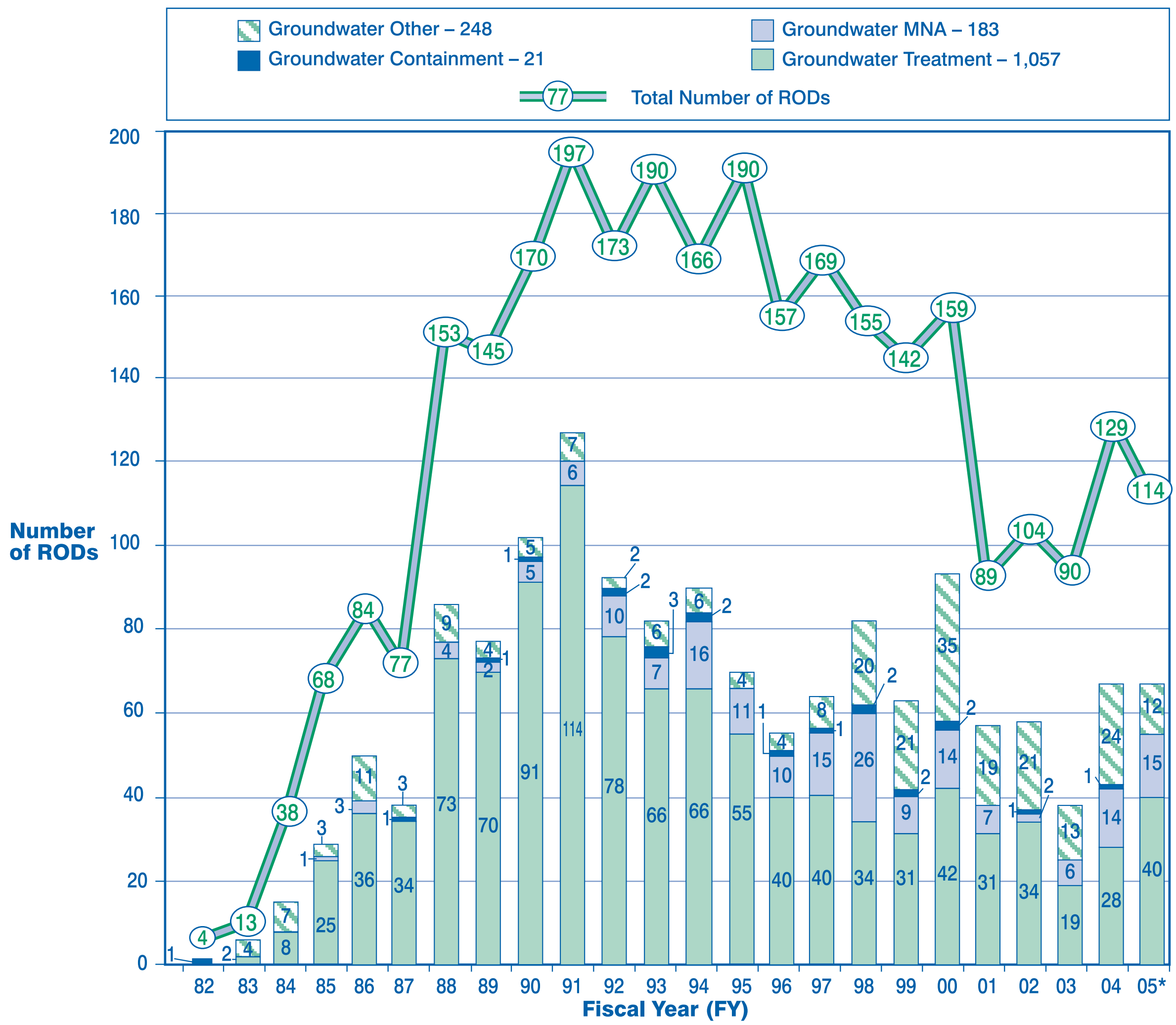
Remedy Type	Number of RODs
Groundwater Pump and Treat	958
In Situ Treatment of Groundwater	195
MNA of Groundwater	303
Groundwater Containment	60
Other Groundwater	579

MNA = Monitored natural attenuation
ROD = Record of Decision (Note: Data include ROD amendments)
**Includes information from an estimated 74 percent of FY 2005 RODs and amendments available as of October 2006.*
No hierarchy is used for this table; RODs may be counted in more than one category.
Sources: 3, 4, 7. Data sources are listed in Section 6.

Figure 15 shows the number of RODs for groundwater that have selected each groundwater remedy type. Each ROD, which may select multiple remedies, is assigned a single remedy type for the figure based on a hierarchy used in the ASR Eleventh Edition and previous editions. The hierarchy is groundwater treatment (including *in situ* and P&T), MNA, groundwater containment, and groundwater other. For example, RODs that select treatment are considered "groundwater treatment RODs" even though they may also have selected additional remedies, including MNA, groundwater containment using VEBs, or other remedies. "Groundwater MNA RODs" select MNA but may also have selected groundwater containment using VEBs or other remedies. RODs that selected groundwater containment using VEBs (counted as "Groundwater containment RODs")

Figure 15: RODs Selecting Groundwater Remedies (FY 1982 - 2005)*

Total Number of RODs = 1,509



The number of RODs selecting groundwater remedies peaked in 1991, 11 years after CERCLA was enacted. At that time, pump and treat was by far the most common groundwater remedy.

MNA = Monitored natural attenuation
ROD = Record of Decision (Note: Data include ROD amendment)
**Includes information from an estimated 74 percent of FY 2005 RODs available as of October 2006.*
RODs are counted only once in this figure using the following hierarchy: groundwater treatment (either pump and treat or in situ treatment), groundwater MNA with no treatment, groundwater containment with no treatment or MNA, then groundwater other remedies only.
Sources: 3, 4, 7. Data sources are listed in Section 6.

may also have selected other remedies. Other groundwater remedies (such as institutional controls, engineering controls, and others) are the only remedy type represented in the "Groundwater other" column. Figure 15 indicates that:

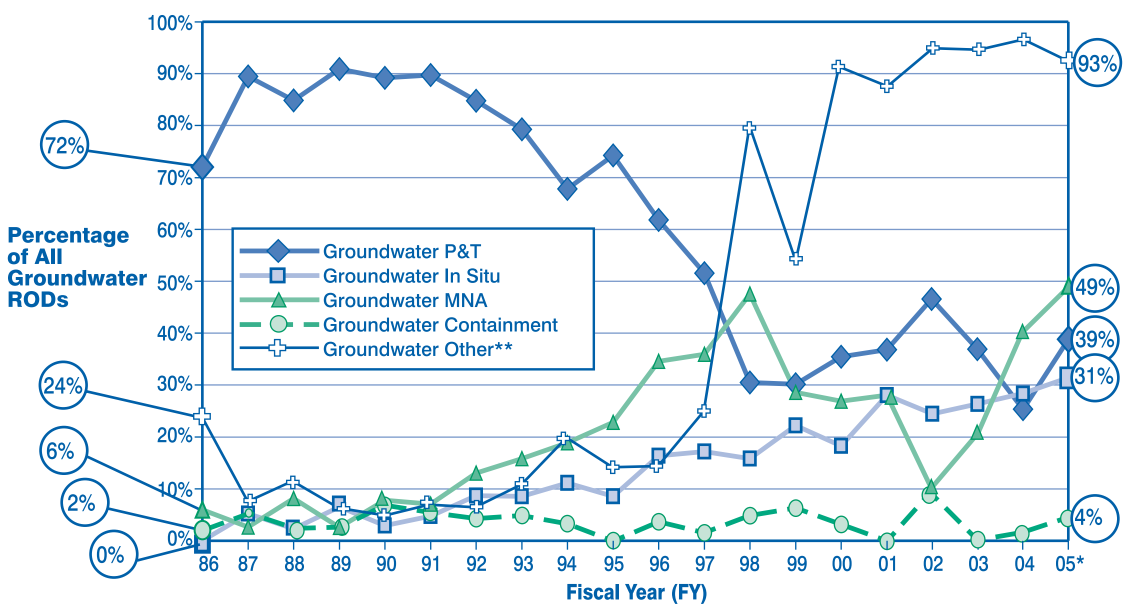
- The number of groundwater treatment RODs (including *in situ* and *ex situ* remedy types) peaked in FY 1991 at 114 and has been generally decreasing in line with the overall number of RODs. This peak matches the crest in the total number of RODs in FY 1991.
- From FY 1988 through 1995, the number of groundwater treatment RODs ranged from 55 to 114, while the number ranged from 19 to 42 from FY 1996 through 2005.

The relative percentages of remedies selected in RODs from FY 1986 through 2005 are presented in Figures 16, 17, and 18. These figures do not include FY 1982 through 1985 because of the small number of RODs that were signed during these years. Figure 16 shows the percentages of RODs that selected groundwater remedies. RODs are counted in each category as appropriate (for each remedy selected) in the figure. The combined percentages for all remedies in a given year total more than 100 percent because a ROD may select multiple remedies and may be counted in more than one category. Figure 16 shows:

- Nearly 90 percent of RODs selected P&T from FY 1987 through 1992. This percentage decreased to 30 percent in FY 1998 and has since averaged approximately 35 percent.
- MNA was selected in less than 10 percent of RODs from FY 1986 through 1991, but then increased every year until it peaked at 48 percent in FY 1998. After a decline to 10 percent in FY 2002, RODs that select MNA have increased steadily and reached 49 percent in FY 2005.

Figure 16: Trends in RODs Selecting Groundwater Remedies (FY 1986 - 2005)*

Total Number of Groundwater RODs = 1,458



Since 1991, the percentage of groundwater RODs selecting conventional pump and treat remedies has steadily declined while those selecting in situ or MNA remedies have increased.

MNA = Monitored natural attenuation
P&T = Pump and treat
ROD = Record of Decision (Note: Data include ROD amendments)
**Includes information from an estimated 74 percent of FY 2005 RODs available as of October 2006.*
No hierarchy is used in this figure; RODs may be counted in more than one category.
***Groundwater Other includes institutional controls and other remedies not classified as treatment, MNA, or containment. Note: Other remedies selected prior to 1998 may be under represented in figure.*
Sources: 3, 4, 7. Data sources are listed in Section 6.

- RODs that select *in situ* groundwater treatment have been generally increasing, from none in FY 1986 to 31 percent in FY 2005.
- The percentage of RODs that select groundwater treatment using VEBs has remained consistent, less than 10 percent for all years.
- RODs that select other remedies were less than 25 percent from FY 1986 through 1997, but then increased rapidly. While some of this increase may be attributed to changes in program guidance, it should be noted that data reporting methods used prior to FY 1998 may have resulted in under reporting of other remedies in Figure 16 for those years. About 90 percent of RODs selected other groundwater remedies from FY 2000 through 2005.

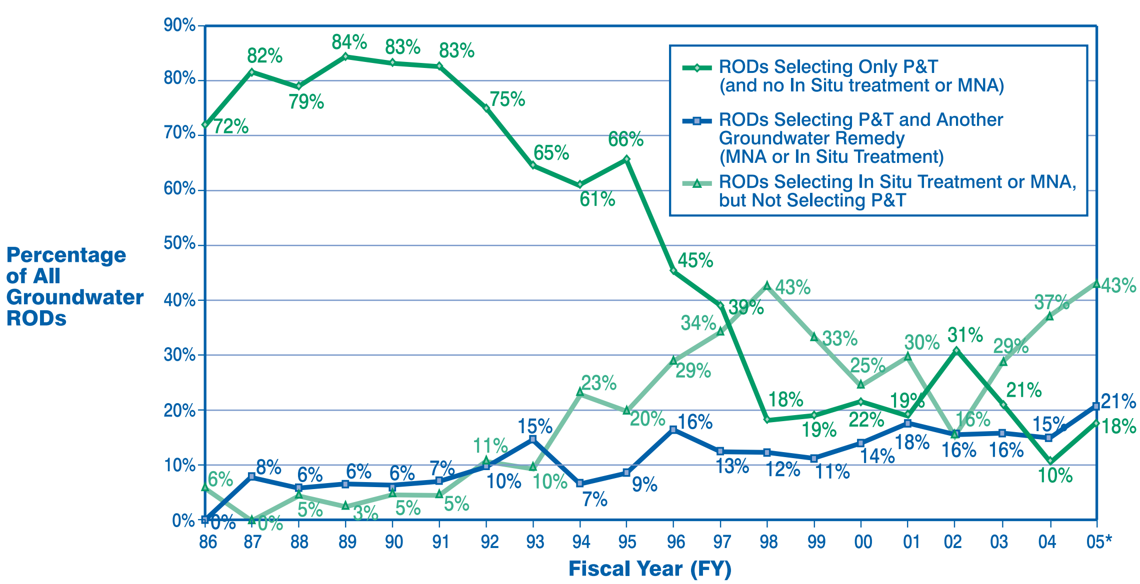
RODs that select P&T alone have decreased from about 80 percent before FY 1992 to an average of 20 percent over the last 5 years (FY 2001 through 2005), as shown in Figure 17. In contrast, P&T is being used increasingly with *in situ* treatment or MNA, or not at all. RODs that select P&T with another remedy generally ranged from 5 to 10 percent through FY 1995, but increased to an average of 17 percent from FY 2001 through 2005. Similarly, RODs that select *in situ* treatment or MNA and not P&T generally ranged from 5 to 10 percent through FY 1993. However, these RODs then increased to a peak of 43 percent in FY 1998 and again in 2005 after the percentage dipped to 16 percent in FY 2002.

The general decrease in the selection of P&T remedies may be a result of a variety of factors, including:

- More widespread acceptance of innovative *in situ* groundwater treatment remedies
- Reduced operation and maintenance costs from use of *in situ* treatment technologies
- Reduced time to address risk and quicker return of sites to beneficial uses by using active *in situ* treatment remedies
- Reduced costs by using MNA

Figure 17: Trends in Groundwater RODs Selecting Pump and Treat (FY 1986 - 2005)*

Total Number of Groundwater RODs = 1,458



Since 1995, RODs selecting pump and treat alone have dropped, while RODs selecting in situ treatment or MNA, with or without pump and treat, have increased.

MNA = Monitored natural attenuation
P&T = Pump and treat
ROD = Record of Decision (Note: Data include ROD amendments)
**Includes information from an estimated 74 percent of FY 2005 RODs available as of October 2006. RODs are counted only once in this figure as appropriate.*
Sources: 3, 4, 7. Data sources are listed in Section 6.

The general increase in the selection of P&T with MNA or *in situ* treatment may in turn be a result of a variety of factors, including:

- More active *in situ* treatments can reduce P&T treatment times by remediating hot spots and contaminant sources
- MNA can reduce P&T treatment times by allowing P&T systems to be shut down when contaminants reach levels that can effectively be treated by MNA
- MNA can treat areas of a contaminant plume with low concentrations, reducing the amount of the contaminant plume treated by P&T

Figure 18 counts all RODs that selected *in situ* groundwater treatment (regardless of whether additional remedies were selected). The percentage of groundwater RODs that select *in situ* treatment peaked in FY 2005 at 31 percent. The gradual upward trend in selection of *in situ* treatment may be a result of several factors:

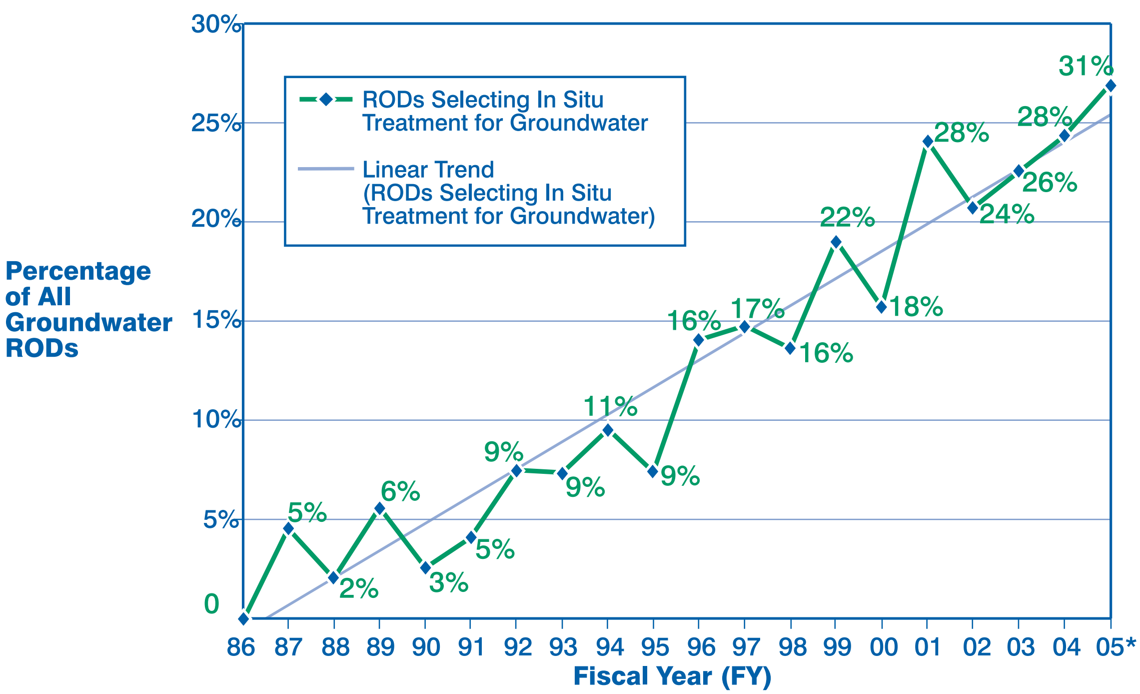
- Development of these technologies is growing rapidly
- They have been more frequently used in recent years to treat some media and contaminants, which are difficult to remediate, such as NAPL, chlorinated solvents, and fractured bedrock

Box 14. Groundwater MNA

Groundwater MNA includes a variety of physical, chemical, or biological processes that, under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil or groundwater. These *in situ* processes include biodegradation; dispersion; dilution; sorption; volatilization; radioactive decay; and chemical or biological stabilization, transformation, or destruction of contaminants.

Figure 18: Trends in Groundwater RODs Selecting In Situ Treatment (FY 1986 - 2005)*

Total Number of Groundwater RODs = 1,458



The selection of in situ treatment remedies has generally increased since 1986.

ROD = Record of Decision (Note: Data include ROD amendments)
**Includes information from an estimated 74 percent of FY 2005 RODs and amendments available as of October 2006.*
Sources: 3, 4, 7. Data sources are listed in Section 6.

RODs That Select MNA

Groundwater MNA relies on natural attenuation processes (within the context of a carefully controlled and monitored approach to site cleanup) to achieve site-specific remediation objectives within a time frame that is reasonable, compared with other, more active methods.

Cumulatively, 303 RODs have selected MNA (see Appendix E for a list of these RODs); of those, 60 percent selected MNA without a groundwater treatment remedy. Figures 16 and 17 present information about RODs selecting MNA.

- Since FY 1986, the fraction of groundwater RODs that select MNA, both alone and in combination with P&T or *in situ* treatment, has increased.
- The selection of MNA, both alone and with groundwater treatment remedies, generally increased through FY 1998. In that year, MNA was selected in 48 percent of RODs.
- From FY 1999 through 2001, there was a general decline in the selection of MNA, with a significant reduction in FY 2002. RODs selecting MNA have generally increased since then, exceeding their previous high of 48 percent in FY 2005.

The decrease in the selection of MNA from FY 1999 through 2002 coincided with publication of EPA's guidance on the use of MNA in 1999. The directive was issued to clarify EPA's policy on use of MNA to remediate contaminated soil and groundwater at sites administered by EPA's Office of Solid Waste and Emergency Response and contained technical guidance for implementation of MNA. The guidance may have influenced remedy identification and selection by providing a more specific definition of MNA. The guidance described three "lines of evidence" that should be evaluated to support a MNA remedy, which include (1) data showing a decrease in contaminant mass or concentration, (2) hydrogeologic and geochemical data to indirectly demonstrate MNA processes, and (3) data from field or microcosm studies that directly demonstrate MNA processes. Some remedies that were previously identified as MNA no longer met the definition provided in the directive. RODs prepared following the issuance of the guidance may have classified some of those remedies as monitoring only or no action or no further action (NA/NFA).

In Situ Groundwater Treatment Projects

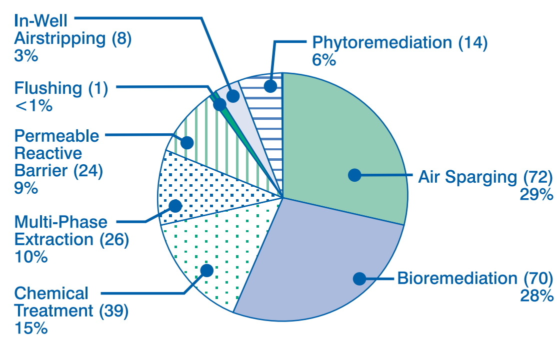
This section provides additional information about the innovative technologies used for *in situ* groundwater treatment, applications that treat the contaminated groundwater or eliminate the contaminants without extracting, pumping, or otherwise removing the groundwater from the aquifer.

In Situ Groundwater Treatment Remedy Trends

The most common *in situ* technologies are air sparging, bioremediation, chemical treatment, permeable reactive barriers (PRB), and multi-phase extraction. Figure 19 shows the total number of projects for each type of *in situ* groundwater treatment technology.

Figure 19: In Situ Groundwater Treatment Projects (FY 1982 - 2005)*

Total Number of Projects = 254



Bioremediation and air sparging account for more than half of all in situ groundwater treatment projects, but in recent years bioremediation and chemical treatment have become more common (see Table 9).

**Includes information from an estimated 74 percent of FY 2005 records of decision available as of October 2006 and project data available in CERCLIS as of October 2006.*

Sources: 3, 4, 7. Data sources are listed in Section 6.

The number of *in situ* groundwater treatment projects selected in RODs from FY 2002 to 2005 is presented in Table 9. The table shows that selection and use of bioremediation and chemical treatment for *in situ* groundwater continue to increase. Although air sparging represents the most projects cumulatively, its use is beginning to decrease. Bioremediation and chemical treatment have increased significantly, with approximately 70 and 80 percent of projects, selected in the past six years.

As shown in Figure 20, *in situ* groundwater technologies treat eight major groups of contaminants categorized for this report as follows, with the exceptions listed in the figure notes:

- VOCs – either halogenated or non-halogenated
- SVOCs – either halogenated or non-halogenated
- PAHs
- BTEX
- Organic pesticides/herbicides
- Metals and metalloids

Table 9. In Situ Groundwater Treatment Projects

Technology	ASR 11th Edition Number of New Projects Selected in FY 2000-2002*	ASR 12th Edition Number of New Projects Selected in FY 2002-2005**
Bioremediation	21	26
Chemical Treatment	15	17
Permeable Reactive Barrier	7	6
Air Sparging	10	6
Phytoremediation	3	5
Multi-Phase Extraction	4	5
In-Well Air Stripping	3	2
Flushing	2	0
Total	**65**	**67**

In situ groundwater treatment applications of bioremediation and chemical treatment are being selected more frequently than in prior years.

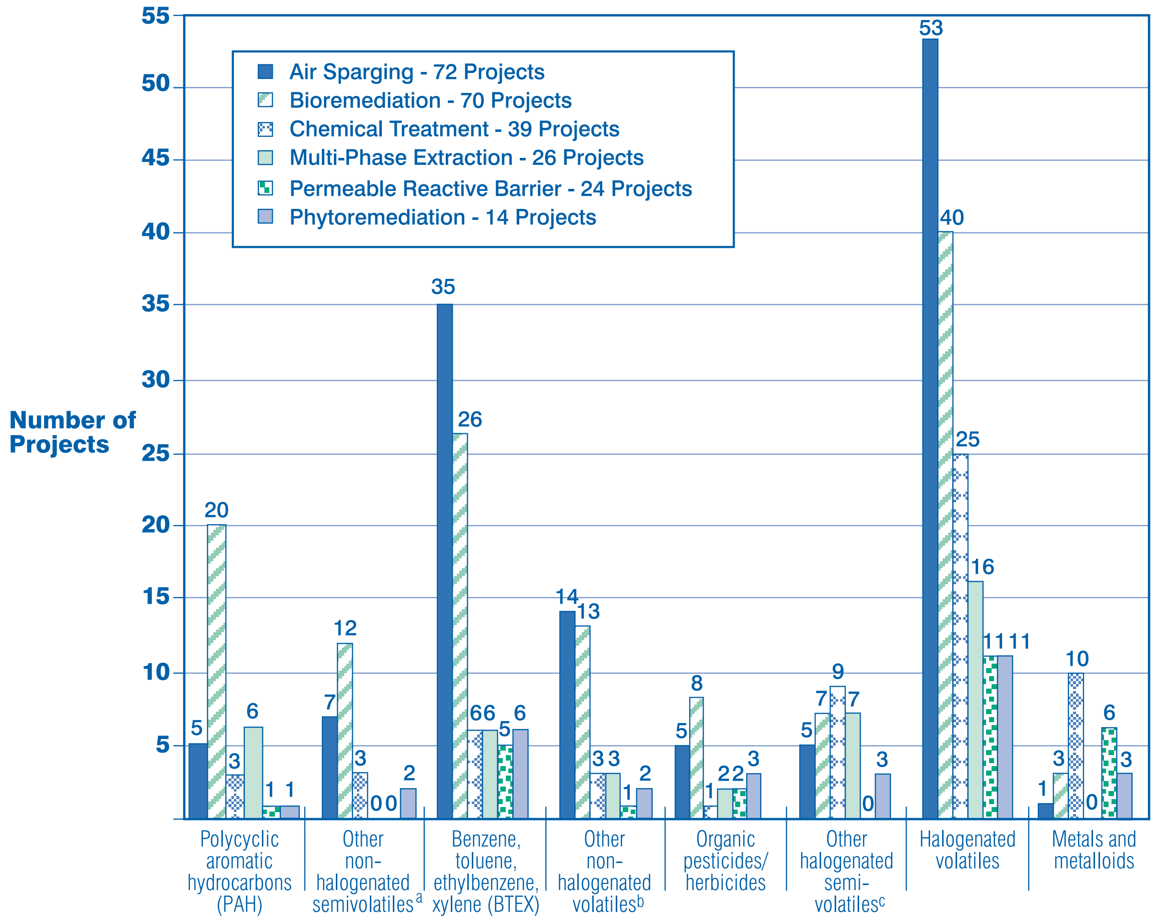
**Includes information from an estimated 70 percent of FY 2002 records of decision (ROD) and amendments available as of March 2003.*
***Includes information from an estimated 74 percent of FY 2005 RODs and amendments available as of October 2006 and project data available in CERCLIS as of October 2006.*
Sources: 3, 4, 7. Data sources are listed in Section 6.

Overall, VOCs — including BTEX and halogenated VOCs — are the contaminants most commonly treated in groundwater using *in situ* technologies. Halogenated SVOCs (including organic pesticides and herbicides) and metalloids and metals in groundwater are treated least frequently with *in situ* remedies. The number of projects in Figure 20 exceeds the total number of *in situ* groundwater projects because some projects involve more than one type of contaminant. These projects, therefore, are repeated in Figure 20 under each contaminant type treated by the remedy.

The selection of a treatment technology for a site depends on the physical and chemical properties of the contaminants. For example, VOCs are amenable to air sparging and in-well air stripping because of their volatility. Conversely, metals, which are not volatile and do not degrade, are not amenable to these technologies, and are most often treated using chemical treatment and PRBs. As Figure 20 shows, BTEX and halogenated VOCs are treated most frequently using air sparging. PAHs and other non-halogenated SVOCs, which are not as volatile as BTEX and halogenated VOCs but can be destroyed through microbial processes, are treated most frequently by bioremediation. Metalloids and metals are typically not amenable to bioremediation; one exception is the use of *in situ* bioremediation to reduce hexavalent chromium to its less toxic trivalent form. This technology, which uses biological activity to create conditions that result in chemical reduction of chromium, is being applied at one NPL site. Bioremediation to treat arsenic is currently planned at two additional sites. Metals and metalloids may undergo chemical reactions with certain substances to form compounds that are less toxic or mobile. The PRBs were used most often to treat halogenated VOCs, BTEX, and metals and metalloids.

The selection of groundwater treatment technologies may also depend on site-specific factors, such as soil type and hydrogeology. For example, air sparging may be an effective treatment for VOCs at a site with sandy soil but may not be effective at a site with tightly packed clay soil. In addition, chemical treatment may be ineffective at sites with low-permeability soils because of the resulting uneven or limited chemical distribution in the subsurface.

Figure 20: Contaminant Groups Treated by In Situ Groundwater Projects (FY 1982 - 2005)*



In situ treatment technologies are usually selected to address halogenated volatiles and BTEX. Fewer in situ methods are available for other types of contaminants.

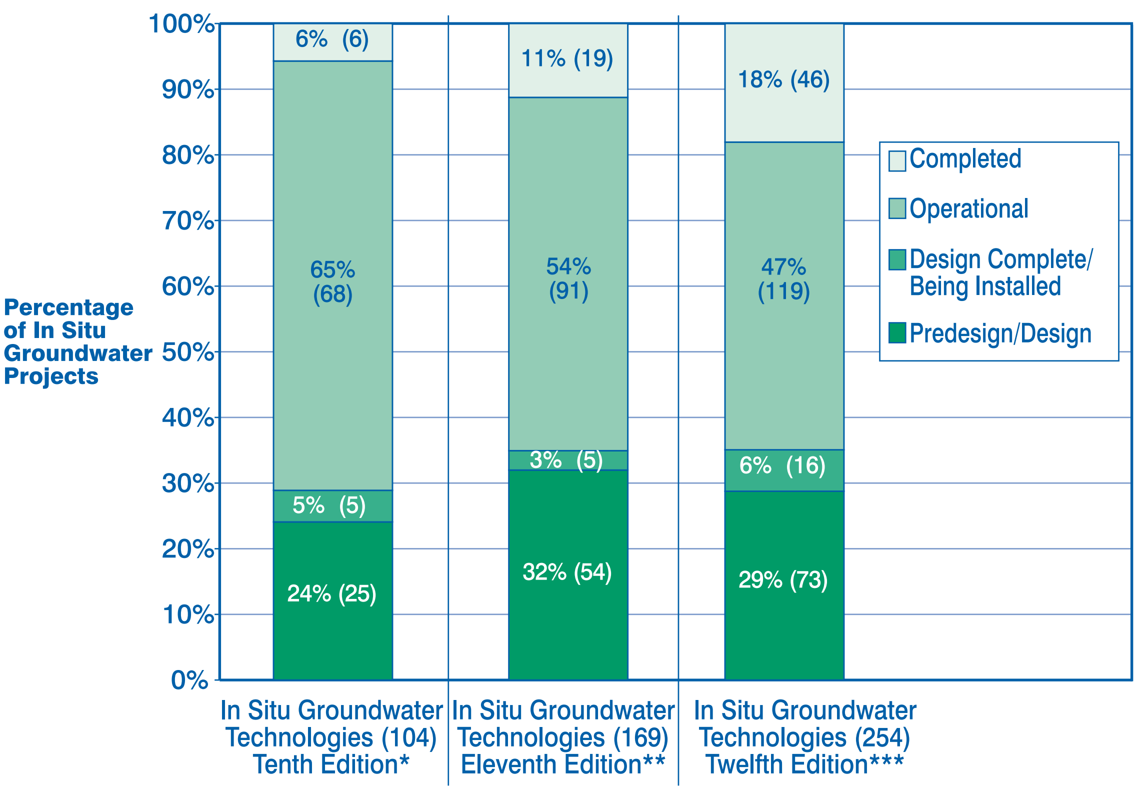
[a] *Does not include PAHs.*
[b] *Does not include BTEX.*
[c] *Does not include organic pesticides and herbicides.*
**Includes information from an estimated 74 percent of FY 2005 records of decision and amendments available as of October 2006 and project data available in CERCLIS as of October 2006.*
Data for in-well air stripping and flushing are not included.
Projects may treat more than one contaminant group.
Sources: 3, 4, 7. Data sources are listed in Section 6.

Status of In Situ Groundwater Projects

A snapshot of the status of *in situ* groundwater treatment technologies is presented in Figure 21. The data in Figure 21 show:

- The total number of *in situ* groundwater treatment projects increased by 50 percent, from 169 to 254, between the Eleventh and Twelfth Editions.
- An additional 27 *in situ* groundwater projects were completed, increasing the percentage of completed *in situ* groundwater projects from 11 percent to 18 percent. These completed projects included 14 air sparging, 5 bioremediation, 4 chemical treatment, 2 multi-phase extraction, and 2 PRBs.
- Nearly half (47 percent) of *in situ* groundwater treatment projects are operational.
- Although the percentage of *in situ* groundwater projects that are operational decreased, the total number of operational projects increased from 91 to 119. The technologies that exhibited the largest increase in the number of operational projects were phytoremediation (6 projects), bioremediation (6 projects), multi-phase extraction (5 projects) and PRBs (5 projects).
- The number of *in situ* groundwater treatment projects in the design phase increased. The technologies with the largest increase in the number of projects in the design phase were bioremediation (11 projects) and chemical treatment (9 projects).

Figure 21: Status of In Situ Groundwater Treatment Projects - Comparison Between Tenth, Eleventh and Twelfth Editions of the ASR (FY 1982 - 2005)***



As with source control treatment projects (see Figure 11), projects addressing contaminated groundwater have progressed. The percentage of completed in situ groundwater treatment projects has increased by 13 percent since the ASR Tenth Edition.

**Includes information from records of decision (RODs) and amendments through FY 1999 available as of summer 2000.*
***Includes information from an estimated 70 percent of FY 2002 RODs and amendments available as of March 2003.*
****Includes information from an estimated 74 percent of FY 2005 RODs and amendments available as of October 2006 and project data available in CERCLIS as of October 2006.*
Sources: 3, 4, 10. Data sources are listed in Section 6.

Between FY 2002 and 2005, 82 *in situ* treatment technology projects for groundwater were selected. Of those, 67 have been added since the Eleventh Edition of the ASR (see Table 9). Technologies most frequently selected include bioremediation (26 projects), chemical treatment (17 projects), PRBs (6 projects), and air sparging (6 projects). The status of *in situ* groundwater treatment projects selected in FY 2002 through 2005 at NPL remedial action sites includes:

- One bioremediation project selected in the period has been completed
- Eighteen projects selected in the period became operational
- An additional five projects have progressed beyond the design phase, and the remedies are being installed

The specific types of *in situ* treatment technologies and their status are listed in Table 10. *In situ* treatment of groundwater has been selected 254 times at 190 sites. Among these technologies, air sparging and bioremediation have been the technologies most frequently selected; although recent trends indicate that bioremediation has been increasing while air sparging is decreasing. A large number of projects in the operational phase use these technologies. The treatment rate of these technologies is typically limited by site-specific factors. For example, air sparging may require long treatment times when continuing sources of contaminants, such as light nonaqueous phase liquids (LNAPL) and DNAPL, are present. Likewise, bioremediation may be limited by the rate the microbes can break down contaminants, which can depend on a variety of factors such as climate, soil conditions, contaminant concentrations, and solubility.

The third most frequently selected technology is chemical treatment. Chemical treatment is typically applied as an aggressive technology that requires a relatively short treatment time to achieve cleanup goals. It may also be effective in treating small amounts of DNAPL and LNAPL. The number of chemical treatment projects has nearly doubled from 21 to 39 since the ASR Eleventh Edition. PRBs are a passive technology that relies on natural groundwater flow to carry contaminants into a reactive zone, where they are treated; therefore, this technology does not treat contaminants upgradient of the reactive zone. Most PRBs (15 of 24) are in the operational phase, and two are completed.

Groundwater Pump and Treat Projects

This section presents information about P&T projects. P&T extracts groundwater from an aquifer and treats it aboveground. The extraction step usually is conducted by pumping groundwater from a well or trench. The treatment step can

Table 10. Status of In Situ Groundwater Treatment Projects by Technology (FY 1982 - 2005)*

Technology	Predesign/ Design	Design Complete/ Being Installed	Operational	Completed	Total
Air Sparging	9	5	38	20	72
Bioremediation	29	4	27	10	70
Chemical Treatment	19	2	9	9	39
Permeable Reactive Barrier	6	1	15	2	24
Multi-Phase Extraction	6	1	14	5	26
Phytoremediation	3	1	10	0	14
In-Well Air Stripping	1	1	6	0	8
Flushing	0	1	0	0	1
Total	**73**	**16**	**119**	**46**	**254**
Percentage of In Situ Groundwater Technologies	29%	6%	47%	18%	—

Almost half of in situ groundwater treatment projects are operational.

**Includes information from an estimated 74 percent of FY 2005 records of decision and amendments available as of October 2006 and project data available in CERCLIS as of October 2006.*

Sources: 3, 4, 7. Data sources are listed in Section 6.

Download file containing source data for Table 10.

include a variety of technologies, with the most common being air stripping and carbon adsorption (refer to Appendix C for all technology descriptions).

Status of Pump and Treat Projects

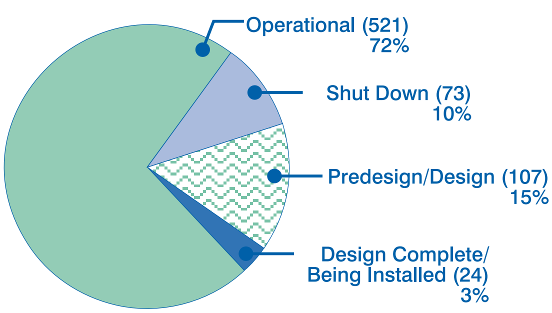
This report contains information about 725 P&T projects at NPL sites. Figure 22 shows the status of these projects and allows for the following conclusions:

- Most P&T projects (72 percent) are operational.
- Fifteen percent are in the predesign or design phase.
- 73 P&T projects (10 percent) have been shut down (no longer operational).

The status "shut down" does not indicate that goals were met for these projects. Although 38 percent (28 projects) had met the goal of either restoration or hydraulic containment of groundwater, others were shut down for various reasons: replaced with another remedy, such as *in situ* treatment or MNA; for monitoring to evaluate whether goals have been achieved; or because of technical issues, such as well fouling or limited pumping capacity. Appendix G lists 73 P&T projects along with their reasons for shutdown.

Figure 22: Status of Groundwater Pump and Treat Projects (FY 1982 - 2005)*

Total Number of Projects = 725



Nearly 75 percent of pump and treat projects are operational, presenting a continuing challenge and opportunity for optimization efforts (see Box 15).

**Includes information from an estimated 74 percent of FY 2005 records of decision and amendments available as of October 2006 and project data available in CERCLIS as of October 2006.*

Sources: 3, 4, 7. Data sources are listed in Section 6.

Download file containing source data for Figure 22.

Contaminants Treated by Pump and Treat Projects

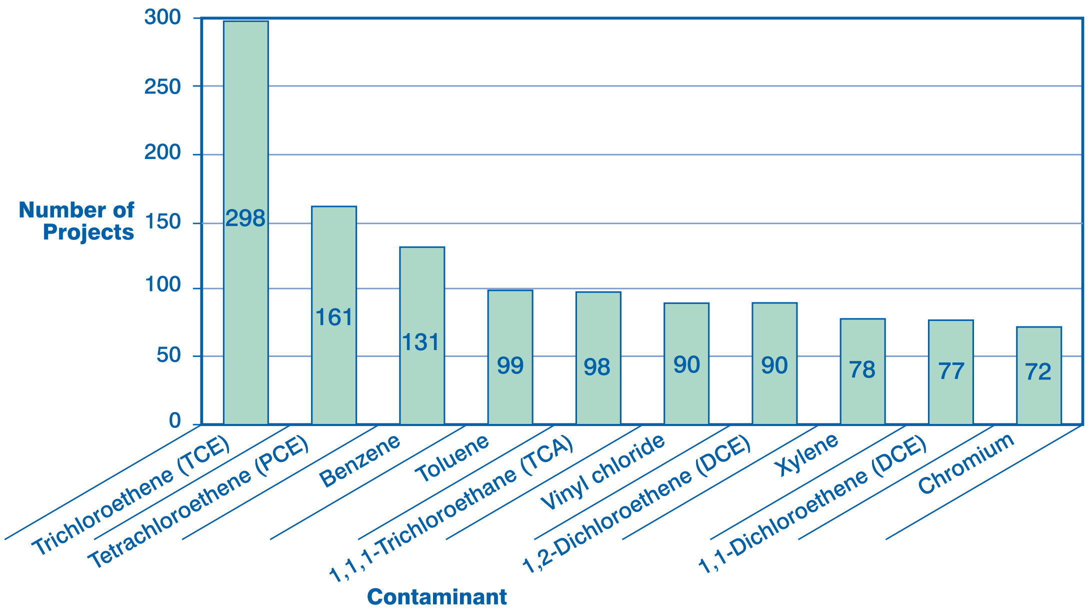
The contaminants treated by 514 P&T projects were identified, and the 10 most frequently treated contaminants are shown in Figure 23. (Note that contaminant information was available for 70 percent of projects.) Chlorinated VOCs are the most commonly treated group of contaminants. The contaminant treated most often is trichloroethene (TCE). Other frequently treated chlorinated VOCs include tetrachloroethene (PCE); 1,1,1-trichloroethane (TCA); vinyl chloride (VC); 1,2-dichloroethene (DCE); and 1,1-DCE. Frequently treated nonchlorinated VOCs include benzene, toluene, and xylene. P&T systems also are frequently used to treat metals and metalloids, including chromium. Projects that treat more than one contaminant are counted once for each contaminant listed in Figure 23.

Pump and Treat Remedy Changes

One goal of this report is to compile a current list of all P&T projects. As discussed earlier, remedies selected for remedial actions at NPL sites are documented through a ROD, and changes to the original remedies may be formally documented. Remedies often change during the pre-design or design phase of a project when new information about site characteristics is discovered or treatability studies for the selected technologies are completed.

EPA updated the status of 725 P&T projects, primarily by reviewing site documents, such as 5-year review reports and PCORs. In addition to these 725 P&T projects, nearly 100 additional P&T projects were changed to other groundwater remedies. These remedies were most often changed to *in situ* groundwater treatment or non-treatment remedies, such as institutional controls and MNA. The most commonly cited reason for changing a P&T remedy was that further site investigation revealed that the concentration or extent of contamination was less than expected. Other frequently cited reasons included problems in implementing the remedy because of site conditions such as hydrogeology, implementation of a more effective *in situ* treatment remedy, and high costs. For additional information about remedy updates, see *Updating Remedy Decisions at Superfund sites – Summary Report FY 2004 and FY 2005*, February 2007 (EPA 540-R-06-074).

Figure 23: Contaminants Most Commonly Treated by Pump and Treat Systems (FY 1982 - 2005)*



Volatile organic compounds, such as TCE and PCE, are the contaminants treated most commonly by pump and treat systems.

**Includes information from an estimated 74 percent of FY 2005 records of decision and amendments available as of October 2006 and project data available in CERCLIS as of October 2006.*
Only the most common contaminants have been included for the 514 projects with contaminant data.
Sources: 3, 4, 7. Data sources are listed in Section 6.

Box 15. P&T Optimization

Once remediation systems have been functioning for a period of time, opportunities may exist to optimize the system, particularly if they are long-term remedies. The purpose of optimization is to identify potential changes that will improve the effectiveness of a system and reduce operating costs without compromising the effectiveness of the remedy or the achievement of other cleanup objectives.

EPA recognizes that long-term remedial approaches should not remain static, that conditions change over time, and that better technologies, tools, and strategies evolve, which allow for continuous improvement of remedy performance. In *OSWER Directive No. 9200.0-33, Transmittal of Final FY00 - FY01 Superfund Reforms Strategy, dated July 7, 2000*, EPA outlined a commitment to optimize Superfund-lead P&T systems at Superfund sites. Superfund-lead P&T systems include systems that are either EPA-lead or state-lead that are funded from the Superfund Program.

Initially, EPA performed a Remediation System Evaluation (RSE) on 20 Superfund-lead groundwater P&T systems during 2000 and 2001. The results of this initiative are documented in two reports: (1) *Groundwater Pump and Treat Systems: Summary of Selected Cost and Performance Information at Superfund-Financed Sites* and (2) *Pilot Project to Optimize Superfund-financed Pump and Treat Systems: Summary Report and Lessons Learned*. Since the initial set of RSEs, EPA has prepared 17 RSEs for Superfund-lead P&T systems and 1 for a responsible-party site. EPA is also preparing additional RSEs for Superfund-financed sites. The summary reports, RSEs, and other reports are available at http://clu-in.org/rse. Additional information on RSE and optimization of remedies is available at http://www.frtr.gov/optimization. This site includes information on optimization tools and techniques, including checklists that can be used to identify optimization opportunities for specific groundwater treatment technologies.

Conclusion

Several conclusions can be drawn from the analysis of the latest data and historical trends associated with *in situ* and *ex situ* groundwater treatment projects. Of the RODs that select groundwater treatment, 18 percent (195) used *in situ* treatment remedies, whereas more than 90 percent (958) used P&T remedies. A total of 254 *in situ* treatment projects and 725 P&T projects were implemented or planned from those RODs. Those projects consist of a wide range of technologies used to address a broad spectrum of contaminants at various stages in design and implementation. Although annual fluctuations occur, some trends and general observations can be noted:

- RODs that select *in situ* groundwater treatment have been generally increasing, from none in 1986 to a high of 31 percent in FY 2005.
- RODs that select P&T alone have decreased from about 80 percent before FY 1992 to an average of 20 percent over the last 5 years (FY 2001 through 2005).
- RODs that select only MNA (with no groundwater treatment) experienced a decline from FY 1999 to 2002, coinciding with publication of EPA guidance on the use of MNA in 1999. Since FY 2002, RODs that select MNA have been increasing.
- The most common *in situ* technologies include air sparging, bioremediation, chemical treatment, PRBs, and multi-phase extraction.
- Cumulatively, air sparging represents almost 30 percent of all *in situ* groundwater treatment projects, with bioremediation representing 27 percent.
- *In situ* bioremediation and chemical treatment have increased significantly in recent years, with approximately 70 to 80 percent of these projects selected in the past 6 years.
- More than 70 percent of P&T projects selected are currently operational. Another 10 percent have been shut down. Eighteen percent of *in situ* groundwater projects have been completed, and nearly 50 percent continue to operate.

Selection and implementation of *in situ* groundwater treatment technologies have been increasing and may continue to do so as their applicability and performance are demonstrated at a larger number of sites and a wider variety of conditions. Site owners, remedial project managers, and other stakeholders may look more favorably to these options when they consider groundwater cleanup alternatives because these systems do not require extraction of contaminated groundwater. Additionally, they generally have shorter operating periods than P&T remedies.

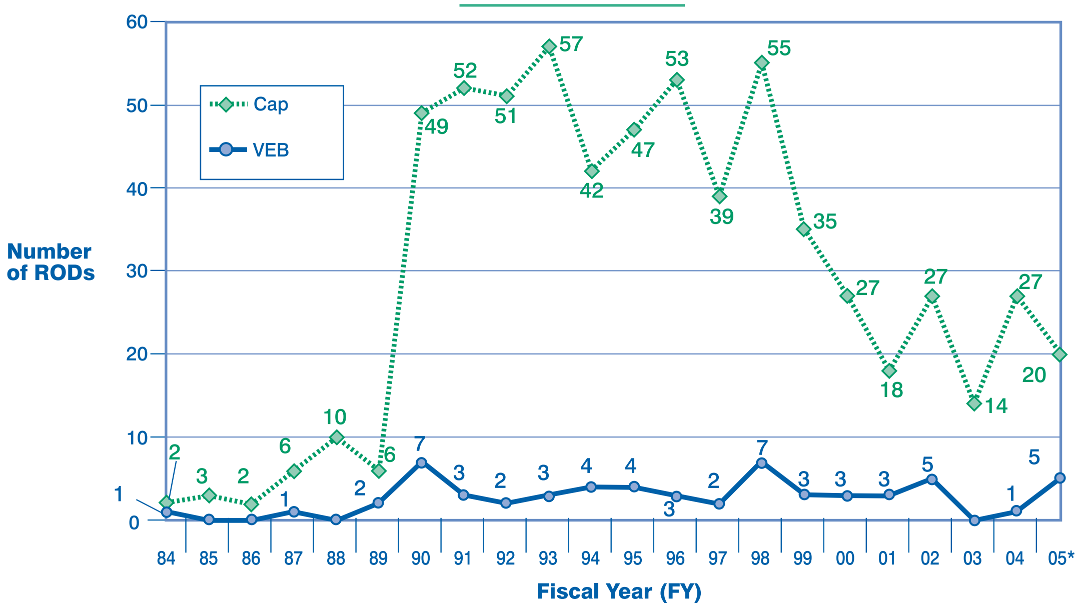
Section 5: Report Focus Area - On-Site Containment Remedies

The ASR focuses on the documentation and analysis of treatment technology applications for Superfund remedial action sites. Given the prevalence of on-site containment remedies, EPA expanded the scope of the report beyond treatment technologies to include information on groundwater containment remedies, specifically VEBs, in the Tenth Edition. With this Twelfth Edition, the scope was expanded further in an effort to understand the state of the practice of on-site containment remedies, such as final cover systems (commonly referred to as caps), to prevent the migration of contaminants or contaminated media. An initial analysis has been conducted for source control cover systems. These details are provided for a limited subset of cover systems at surface contamination sites, landfills, and disposal units. In total, information and analysis are presented for 112 cover system remedies at 89 NPL sites and 57 VEB remedies at 55 NPL sites. The information provided in this section, therefore, only suggests the state of the practice, and is not a "status report" on these remedies. This section provides an overview of the data collected about on-site containment remedies and presents the findings derived. Specific types of containment remedies are identified in Appendix F.

From FY 1982 to 2005, 17 percent (503) of RODs selected containment without treatment and an additional 16 percent (475) of RODs selected containment in conjunction with a treatment remedy. Trends associated with selection of on-site containment remedies are presented in Figure 24. Overwhelmingly, the most common type of on-site containment remedy is a cover system. Although RODs selecting other on-site containment remedies, such as VEBs, have remained constant over time — with less than 10 selected per year — RODs that select a cover system as a remedy surged in FY 1990 and reached a peak of 57 in FY 1993. Since then, the number of RODs that have selected cover systems has been steadily declining but still represents the majority of on-site containment remedies selected.

While other sections of the ASR focus on treatment remedies, information about containment remedies has also been included (see Figures 1, 2, 6, 7, 15, and 16 and Tables 1, 2, 6, 7, and 8). The remainder of this section focuses on the analysis performed on a limited sample of on-site containment remedies.

Figure 24: RODs Selecting On-Site Containment (FY 1984 - 2005)*



The number of RODs selecting capping generally tracked the total number of RODs since 1984 (see Figure 6).

**Includes information from an estimated 74 percent of FY 2005 records of decision (ROD) and amendments available as of October 2006 and project data available in CERCLIS as of October 2006.*
Sources: 3, 4, 7. Data sources are listed in Section 6.

Collection of Data about On-Site Containment Projects

Detailed project-level information about on-site containment remedies was collected for a limited number of sites for this edition of the ASR. Sites identified for the survey included:

- Sites classified as "Fund-Lead," that is, funded and implemented by EPA, and
- Sites in the remedial action (RA) phase

These sites were selected because it was expected that implementation data would be more readily available. The application of these two criteria narrowed the list of prospective sites with on-site containment from 656 to 91 (based on CERCLIS data as of September 2006).

The breakdown of sites with RODs that select containment remedies and the relative proportion of cover systems are as follows:

- Of 656 sites with on-site containment remedies, 634 included a cover system
- Of 439 sites with on-site containment remedies in the RA phase, 417 included a cover system
- Of 228 sites with on-site containment remedies and EPA funding, 222 included a cover system
- Of 91 sites with on-site containment remedies in the RA phase and EPA funding, 89 included a cover system

As discussed in previous sections, more than one treatment remedy can be specified for a site. Similarly, more than one on-site containment remedy can be specified. The 91 sites included in this analysis yielded 128 on-site containment remedies, of which 112 were cover systems at 89 NPL sites. These cover systems are the focus of this section. Appendix H presents a list that includes each containment remedy and details of the projects that were identified during this update.

Data sources used to obtain information about on-site containment remedies included PCORs and 5-year reviews. These sources provided the most readily available and up-to-date information about the status of containment remedies and their effectiveness at sites. In addition, decision documents, site summaries, and fact sheets also were reviewed for background information. Decision documents, which contain pre-design information, were less reliable than PCORs and 5-year reviews, which often provide actual construction and "as-built" information. Based on these sources, a variety of data was collected on the remedies and associated sites.

Overview of Sites with On-Site Containment

Site types were identified based on activities conducted at the site, which are the likely sources of contamination. Applicable types for each site were established according to the data sources described above. (An NPL site could be classified as more than one site type if appropriate.) Table 11 shows the site types that were identified for the NPL sites with containment remedies. The Other Site Types category consists of site types with only a small number of NPL sites each and includes agricultural applications; chemical distributors; pesticide manufacturing, use, or storage; and textile dye manufacturing.

Each remedy also was categorized according to the source of contaminants contained by the barrier. (More than one source was selected if appropriate.) The 220 sources identified for all remedies and sites include:

- 72 (33 percent) contaminated soil
- 55 (25 percent) hazardous waste
- 30 (14 percent) municipal solid waste
- 16 (7 percent) other
- 12 (5 percent) NAPL
- 35 (16 percent) all other sources (each category represented less than 10 sources)

Table 11. Site Types for On-Site Containment Sites*

Total Number of Sites = 91

Site Types	Number of Sites
Municipal Landfills	25
Industrial Landfills	21
Wood Preserving	18
Metal Ore Mining and Smelting	16
Other Site Types**	64
Total	**144**

**Sites can have more than one type of classification.*
***Category includes such site types as agricultural applications, chemical distributors, pesticide manufacturing, and textile dye manufacturing.*

Data included for a limited sample of Fund-Lead, remedial action phase sites selected from CERCLIS as of October 2006. Includes information obtained from preliminary close-out reports, five-year reviews, and other site documents.
Sources: 3, 4, 7. Data sources are listed in Section 6.

The 91 sites with on-site containment were grouped into four general classifications based on the results of the site type and source of contamination analyses:

1. Landfills/Disposal units — Sites that are municipal or industrial landfills or where the contamination was caused by disposal of waste (44 sites).
2. Surface contamination sites — Sites where dumped waste contaminated the surface medium of the site or where an industrial process contaminated the site. Examples of surface contamination sites are chemical manufacturing facilities and wood treating and preserving facilities (37 sites).
3. Sediment sites — Sites where sediments are capped *in situ* (4 sites).
4. Mine sites — Sites where mining activities contaminated on-site media (11 sites).

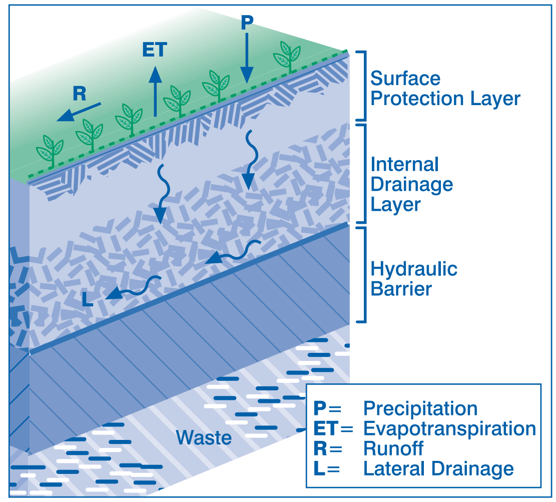
Because of the diverse nature of some NPL sites, a site could have multiple site classifications for the purpose of the review and be counted more than once, as appropriate. One example is Wyckoff Co./Eagle Harbor, which is classified as both a surface contamination site and a sediment site.

Subsequent analysis focuses on cover systems associated with landfills/disposal units and surface contamination sites. The majority of cover systems are associated with these site classifications: 89 cover systems at 77 sites. Data collected include details about the cover system, such as: type, layer components, and size; goals and status; and remedies used in conjunction with those cover systems.

Cover Designs and Layer Components

Most cover systems employ a hydraulic barrier layer to prevent infiltration of water into the contained material. Typical materials used for hydraulic barriers include compacted clay liners, geosynthetic clay liners, geomembranes, and combinations of these materials. A hydraulic barrier is generally used with additional components of the cover system, such as a surface protection layer, a biointrusion layer, a drainage layer, a gas collection layer, and a foundation layer. Cover systems may include some or all of these layers depending on factors such as site type, regulations, goal of the cover, and planned reuse of the site. Additional information about the design of cover systems can be found in the EPA report, *Design and construction of RCRA/CERCLA Final Covers.* This evaluation of on-site containment remedies classified

Example of a Conventional Cap



cover systems according to the general type of cover design and layer components. The three cover system classifications are as follows:

1. Conventional caps — Cover systems that include a hydraulic barrier and a surface protection layer. Types of conventional caps include Resource Conservation and Recovery Act (RCRA) C and D (or similar type caps), Toxic Substances Control Act caps, clay caps, and other multilayer caps that include a hydraulic barrier. The graphic above illustrates a multilayer cap with a hydraulic barrier.
2. Soil caps — Cover systems with a single layer of soil covering the waste and no hydraulic barrier.
3. Asphalt/concrete caps — Cover systems with an asphalt or concrete surface layer but no hydraulic barrier underneath.

Soil and conventional caps constitute the most common cover system types (71 of 89 cover systems). Figure 25 shows the percentages of each cover system type for the landfills and disposal units and surface contamination sites, the two most common site classifications.

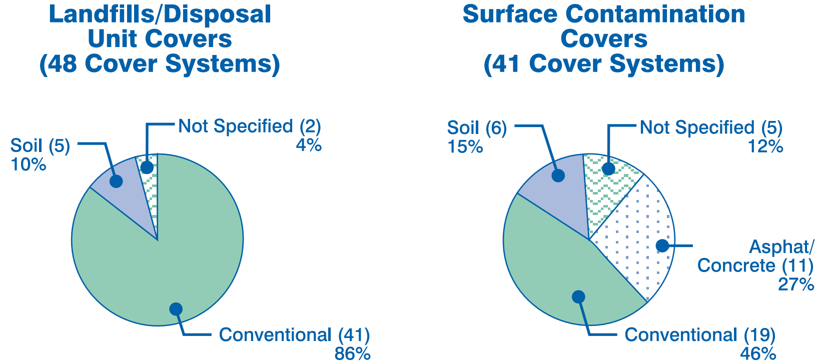
For the landfills/disposal units (48 cover systems):

- Conventional caps represented 86 percent of the cap remedies
- Soil caps represented 10 percent

For surface contamination sites (41 cover systems):

- Conventional caps represented 46 percent of the cap remedies
- Soil caps represented 15 percent
- Asphalt/concrete caps represented 27 percent

Figure 25: Cover System Types for Landfills/Disposal Units and Surface Contamination Sites*



Conventional covers are the most common cover type at both landfills/disposal units and surface contamination sites reviewed (see section on Cover Designs and Layer Components).

**Data included for a limited sample of Fund-Lead, remedial action phase sites selected from CERCLIS as of October 2006. Includes information obtained from preliminary close-out reports, five-year reviews, and other site documents. Sources: 3, 4, 7. Data sources are listed in Section 6.*

Whereas landfills/disposal units relied more frequently on conventional caps, surface contamination sites employed other cover designs, primarily asphalt/concrete as an alternative. A possible explanation for this condition might include the ongoing industrial use of surface contamination sites that requires the use of asphalt/concrete surfaces. Also, surface contamination sites may be more amenable to excavation and disposal. When less contamination remains, an asphalt/concrete cap, with no hydraulic barrier, may be appropriate.

Table 12 lists the numbers and types of hydraulic barriers at landfills/disposal units and surface contamination sites. The most frequently used hydraulic barrier at landfills/disposal units and surface contamination sites is a compact clay liner, which has been used for 17 of 60 cover systems (28 percent). Thirteen of 41 conventional caps (32 percent) at landfills/disposal units used compact clay liners, while 4 of 19 conventional caps (25 percent) at surface contamination sites used them.

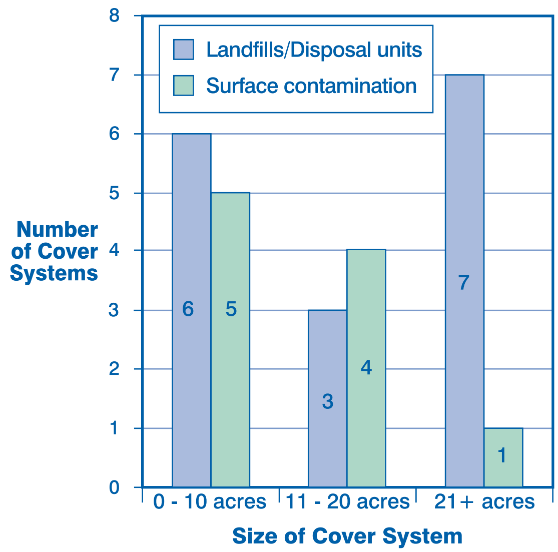
Table 12. Types of Hydraulic Barriers for Conventional Caps at Landfills/ Disposal Units and Surface Contamination Sites*

Type(s) of Hydraulic Barriers	Landfills/disposal Sites (41 projects)	Surface Contamination Sites (19 projects)
Compact Clay	13	4
Geomembrane	7	3
Composite	8	2
Geosynthetic Clay	3	3
Not Documented	10	7

**Composite barriers are hydraulic barriers with multiple types of components (e.g., compact clay and geomembrane).*
Data included for a limited sample of Fund-Lead, remedial action phase sites selected from CERCLIS as of October 2006. Includes information obtained from preliminary close-out reports, five-year reviews, and other site documents.
Sources: 3, 4, 7. Data sources are listed in Section 6.

Figure 26: Cover System Sizes by Site Type

Total Number of Caps = 26



For the sites evaluated, most cover systems at landfills/disposal units and surface contamination sites were less than 20 acres in size.

**Data included for a limited sample of Fund-Lead, remedial action phase sites selected from CERCLIS as of October 2006. Includes information obtained from preliminary close-out reports, five-year reviews, and other site documents.*
Sources: 3, 4, 7. Data sources are listed in Section 6.

Of the total 112 cover systems, information about the size of the cover system was obtained for 35 of the remedies. Based on this available information, the size of the cover systems ranged from as small as 1.2 acres to as large as 190 acres. Of the 35 cover systems, 26 were either conventional or soil caps at landfills/disposal units or surface contamination sites. Figure 26 shows the number of conventional and soil caps within the size ranges for both site types (landfills/disposal units and surface contamination). The number of conventional and soil caps at surface contamination sites decreased as the sizes of the cover systems increased: that is, there are fewer large cover systems. For conventional and soil caps at landfills/disposal unit sites, the least number of cover systems were in the "medium" size range of 11 to 20 acres.

Cover System Goals

Cover systems are used "to contain waste and any waste by-products (e.g., leachate or landfill gas), control moisture and air infiltration into the waste, and prevent the occurrence of odors, disease vectors, and other nuisances. Cover systems are also used to meet erosion, aesthetic, and other post-closure site end use criteria for waste management sites. These systems are intended to achieve their functional requirements for time periods of many decades to hundreds of years." To achieve these goals, most cover systems have a hydraulic barrier that limits (1) the downward migration of water into the contaminated media or waste, thereby minimizing leachate generation, or (2) the outward migration of gas (or volatile constituents) from the contaminated media or waste to the atmosphere.

The primary goals for cover systems evaluated in this report are to contain source or groundwater contamination. Of the 71 cover systems of interest (conventional or soil caps at landfills/disposal units or surface contamination sites), 52 (73 percent) are achieving the primary goal and are functioning as intended. The rest of the remedies have either not been constructed, have just been recently constructed and little performance information is available, or have been removed from the site.

For the landfills and disposal unit sites (46 conventional or soil caps):

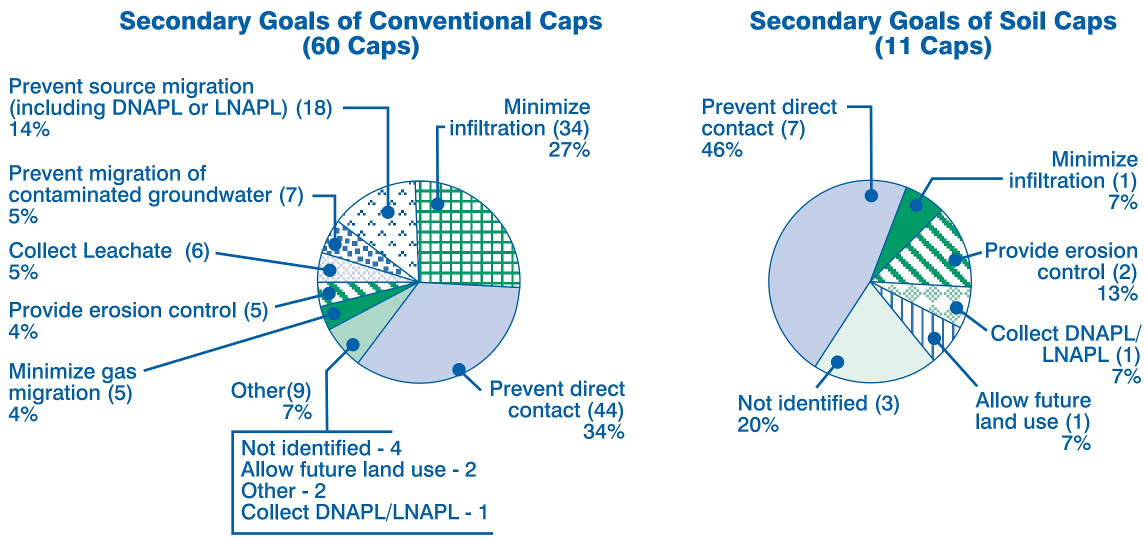
- The goal for 45 of the cover systems was to contain source contamination; the goal for one cover system was both source and groundwater containment.
- 39 of the cover systems (85 percent) were achieving their primary goal.

For the surface contamination sites (25 conventional or soil caps):

- The goal for 19 of the cover systems was to contain source contamination; the goal for 6 cover systems was both source and groundwater containment.
- 13 of the cover systems (52 percent) were achieving their primary goal.

In addition to the primary containment goals, secondary goals for cover systems range from preventing direct contact with the contained waste to allowing for future use of the site at landfills/disposal units and surface contamination sites.

Figure 27: Secondary Goals for Conventional and Soil Caps at Landfills/Disposal Units and Surface Contamination Sites*



For both conventional and soil caps reviewed, the most common secondary goal is preventing direct contact.

**Data included for a limited sample of Fund-Lead, remedial action phase sites selected from CERCLIS as of October 2006.*
Includes information obtained from preliminary closeout reports, five-year reviews, and other site documents.
Each cap may have more than one secondary goal.
Sources: 3, 4, 7. Data sources are listed in Section 6.

Figure 27 shows secondary goals for conventional and soil caps at landfills/disposal units and surface containment sites. The most common secondary goal for both types of cover system is to prevent direct contact with the contamination or waste contained. This is consistent with the primary purpose of a cover system to act as a barrier between contamination and human and ecological receptors.

Gas management and monitoring can be a critical aspect of cover design and performance and often depends on the age and type of waste or media being contained. Of the total 112 cover systems:

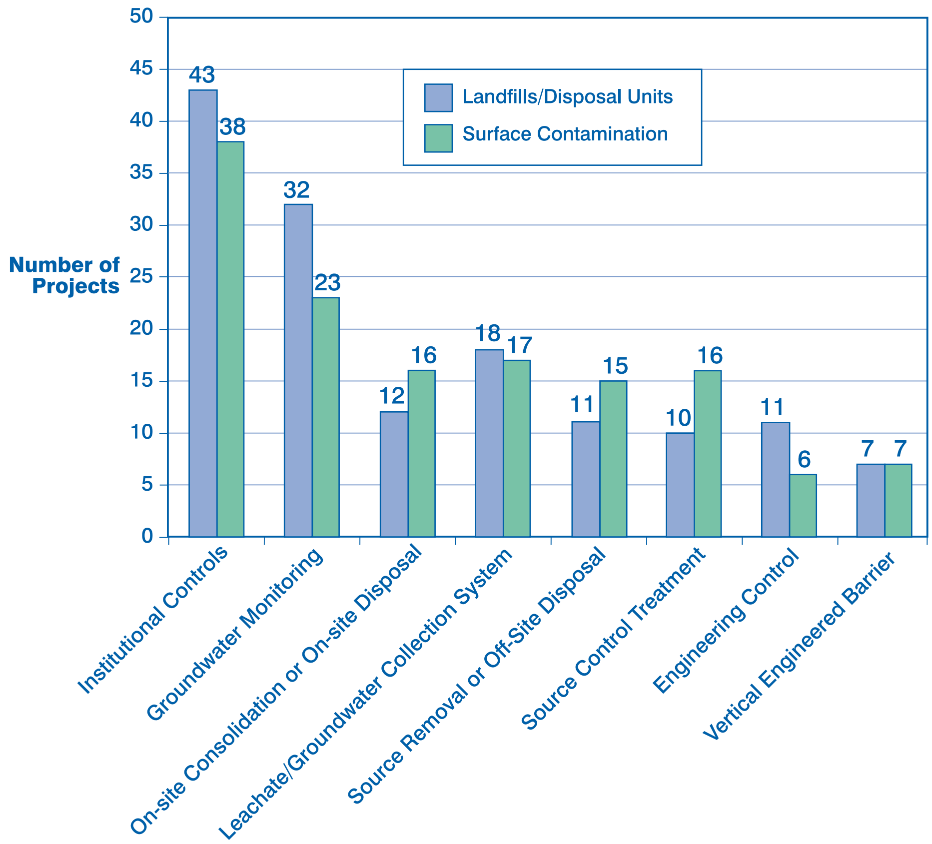
- Gas monitoring was confirmed at 24 sites
- Of the 24 sites, 16 can be classified as municipal solid waste (MSW) landfills.

In addition to monitoring, these remedies also employed gas management technologies. The two most common types of gas management at these sites were open vents and flares. Eight other sites in the study can also be classified as MSW landfills, but it is unclear if gas was being monitored. For these eight sites, there was either an open vent or no gas management.

Another goal of a cover system may be to allow for reuse and redevelopment of a site. Of the information available for all the cover systems, the most common planned reuse for a site was recreational at 14 sites (10 percent). Additional information about reuse of Superfund sites is available at *EPA's Superfund Redevelopment Web site* *(http://www.epa.gov/superfund/programs/recycle/).*

Rarely is on-site containment the only remedy selected for a site. Additional remedies also are implemented at these sites in conjunction with containment to provide additional protection or to expedite treatment of the contaminated media. The selection of other remedies in RODs is discussed in the introduction to this section. The two most common additional remedies for landfills/disposal units and surface contamination sites are institutional controls and groundwater monitoring (at 27 percent and 20 percent of landfills/disposal units and 24 percent and 15 percent of surface contamination sites, respectively). Figure 28 shows the additional remedies used with cover systems at landfills/disposal units and surface contamination sites.

Figure 28: Additional Remedies Used with Cover Systems*



For landfills/disposal units and surface contamination sites reviewed, the remedies most commonly used with cover systems were institutional controls and groundwater monitoring.

**Data included for a limited sample of Fund-Lead, remedial action phase sites selected from CERCLIS as of October 2006. Includes information obtained from preliminary close-out reports, five-year reviews, and other site documents.*
A cover system can have multiple additional remedies.
Additional remedies are those remedies used in addition of the cover system to remediate the source material.
Sources: 3, 4, 7. Data sources are listed in Section 6.

Vertical Engineered Barriers

VEBs are subsurface barriers made of an impermeable material designed to contain or divert groundwater. VEBs can be used to contain groundwater, divert uncontaminated groundwater, or divert contaminated groundwater from reaching resources, such as surface water bodies or drinking water intakes. In addition, VEBs are an integral part of many PRBs. The following information presents updates and additions to information first reported in the ASR Tenth Edition. Four VEBs were selected in RODs from FY 2002 through 2005.

VEBs for groundwater containment were selected at 55 Superfund remedial action sites, for a total of 57 projects. (Some sites have more than one VEB.) Nearly 90 percent of the VEBs have been installed (50 of 57). Table 13 indicates the numbers and types of VEBs. The types of barriers are:

- Slurry wall — Consists of a vertical trench that is filled with a low-permeability slurry of bentonite, soil, or cement.
- Sheet pile — A series of overlapping sheets of impermeable material, such as metal.
- Geosynthetic wall — Constructed by placing a geosynthetic liner into a trench.

- Grout — Constructed by injecting a high-pressure grout mixture into the subsurface. The grout used is typically cement or a mixture of cement and bentonite.
- Deep soil mixing — Overlapping columns created by a series of large-diameter, counter-rotating augers that mix *in situ* soils with an additive, usually bentonite, cement, or grout, that is injected through the augers.

Slurry walls are the most frequently planned or initiated type of VEB. There are five or fewer applications at Superfund remedial action sites for each of the other types of VEBs. Some VEBs incorporate more than one type of barrier.

Additional information on VEBs is available in *Evaluation of Subsurface Engineered Barriers at Waste Sites* (EPA-542-R-98-005), which is available online at *http://clu-in.org*.

Table 13. Types of Vertical Engineered Barriers (FY 1982 - 2005)*

Total Number of Sites = 55

Vertical Engineered Barrier Type	Number of Barriers**
Slurry Wall	54
Sheet Pile	5
Grout	3
Geosynthetic Wall	2
Deep Soil Mixing	2
Other	1
TOTAL	**67**

**Includes information from an estimated 74 percent of FY 2005 records of decision and amendments.*
Sources: 3, 4, 7. Data sources are listed in Section 6.
***Some VEBs incorporate more than one type of barrier.*

Section 6: References and Sources of Additional Information

Listed below are references and sources of additional information. The references identify sources of data and other information presented in the ASR Twelfth Edition. Online resources also are identified to download ASR spreadsheets or search ASR databases.

References

1. List of Superfund National Priorities List (NPL) sites that are final. *www.epa.gov/superfund/sites/query/queryhtm/nplfina.txt*. September 2005.
2. List of Superfund NPL sites that have been deleted. *www.epa.gov/superfund/sites/query/queryhtm/npldela.txt*. September 2005.
3. Records of Decision (RODs), ROD Amendments, and Explanations of Significant Difference from FY 1982 - 2005.
4. Innovative Treatment Technologies: Annual Status Report (ASR) Eleventh Edition (EPA-542-R-03-009). EPA. Office of Solid Waste and Emergency Response (OSWER). February 2004.
5. Groundwater Remedies Selected at Superfund Sites (EPA-542-R-01-022). EPA. OSWER. January 2002.
6. Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites. OSWER Directive 9200.4-17P. EPA. April 21, 1999.
7. Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS). *http://cfpub.epa.gov/supercpad/cursites/srchsites.cfm*.
8. The Role of Cost in the Superfund Remedy Selection Process (EPA 540-F-96-018). EPA. OSWER. September 1996.
9. Design and Construction of RCRA/CERCLA Final Covers (EPA/625/4-91/025). EPA. Office of Research and Development. May 1991.

Online ASR Resources

EPA maintains several resources online to allow users of the ASR access to additional information, including:

- ASR spreadsheets that can be downloaded from *http://clu-in.org/asr*:
  - o Table 1. Source Control Remedy Types at NPL Sites
  - o Table 3. Status of Source Treatment Projects by Technology
  - o Table 6. Groundwater Remedy Types at NPL Sites
  - o Table 10. Status of In Situ Groundwater Treatment Projects by Technology
  - o Figure 22. Status of Groundwater Pump and Treat Projects

  For these tables and figures, EPA prepared spreadsheets listing the specific sites names, locations, CERCLIS identification numbers, and types of remedies selected in RODs for the sites.
- Appendices available online at *http://clu-in.org/asr:*
  - o Appendix A. Treatment Technologies by Fiscal Year
  - o Appendix B. Treatment Technology Summary Matrix
  - o Appendix C. Definitions of Specific Treatment Technologies
  - o Appendix D. Treatment Technologies: Summary of Status Report Additions, Changes, and Deletions
  - o Appendix E. RODs Selecting Natural Attenuation
  - o Appendix F. Identification of Remedy and Record of Decision Types for Superfund Remedial Actions
  - o Appendix G. Reasons for Shut Down of 73 Groundwater Pump and Treat Systems
  - o Appendix H. On-Site Containment Remedies

  Some appendices (B, D, E, and H) have expanded over time and are not available in the printed version of this report.

ASR Search System — EPA created a searchable, online system to allow access to the data that form the basis for this report. See Box 16 for a list of the types of information available from the ASR Search System. This system is available at *http://cfpub.epa.gov/asr/*.

Box 16. Information in ASR Search System

Site Information
- Site name and location (city and state)
- CERCLIS ID
- Description

Project-Specific Information
- Operable unit name
- Cleanup type
- ROD date
- Lead agency and funding information

Contact Information
- Contact name and affiliation
- Address, phone number, and e-mail

Technology Information
- Technology and type (*in situ* or *ex situ*)
- Description of technology
- Treatment of residuals, if applicable
- Details (such as type of additives)
- Indicate whether part of a treatment train

Media and Quantity Information
- Media and quantity

Contaminant Information
- Contaminants treated
- Contaminants not treated

Status Information
- Status
- Date began operation
- Date completion is planned

Completed Project Information
- Cost
- Contaminant concentrations before and after treatment

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Treatment Technologies for Site Cleanup:
Annual Status Report, Twelfth Edition

Office of Solid Waste and
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