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Road Map to Understanding Innovative Technology Options for Brownfields Investigation and Cleanup, Second Edition

Road Map to Understanding Innovative Technology Options for Brownfields Investigation and Cleanup, Second Edition

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

NOTICE

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CONTENTS

BACKGROUND

The U.S. Environmental Protection Agency (EPA) has defined brownfields sites as "abandoned, idled, or under-used industrial and commercial facilities where expansion or redevelopment is complicated by real or perceived environmental contamination." EPA established its Brownfields Economic Redevelopment Initiative to empower states, communities, and other stakeholders involved in economic revitalization to work together to accomplish the redevelopment of such sites. Many states and local jurisdictions also help business and communities adapt environmental cleanup programs to the special needs of brownfields sites.

Preparing brownfields sites for productive reuse requires the integration of many elements—financial issues, community involvement, liability considerations, environmental assessment and cleanup, regulatory requirements, and more—as well as coordination among many groups of stakeholders. The assessment and cleanup of a site must be carried out in a way that integrates all those factors into the overall redevelopment process. In addition, the cleanup strategy will vary from site to site. At some sites, cleanup will be completed before the property is transferred to new owners. At other sites, cleanup may take place simultaneously with construction and redevelopment activities. Regardless of when and how cleanup is accomplished, the challenge to any Brownfields program is to clean up sites in accordance with redevelopment goals. Such goals may include cost-effectiveness, timeliness, and avoidance of adverse effects on structures on the site and on neighboring communities, as well as redevelopment of the land in a way that benefits communities and local economies.

Numerous technology options are available to assist those involved in brownfields cleanup. EPA's Technology Innovation Office (TIO) encourages the use of innovative, cost-effective technologies to characterize and clean up contaminated sites. Innovative technologies for evaluating the nature and extent of contamination and for addressing the cleanup of brownfields sites hold promise for reducing the cost of cleanup and accelerating the cleanup schedule—potentially producing significant benefits to brownfields stakeholders by reducing

barriers to redevelopment that add to costs or time schedules, or create uncertainties. When such factors as lower cost, increased environmental protection, and improved effectiveness are considered, innovative technologies frequently are more cost-effective and provide better and more efficient cleanup than established treatment technologies. Often, they also are more acceptable to communities.

Innovative does not mean unproven. EPA defines an innovative technology as one that has been used in the field but that is not yet considered routinely for use. In addition, cost and performance data on the technologies may be insufficient to encourage managers of cleanup projects to select those technologies over established methods. Nevertheless, innovative technologies are being used in many cleanup programs to assess contamination and to treat a variety of hazardous substances and petroleum products that have been released into the environment.

Many initiatives undertaken to promote the use of innovative technologies have been successful. For example, soil vapor extraction and thermal desorption, formerly defined as innovative technologies, are now categorized as established technologies according to EPA's Treatment Technologies for Site Cleanup: Annual Status Report (ninth edition). Because of the large number of applications and increased availability of information about cost and performance, those technologies have graduated from innovative to established status.

An **Emerging Technology** is an innovative technology that currently is undergoing bench-scale testing, in which a small version of the technology is tested in a laboratory.

An **Innovative Technology** is a technology that has been field-tested and applied to a hazardous waste problem at a site, but lacks a long history of full-scale use. Information about its cost and how well it works may be insufficient to support prediction of its performance under a wide variety of operating conditions.

An **Established Technology** is a technology for which cost and performance information is readily available. Only after a technology has been used at many different sites and the results fully documented is that technology considered established.

Comprehensive information about the range of these technologies and their use, as well as technical expertise pertinent to them, is available from EPA's Brownfields Technology Support Center (TSC), coordinated through TIO and supported by EPA's Office of Research and Development (ORD). Newly established in 1999 as a pilot program, the TSC assists brownfields decision makers by presenting strategies for streamlining site assessment and cleanup, identifying information about technology options, evaluating plans and documents, describing complex technologies to communities, and providing demonstration support (see page 10 for more information about the TSC).

INTRODUCTION

The *Road Map to Understanding Innovative Technology Options for Brownfields Investigation and Cleanup, Second Edition*, is designed to assist in the identification and selection of innovative characterization and cleanup technologies for brownfields redevelopment. The Road Map provides a generally applicable outline of the steps involved in the cleanup of a site slated for redevelopment and introduces brownfields stakeholders to the range of innovative technology options and resources available to them. The Road Map is intended for the various individuals involved in or affected by the redevelopment of brownfields sites, whether public projects, private developments, or public-private partnerships. The second edition, which incorporates minor revisions in the structure and content of the first edition, has been expanded significantly to include new and updated resources and is accompanied by the *Tool Kit of Information Resources for Brownfields Investigation and Cleanup*, now available in CD-ROM format, or on line at <*http://clu-in.org*>.

This Road Map is primarily targeted at those stakeholders who will make decisions about brownfields sites, but who may not be familiar with many of the elements involved in cleaning up those sites. Its purpose is to promote innovative site characterization and cleanup technologies that can speed up the progress of brownfields projects and reduce the expense they entail.

It is important to understand that the cleanup process may not occur in the sequence outlined in the following chapters. At many sites, several activities may be undertaken concurrently with other phases. In addition, some steps reoccur throughout the process. For example, many technologies that are useful for investigating and characterizing sites during the preliminary phases of a brownfields project also are appropriate for use in later stages for cleaning up and monitoring sites. It is very important to understand the logical progression of the process, though, to ensure that the groundwork is laid for future phases, as well as to determine whether activities can be combined or implemented concurrently.

The Road Map is not an official guidance document. Instead, it draws upon EPA's experiences with Superfund sites, corrective action sites under the Resource Conservation and Recovery Act (RCRA), and Underground Storage Tank (UST) sites. Specific conditions—such as the kinds and amount of contamination, the proposed reuses of the property, the financial resources available, and the level of support from neighboring communities—vary from site to site.

How to Use the Road Map

The first section, Before You Begin, discusses important factors that set the stage for the assessment and cleanup of brownfields sites and lists applicable resources. Regulatory guidelines that will guide the process are introduced, and innovative technologies are discussed within the overall framework of the selection of characterization and cleanup technologies.

The remaining four sections of the Road Map summarize the general phases of the cleanup of potentially contaminated sites: site assessment, site investigation, assessment of cleanup options, and design and implementation of the remedy. Each section describes the objective to be accomplished, outlines the key questions to be answered, summarizes the activities undertaken during that phase, discusses key questions for technology selection and lists several information resources available to assist in selecting technologies, and points to specific actions to be taken at the completion of the phase. The resources are grouped by type of resource — technology resources, site-specific resources, or technology-specific resources — and are listed in alphabetical order under each category. Technology resources provide general information about technologies and their application, site-specific resources provide information about the application of innovative technologies to specific contaminants and site types, and technology-specific resources present detailed information about specific technologies and the application of those processes to specific contaminants and media. In addition, the section features a brief overview of technologies that can be used during that phase.

The Road Map is intended to identify and answer questions related to the selection of technologies, not those questions related to other brownfields issues. Please remember that the key questions and activities to be conducted are intended to guide the reader in identifying issues that should be addressed. To serve as guideposts to the cleanup process, the questions take the point of view of the various groups involved in that process. They ask what stakeholders as a group working together—the "we" of each question—must do as assessment and cleanup progresses.

Several appendices also are included to help stakeholders understand technical issues and terms related to cleanup. *Appendix A, Guide to Contaminants Found at Typical Brownfields Sites*, identifies activities that may have caused contamination at sites being considered for redevelopment. *Appendix B, List of Acronyms and Glossary of Key Terms*, defines specialized terms and acronyms used in discussing and describing brownfields cleanup efforts. *Appendix C, List of Brownfields and Technical Support Contacts*, provides information about state and EPA regional and technical points of contact. *Appendix D, How to Order Documents*, provides information about ordering the documents listed in the Road Map.

Tool Kit of Information Resources for Brownfields Investigation and Cleanup CD-ROM

The Road Map is accompanied by the *Tool Kit of Information Resources for Brownfields Investigation and Cleanup CD-ROM*. The organization of the CD-ROM matches that of the Road Map — by sections titled "Before You Begin," "Site Assessment," "Site Investigation," "Cleanup Options," and "Cleanup Design and Implementation." Each of the resources identified in the Road Map can either be viewed or downloaded directly from the CD-ROM, or accessed or ordered on line using links provided on the CD-ROM. The resources can be searched alphabetically by title and by section.

How to Submit Comments

To help ensure that any future versions of the Road Map document meet the needs of its intended audience, EPA invites comments from the members of the brownfields community. Please submit comments to:

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How to Obtain Additional Copies

Additional copies of this document can be obtained from:

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P.O. Box 42419
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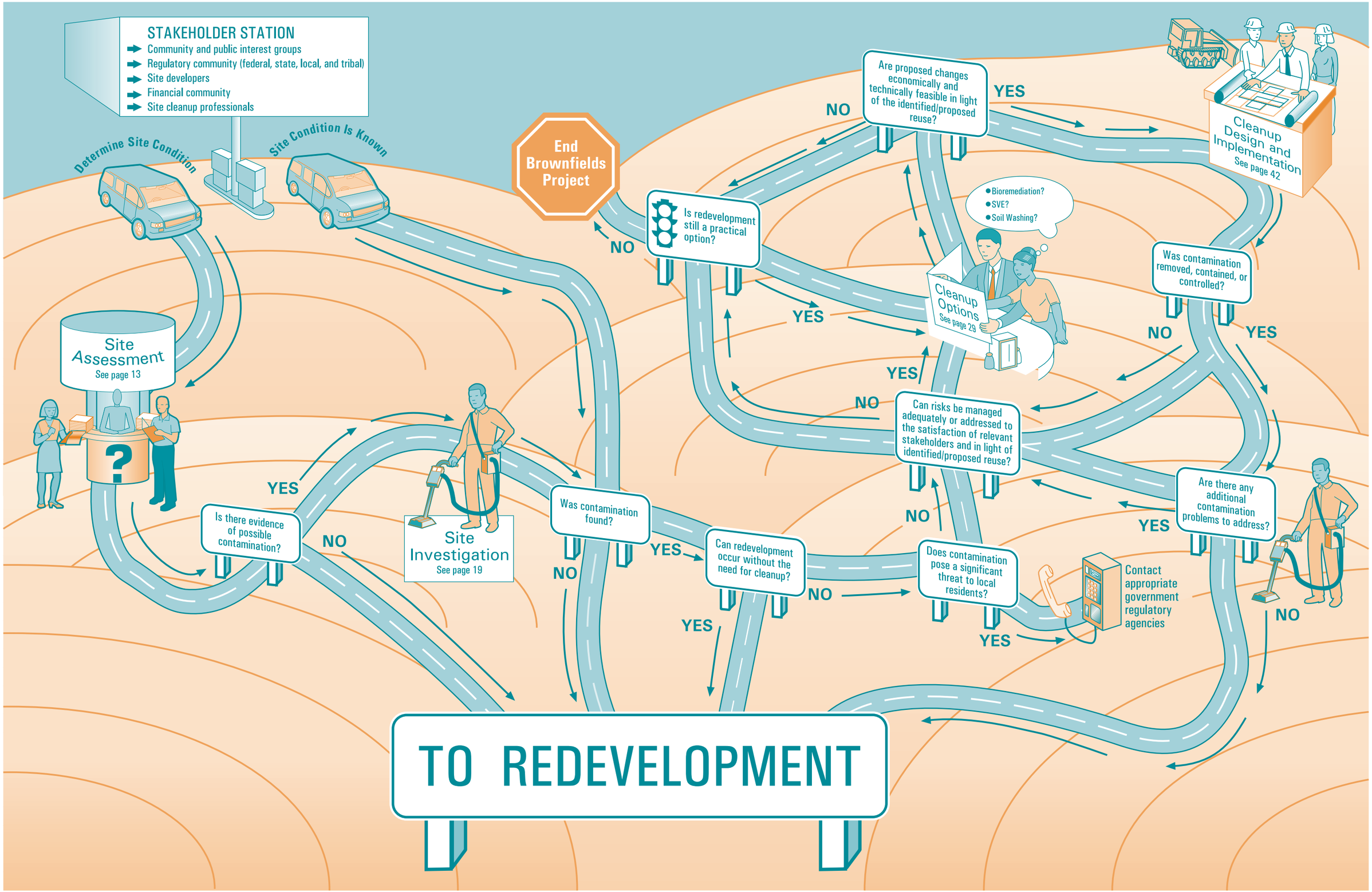
WWW: *<http://www.epa.gov/ncepihom/>*

When ordering, refer to document number EPA 542-B-99-009.

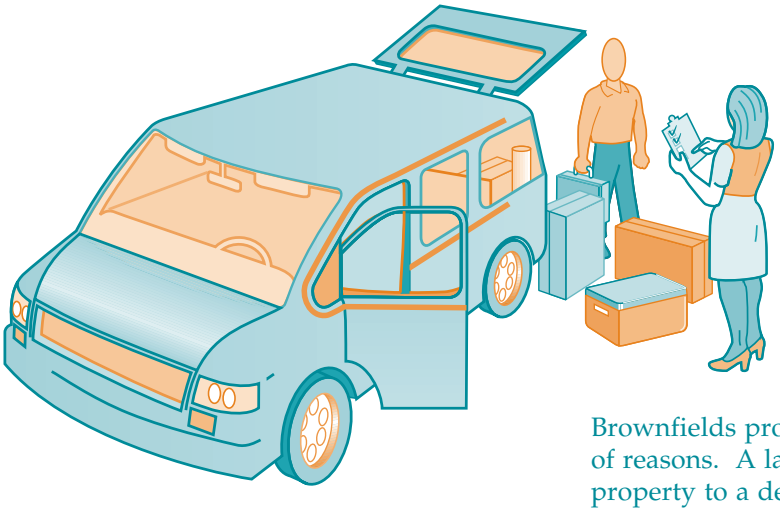

STAKEHOLDER STATION
Community and public interest groups
Regulatory community (federal, state, local, and tribal)
Site developers
Financial community
Site cleanup professionals
Determine Site Condition
Site Condition Is Known
End Brownfields Project
Site Assessment
See page 13
Is there evidence of possible contamination?
YES
NO
Site Investigation
See page 19
Was contamination found?
NO
YES
Is redevelopment still a practical option?
NO
YES
Can redevelopment occur without the need for cleanup?
YES
NO
Are proposed changes economically and technically feasible in light of the identified/proposed reuse?
NO
YES
Cleanup Options
See page 29
Bioremediation?
SVE?
Soil Washing?
Can risks be managed adequately or addressed to the satisfaction of relevant stakeholders and in light of identified/proposed reuse?
YES
NO
Does contamination pose a significant threat to local residents?
NO
YES
Contact appropriate government regulatory agencies
Cleanup Design and Implementation
See page 42
Was contamination removed, contained, or controlled?
NO
YES
Are there any additional contamination problems to address?
YES
NO
TO REDEVELOPMENT

BEFORE YOU BEGIN

What is the Planned End Use? A Word About Redevelopment

It is important to consider potential redevelopment plans from the outset of any brownfields project. The redevelopment plan (or lack thereof) will govern most brownfields projects, from the identification of site investigation and cleanup standards and the ability to obtain financing to the ultimate affordability or profitability of the project.

Defining and understanding the overall long-term goals of the brownfields project and the decisions to be made throughout the project in support of those goals is a crucial element in identifying appropriate technologies for site investigation and cleanup.



Technology tools, when carefully selected, will assist those responsible for the brownfields project in collecting the data necessary to support such decisions and accomplish the established goals. During the many phases of a brownfields project, it is important to keep in mind that technology options are an effective means of achieving the desired result at a site, rather than an end in themselves.

Brownfields projects may be initiated for a number of reasons. A landowner may want to sell a property to a developer who wants to purchase and develop it. A municipality may want to clean up a parcel or area that has become an eyesore, create space for business development, or create a park in a disadvantaged area. A local comprehensive plan may call for infill development of a certain type in a brownfields area. The brownfields process will be tailored to the specific end use, if that use is known. For example, if the redevelopment plan calls for the construction of a light industrial facility, it may be appropriate to apply industrial investigation and cleanup standards that are less stringent than those applicable to property that is to be redeveloped for residential use. The standards required will affect every aspect of the project, from its overall cost (which is generally greater as the standards become more conservative) to the applicability of innovative characterization and cleanup technologies. Keep in mind, however, that new information about contamination or cleanup may require that reuse plans be altered; develop flexible plans so that revised cleanup needs can be

incorporated into them.

If the end use is not known at the beginning of the project, the individuals involved should make every attempt at least to identify the general type of desired development, whether industrial, commercial, or residential or a mixed-use development of some sort. Absent that information, the most conservative assumptions will be made at every stage of the brownfields project, a circumstance that could increase significantly the time and expense of the project and may even make it infeasible.

Understanding Regulations and Regulatory Guidelines and Standard Industry Practices

Understanding the applicable environmental laws and regulations is crucial to selecting the appropriate technologies for cleaning up a site. It is important to note that many brownfields sites will be managed under state regulatory authorities. Therefore, the state regulatory authority will identify and oversee many of the requirements for, and steps in, site assessment, site investigation, the selection of cleanup options, the design and implementation of cleanup, and the management of wastes generated during the cleanup. State regulatory agencies should be consulted to determine what, if any, site-specific requirements or permits are applicable. State regulators also can help to identify other requirements (such as applicable federal statutes) that also may affect the site. For these reasons, it is important to research federal and state laws, regulations, and applicable policies or guidelines at the outset and to remain in constant contact with appropriate state and federal regulatory agencies throughout the cleanup process.

It is important to realize that, apart from cleanup, redevelopment may be governed by other government, nongovernment, and private institutions and practices. Many of the standards are designed to help the brownfields redevelopment project obtain financing from public programs and private banks and institutions. Guidance and standards are issued by government and nongovernment organizations, such as the American Society for Testing and Materials (ASTM), the Federal Deposit Insurance Corporation (FDIC), and state and local economic development authorities, and even private lenders.

Although compliance with regulations and official policy directives under other federal regulatory and cleanup programs, such as Superfund, may not be required, some of the information gathered and lessons learned under such programs may be useful in the investigation and cleanup of brownfields sites. For example, in the past, a number of sampling events and field mobilizations have been required at many RCRA and Superfund sites to gather sufficient information to characterize the site adequately. Additional sampling has been found necessary for a number of reasons — for example, to ensure that sampling was performed for all potential contaminants, to adequately analyze all pathways of exposure, to obtain representative samples of wastes and environmental media, and to obtain analytical results of the appropriate accuracy to enable regulatory authorities to make decisions about the cleanup with confidence. Multiple sampling events have increased costs and extended the decision-making period for selecting options for site cleanups. When possible, sampling plans should be flexible and dynamic and should allow for adjustments in the field in light of actual field conditions observed and the analytical results. Such a dynamic approach usually requires a well-rounded technical team that comprises a broad range of technical expertise and the use of field analytical technologies, including an on-site mobile laboratory, to provide quick turnaround analyses.

EPA also can be a valuable resource for brownfields stakeholders by providing regulatory and policy support to facilitate the selection of technologies (see *Appendix C, List of Brownfields and Technical Support Contacts* for information about EPA regional and technical points of contact).

Seeking External Support (Community Relations and Professional Support)

A wealth of information and expertise related to site cleanup is readily available. It is important that members of the brownfields community have access to that information and are able to draw upon lessons learned to benefit from the experience of others.

Most decision makers at brownfields sites will require technical and legal assistance to fully understand the complexities of investigating and cleaning up a contaminated site. In fact, some states may require the participation of certified or licensed professionals to help guide the site investigation and cleanup process. State regulatory agencies should be

consulted to determine the requirements, if any, for the participation of certified or licensed cleanup professionals. It is recommended that site cleanup professionals and legal and other experts be recruited as members of the brownfields team.

The brownfields community can benefit from EPA's assistance in directing its members to appropriate resources and providing opportunities to network and participate in the sharing of information. A number of Internet sites, databases, newsletters, and reports provide opportunities for brownfields stakeholders to network with other stakeholders to identify information about site cleanup and technology options. As noted in the preceding section, EPA's Brownfields Technology Support Center is a valuable new resource for brownfields decision makers (see page 10 for more information).

Comparing Innovative Technologies to Other Characterization and Cleanup Options

The Road Map focuses on innovative characterization and treatment options. Although the Road Map emphasizes the use of innovative technologies to address contamination, the use of other technologies or non-treatment options also should be considered. For example, established or even non-treatment options such as containment, or more standard technology options also may be appropriate to address contamination at brownfields sites. Examples of containment include excavation with off-site disposal in a landfill, or containing contaminated soil on site using a cap and a vertical engineering barrier such as a slurry wall. In either case, containment does not involve actively treating the waste to recover or degrade contaminants. Established technologies, such as solidification/stabilization, soil vapor extraction, thermal desorption, incineration, and pump-and-treat processes for groundwater contamination, also are alternatives to innovative technologies for use in addressing contamination.

When deciding between innovative and established technologies or between treatment and containment technologies, brownfields stakeholders should compare the effectiveness and efficiency of each technology against the specific needs of the individual site and stakeholders. It also is important that brownfields decision makers consider both the current effects of the selected technology approach and its future effects on potential development of the site, as well as the capability of the approach, to ensure long-term protectiveness.

Information Centers, Training, and Other Resources

Described on the next three pages are some of the resources available to brownfields projects from government and nongovernment institutions, including the various EPA hotlines for statutory and regulatory programs that may affect brownfields projects. The resources provide more general information about the brownfields process than the technology resources identified in the chapters that follow. Training courses and programs provided by EPA, as well as other organizations, also are identified. Information about state and local resources can be obtained from the contact for each state listed in *Appendix C, List of Brownfields and Technical Support Contacts.*

INFORMATION CENTERS, TRAINING, AND OTHER RESOURCES

An Analysis of State Superfund Programs: 50-State Study, 1998 Update

The document, prepared by the Environmental Law Institute (ELI) in association with EPA, provides an analytical overview of state Superfund programs, and includes information about statutes, program staffing and organization, sites, cleanup activities, cleanup policies and standards, requirements for public participation, funding and expenditures, and enforcement tools. It highlights the most noteworthy developments in state capabilities that have emerged since the 1995 update. The report also discusses the voluntary remediation and brownfields programs established by the states and presents detailed program information arranged in tables that facilitate comparisons among the states. A copy of the report can be downloaded from ELI's Web site at *<http://www.eli.org/bookstore/research.htm>*; select "1998 Research Reports" to download the report.

Brownfields: A Comprehensive Guide to Redeveloping Contaminated Property

This book, published by the American Bar Association (ABA), is aimed at an audience of real estate and environmental attorneys, property owners and developers, environmental regulators and consultants, and state and local government leaders. The book provides an overview with background information about the issues and explanations of the federal and state laws governing brownfields. Legal, business, financial, and political issues associated with redeveloping contaminated property also are addressed. The book presents the scientific concepts used to clean up contaminated property, describing risk assessment and remediation strategies. Comprehensive information about state voluntary cleanup programs, with more than 400 pages of information on existing programs, also is provided. The book, published in 1997, can be purchased through ABA's Web site at *<http://www.abanet.org>* or at bookstores across the country. The ISBN number for the book is 1-57073-439-9.

Brownfields Technology Support Center

Coordinated through TIO, and with the support of EPA's ORD laboratories, the Brownfields TSC ensures that brownfields decision makers are aware of the full range of technologies available, can make "smart" technology decisions for their sites, and can determine whether innovative options are available and feasible for their sites. The center provides a readily accessible resource for unbiased assessments and supporting information about options relevant to specific sites. The center also will provide a technology-oriented process for reviewing cleanup plans for those sites. Requests for assistance can be submitted on the Internet at *<http://clu-in.org/brownfieldstsc>* or by telephone at 877-838-7220. Soon to be published by the TSC, the *Directory of Technology Support Services to Brownfields Localities (EPA 542-R-99-010)* provides information about EPA program offices, organizations funded by EPA, other federal agencies, and nongovernment organizations that may be able to provide expertise to assist in the selection of technologies for the characterization and cleanup of brownfields properties. Additional resources and Web sites also are listed. The directory will be available on the Internet at *<http://clu-in.org>*.

EPA Brownfields Economic Redevelopment Initiative Internet Site

This Internet site, coordinated by EPA's Office of Solid Waste and Emergency Response (OSWER) Outreach and Special Projects Staff (OSPS), provides extensive information about EPA's Brownfields Economic Redevelopment Initiative and resources related to the initiative. Descriptions of EPA's brownfields pilots and points of contact in each of the EPA regional offices are provided, as well as publications, regulations, and other documents. Brownfields stakeholders involved in the selection and use of technologies for environmental cleanup may have particular interest in learning more about EPA's Brownfields Cleanup Revolving Loan Fund (BCRLF) Pilots, a program that includes, among other elements, funding of assessment demonstration pilot programs for the assessment of brownfields properties and testing of cleanup and redevelopment models. Specific details about the program, including criteria for eligibility and a list of BCRLF pilots that have been awarded, are available on the Web site. For additional information, visit the Web site at *<http://www.epa.gov/brownfields>*.

INFORMATION CENTERS, TRAINING, AND OTHER RESOURCES

Hazardous Substance Research Centers

The Hazardous Substance Research Centers (HSRC) is a national organization, funded in part by EPA, the U.S. Department of Energy (DOE), and the U.S. Department of Defense (DoD), that carries out a program of basic and applied research, technology transfer, and training. HSRC provides free technical assistance to communities with environmental contamination issues through two outreach efforts, the Technical Outreach for Communities (TOSC) Program and the Technical Assistance to Brownfields (TAB) Communities Program. TOSC uses the researchers and professionals at more than 30 universities to help community groups understand the technical issues at hazardous waste sites. Through the TOSC program, toll-free information hotlines are available and workshops and other educational programs are offered. TAB helps communities to clean up and redevelop properties that have been damaged or undervalued by environmental contamination. Through five regional training centers, HSRC's TAB provides training for community members involved with brownfields efforts on the following subjects: leadership, risk assessment, brownfields processes, site assessment, and cleanup alternatives. More information is available on HSRC and their Brownfields initiatives on their Web site at *<http://www.hsrc.org>*. Detailed information about the TOSC and TAB programs is available at *<http://toscprogram.org/>*.

Hazardous, Toxic and Radioactive Waste Center of Expertise

Coordinated through the U.S. Army Corps of Engineers, the Hazardous, Toxic and Radioactive Waste Center of Expertise (HTRW-CX) provides technical assistance and information about the use of innovative technologies for cleanup of contaminated properties. Detailed information about a variety of available innovative technology resources, points of contact at the HTRW-CX, and upcoming training courses and workshops is provided on the Center's Web site. More than 50 case studies of successful applications of innovative technologies also are described. Visit the HTRW-CX Web site at *<http://www.environmental.usace.army.mil/info/technical/it/it.html/>* for more information.

Interstate Technology and Regulatory Cooperation

The Interstate Technology and Regulatory Cooperation (ITRC), created through the Western Governors Association, promotes the use of innovative hazardous waste and remediation technologies. Made up of more than 25 states, 3 federal partners, stakeholders, and 2 state associations, the ITRC: (1) provides a forum through which states can exchange technical information; (2) creates a network of state contacts for the promotion of innovative technologies; (3) identifies interstate barriers to the deployment of technologies; (4) benchmarks state perspectives about innovative technologies; and (5) develops consensus among state regulators, in collaboration with industry and public stakeholders, on technical regulatory aspects of the use of innovative technologies. Brownfields decision makers who wish to obtain applicable guidance documents for the use of innovative technologies will find several guidance documents developed by the ITRC on ITRC's Web site. For additional resources and points of contact, visit the ITRC's Web site at *<http://www.ITRCweb.org/>*.

RCRA, Superfund, and Emergency Planning and Community Right-to-Know Act (EPCRA) Hotline

This hotline provides up-to-date information about the RCRA, Superfund, and EPCRA programs. The hotline handles information about EPA's RCRA regulations and programs implemented under RCRA, including the UST program, the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), EPCRA, the Superfund Amendments and Reauthorization Act (SARA) Title III, and the Oil Pollution Act (OPA). The hotline also provides referrals for obtaining related documents concerning the RCRA, UST, Superfund/CERCLA, and Pollution Prevention/Waste Minimization programs. The hotline operates daily Monday through Friday, 9:00 a.m. to 6:00 p.m. Eastern Standard Time (EST). The hotline can be reached by telephone at 800-424-9346 for all nongovernment locations outside the Washington, DC metropolitan local calling area, or 703-412-9810 for all locations in the Washington, DC metropolitan local calling area.

INFORMATION CENTERS, TRAINING, AND OTHER RESOURCES

RCRA Information Center (RIC)

The RIC indexes and provides public access to all regulatory materials supporting EPA's actions under RCRA and disseminates publications from EPA's Office of Solid Waste. The information center operates daily, Monday through Friday, 9:00 a.m. to 4:00 p.m. EST. The information center can be reached by telephone at 703-603-9230, by facsimile at 703-603-9234, or by e-mail at <*RCRA.Docket@epa.gov*>.

Superfund Docket and Information Center

The Superfund Docket and Information Center provides access to Superfund regulatory documents, Superfund Federal Register Notices, Records of Decision (ROD), and public comments sent to EPA. The center operates daily, Monday through Friday, 9:00 a.m. to 4:00 p.m. EST. The center can be reached by telephone at 703-603-9232 or by facsimile at 703-603-9240.

TechDirect

TechDirect, hosted by EPA's TIO, is a free electronic mail service that highlights new publications and events of interest to site assessment and remediation professionals. At the beginning of each month, TIO sends subscribers an e-mail message announcing the availability of publications and the scheduling of events. The message also directs subscribers to sources from which they can obtain more information. Contact Mr. Jeff Heimerman at 703-603-7191 or by e-mail at <*heimerman.jeff@epa.gov*> for more information, or view on-line at <*http://clu-in.org/techdrct/default.htm*>.

Toxic Substances Control Act (TSCA) Assistance Information Service

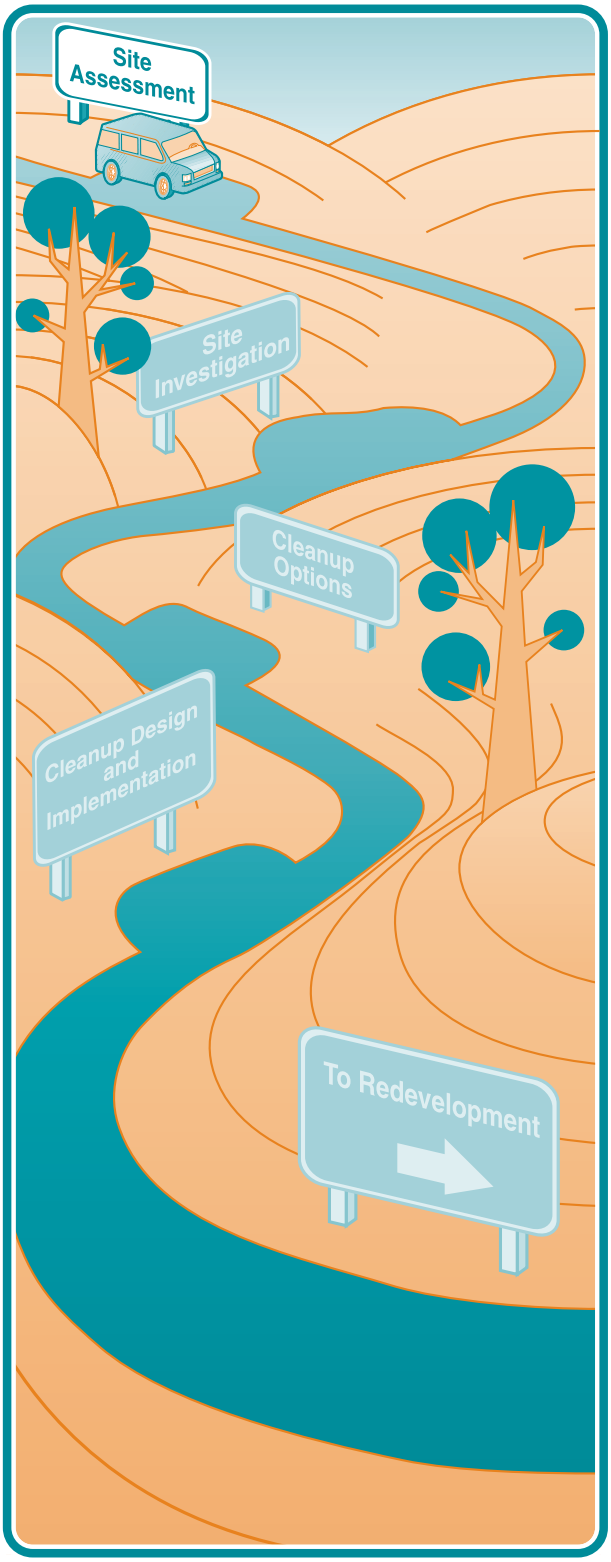
The information service provides information about regulations under TSCA to the chemical industry, labor and trade organizations, environmental groups, and the general public. Technical as well as general information is available. The information service operates daily, Monday through Friday, 8:30 a.m. to 5:00 p.m. EST. The information service can be reached by telephone at 202-554-1404, by facsimile at 202-554-5603, or by e-mail at <*tsca-hotline@epa.gov*>.

Training Information

Training courses and programs that can be useful to brownfields stakeholders, particularly those involved in technology selection, are identified below:

- EPA's Training-Exchange (TRAINEX), an Internet site that provides a range of training information for representatives of federal, state, local, and tribal agencies, is intended primarily for individuals involved in hazardous waste management and remediation. The site provides information about more than 65 classes, as well as schedules for their delivery. Visit the TRAINEX Web site at <*http://www.trainex.org*> for additional information.
- EPA's Field-Based Technologies Training Program and the Innovative Treatment Technologies Course are particularly appropriate for individuals involved in selecting technologies for site investigation and cleanup. The Field-Based Technologies Training Program consists of two advanced-level training courses — the *Field-Based Site Characterization Technologies Course*, which introduces a wide array of characterization technologies and the *Strategies for Field-Based Analytical and Sampling Technologies Course*, which provides an overview of the planning and process issues associated with the use of field analytical and sampling technologies. Both courses are designed for environmental professionals and regulators. The Innovative Treatment Technologies Course provides information about technical, financial, and practical factors to be considered when determining the appropriateness of innovative treatment technologies. That course is intended only for personnel of federal, state, and local agencies and tribes. For information about the courses and schedules for their delivery, visit the TRAINEX Web site at <*http://www.trainex.org*>; select "CERCLA Education Center (CEC)."
- Information about upcoming courses, provided by a variety of federal and non-federal organizations, is provided on TIO's CLU-IN Web site at <*http://clu-in.org*>; select "Upcoming Courses and Conferences" under "What's Hot? What's New?
- ASTM also offers many technical and professional training opportunities which may be of interest to brownfields decision makers. For more information, visit their Web site at <*http://www.astm.org/TRAIN/envdates.html*>.

SITE ASSESSMENT



Collect and Assess Information About the Brownfields Site

OBJECTIVE

The purpose of this step is to evaluate the potential for contamination at a particular site by collecting and reviewing existing information. This environmental assessment is an initial investigation usually limited to a search of historical records. The data collected also includes information about past and current environmental conditions and historical uses of the site. The environmental assessment is the most crucial step in the brownfields process, because any further environmental investigation and cleanup will hinge on whether potential environmental concerns are identified during that phase.

During the site assessment phase, it is important to consider the activities and requirements described in the subsequent chapters and determine how they will be affected by the initial site assessment. Because the information obtained in this phase will determine whether any future work must be done at the site, the site assessment must be thorough and tailored to meet specific data objectives. As discussed in the section Before You Begin, decisions made about the end use of a site and the long-term goals of the brownfields project will determine the types and quantity of data that must be collected, as well as the level of quality the data must attain. The data quality objectives (DQO), in turn, will serve as the basis upon which the best decisions will be made about the most appropriate technologies and techniques to be used in collecting and analyzing the data at a particular site (see *Appendix B, List of Acronyms and Glossary of Key Terms,* for a definition of DQO).

The data collected during this initial step of the cleanup process is extremely important for use in identifying and evaluating the applicability of site assessment and cleanup technologies, as well as in determining whether the property can be cleaned up to the level necessary for its intended reuse. If it is carefully planned, some of the follow-on work, such as limited sampling, may also be accomplished during this phase. The site assessment also can provide a preliminary indication of what types of cleanup technologies might be available. It also is essential to assess and address the needs and concerns of the community (for example, the development of social and economic profiles and the identification of acceptable environmental risk).

The potential applicability of innovative site characterization technologies to the site also should be considered. For example, technologies that detect possible contamination in the air may be applicable at this stage as well as some analytical sampling technologies useful for assessing contamination in soil or groundwater. However, since much of the work at this stage involves a search of paper and electronic records, the use of technologies may be somewhat limited.

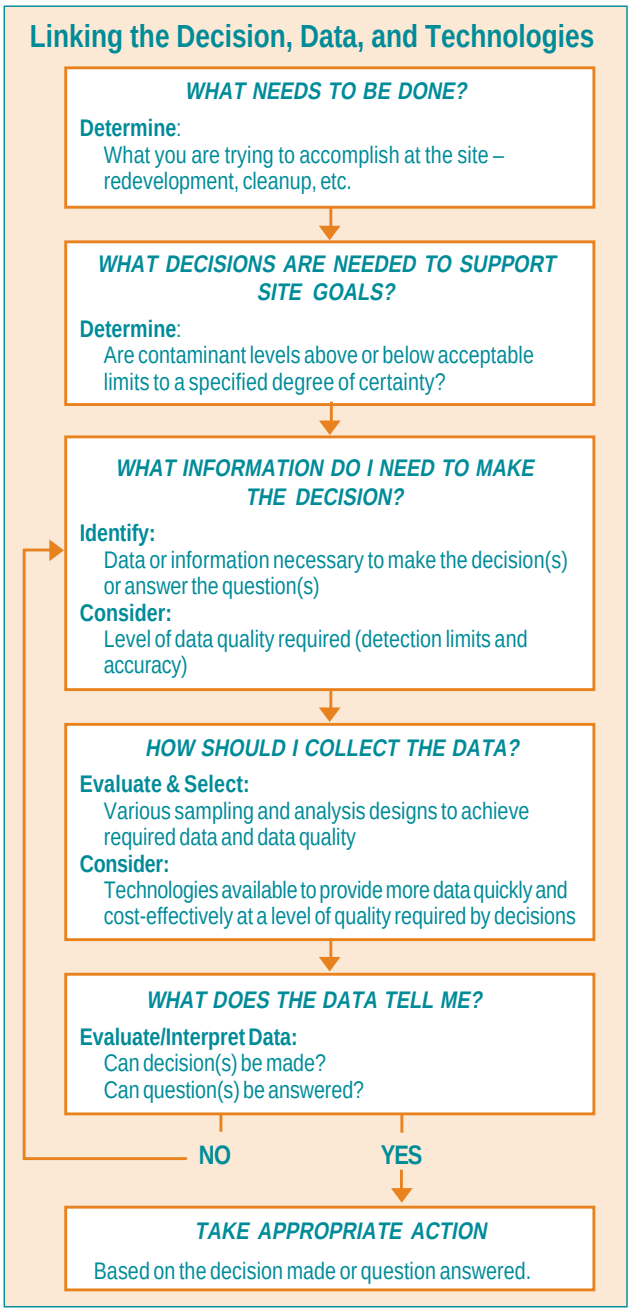
What Do We Need to Know?

KEY QUESTIONS

Factors that should be considered during this phase include:

1. Has a redevelopment plan been prepared or a proposed end use identified? Is the site located in an area targeted for redevelopment? Is the site located in an industrial area? Will it remain industrial or be rezoned for commercial use? Or is a residential development planned? Will community members who use the property be exposed directly to the soil or sediment?
2. What data are needed to support the long-term goals of the project, address concerns related to it, and ensure its acceptability? What level of quality or uncertainty is necessary to meet those goals?
3. What is known about the site? What records exist that indicate potential contamination and past use of the property? Have other environmental actions occurred (such as notices of violation)? Has an environmental audit been conducted? What information is needed to identify the types and extent or the absence of contamination?
4. If the site is located in an area targeted for redevelopment, is the site being considered for cleanup under a federal or state Superfund cleanup initiative?
5. Will the site be entered into a Voluntary Cleanup Program (VCP)? If not, what agency (federal, state, local, or tribal) would be responsible for managing oversight of cleanup? Are there other federal, state, local, or tribal regulatory requirements for site assessment?
6. What are the special needs and concerns of the community? How can community involvement be encouraged? How will community views be solicited?
7. What environmental conditions will the community find acceptable? What environmental standards should be considered to ensure that community stakeholders are satisfied with the outcome of the cleanup, in light of the identified and proposed reuse?
8. If the site shows evidence of contamination, who and what will be affected? Who will pay for the cleanup?

The following figure depicts the linkages among the decisions to be made, the data to be collected, and the selection of technologies to expedite the collection of data.



How Do We Find the Answers?*

Activities to be conducted during the initial survey of a site include:

- Establish the technical team and take advantage of the team's expertise to determine the adequacy of existing site information and identify potential data gaps
- Ensure that the brownfields decision makers (such as regulators; citizens; property owners; and technical staff, such as chemists and toxicologists) are involved in the decision-making process
- Identify future plans for reuse and redevelopment and goals of the site
- Identify data that must be collected to support the goals of the site
- Determine whether contamination is likely through the conduct of an ASTM Phase I environmental site assessment or its equivalent. A records search is performed and the site is visited, but no sampling of soil or groundwater occurs. The effort includes the following activities:
  - *Identify past owners and the uses they made of the property by conducting a title search and reviewing tax documents, sewer maps, aerial photographs, and fire, policy, and health department documentation related to the property*
  - *Review and analyze city government and other historical records to identify past use or disposal of hazardous or other waste materials at the site*
  - *Review federal and state lists that identify sites that may have environmental contamination; such lists include, but are not limited to: 1) EPA's Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS) of potentially contaminated sites, 2) the National Pollutant Discharge Elimination System (NPDES) of permits issued for discharges into surface water, and 3) state records of "emergency removal" actions (for example, the removal of leaking drums or the excavation of explosive waste)*
  - *Interview property owners, occupants, and others associated with the site, such as previous employees, residents, and local planners*
  - *Perform a physical or visual examination of the site, including examination of existing structures for structural integrity and asbestos-containing material*
  - *Test for the presence of various contaminants; for example, lead-based paint, asbestos, and radon in structures*
- Review the applicability of government oversight programs:
  - *Determine whether there is a state VCP and consult with the appropriate federal, state, local, and tribal regulatory agencies to include them in the decision-making process as early as possible*
  - *Determine the approach (such as redevelopment programs, the Superfund program, property transfer laws, or a state Brownfields program) that is required or available to facilitate the cleanup of sites*
  - *Identify whether economic incentives, such as benefits from state Brownfields programs, or federal brownfields tax credits, can be obtained*
  - *Contact the EPA regional brownfields coordinator to identify and determine the availability of EPA support programs and federal financial incentives (see Appendix C, List of Brownfields and Technical Support Contacts)*
- Determine how to incorporate and encourage community participation:
  - *Identify regulatory requirements for public involvement*
  - *Assess community interest in the project*
  - *Identify community-based organizations*
  - *Review any community plans for redevelopment*
- Identify factors that may impede redevelopment and reuse
- Begin identifying potential sources for funding site investigation and cleanup activities at the site, if necessary
- Examine unacceptable environmental conditions in terms of initial costs for site improvement and long-term costs for operation and maintenance — include potential cleanup options and constraints that may affect redevelopment, such as project schedules, cost, and potential for achieving the desired reuse
- Conduct work at the site and collect data as necessary to define site conditions or to resolve uncertainties related to the site

** Please note that the Road Map seeks to answer technology selection questions and is not intended to provide a response to each procedural question identified.*

Where Do We Find Help To Our Technology Questions?

Examples of technology resources that are available to assist in assessing a site are listed below. Although many of the resources are more applicable in later stages, it may be useful to begin thinking now about options and tools for investigation and cleanup. Information about the availability of electronic resources — whether the item is found on the Road Map's accompanying Tool Kit CD-ROM, or on various Web sites — also is provided. *Appendix D, How to Order Documents*, provides complete ordering information for documents that are not available on the CD-ROM or on the Internet.

A. Technology Resources

The documents listed below are resources that provide general information about the availability of technology resources in the form of bibliographies, status reports, and user guidelines. Personal Computer (PC)-based and on-line searchable databases also are included.

Assessing Contractor Capabilities for Streamlined Site Investigations (EPA 542-R-99-009)
View on line at <http://clu-in.org/brownfieldstsc>
Developed by EPA's Brownfields Technology Support Center, the resource will assist decision makers on brownfields projects in evaluating the capabilities of contractors who are being considered to perform work in support of site investigations. The resource also identifies potential activities that contractors can perform to enhance the site investigation process through innovative approaches. A comprehensive series of questions that decision makers can use in interviewing contractors and evaluating those contractors' qualifications is presented, followed by information about the relevance of the questions and potential answers to them.

ASTM Standard Guide for Process of Sustainable Brownfields Development (E1984-98)
Order on line at <http://www.astm.org/>
The guide, developed by ASTM, discusses the redevelopment of a brownfields property for all stakeholders. It identifies impediments to such redevelopment and suggests solutions that can facilitate completion of a successful project. It describes the flexible process of sustainable brownfields redevelopment that actively engages property owners, developers, government agencies, and the community in conducting corrective action, economic evaluation, and other efforts that promote the long-term productive reuse of a brownfields property. The guide, available at $35 per copy, can be downloaded from the ASTM Web site, or ordered by telephone at 610-832-9585 or by facsimile at 610-832-9555.

ASTM Standard Practice for Environmental Site Assessments: Phase I Environmental Site Assessment Process (E1527-97)
Order on line at <http://www.astm.org/>
The purpose of the practice, developed by ASTM, is to define commercial and customary practices in the U.S. for conducting Phase I environmental site assessments of commercial real estate with respect to the range of contaminants within the scope of CERCLA, as well as petroleum products. Research and reporting requirements also are identified. The practice, available at $40 per copy, can be downloaded from the ASTM Web site or ordered by telephone at 610-832-9585 or by facsimile at 610-832-9555.

Clean-Up Information Home Page on the World Wide Web
View on line at <http://clu-in.org>
The Internet site provides information about innovative treatment technologies and site characterization technologies to the hazardous waste remediation community. CLU-IN describes programs, organizations, publications, and other tools for EPA and other federal and state personnel, consulting engineers, technology developers and vendors, remediation contractors, researchers, community groups, and individual citizens. Information about issues related to site characterization also is provided: technology verification and evaluation; technology selection tools; guidance and application support; case studies; regulatory development; and publications.

EPA REmediation And CHaracterization Innovative Technologies (REACH IT) On-line Searchable Database
View on line at <http://www.epareachit.org>
The EPA REmediation And CHaracterization Innovative Technologies (EPA REACH IT) on-line searchable database provides users comprehensive, up-to-date information about more than 150 characterization technologies and 1,300 remediation technologies. During the preliminary phase of a brownfields project, EPA REACH IT will assist brownfields stakeholders to learn about and become familiar with the range of available technology options that can be employed during the investigation and the cleanup phases that follow, as well as data about various types of sites. Information about analytical screening technologies that may be useful for initial sampling of a site also is provided. EPA REACH IT is accessible only through the Internet.

Quality Assurance Guidance for Conducting Brownfields Site Assessments (EPA 540-R-98-038)
View or download portable document format (pdf) file on the Tool Kit CD-ROM
The document informs brownfields site managers about concepts and issues related to quality assurance and provides step-by-step instructions for identifying the type and quality of environmental data needed to present a clear picture of the environmental conditions at a given site.

B. Site-Specific Resources

Listed below are survey reports and on-line tools on the application of innovative technologies to specific contaminants and site types.

EPA Office of Enforcement and Compliance Assurance Industry Sector Notebooks
View or download pdf files on the Tool Kit CD-ROM
Developed by EPA's Office of Enforcement and Compliance Assurance (OECA), the EPA Sector Notebooks provide extensive profiles of selected major industries; each profile includes information about the processes conducted in the industry, chemical releases and transfers of chemicals, opportunities for pollution prevention, pertinent federal statutes and regulations, and compliance initiatives associated with the sector. Profiles are available on line and in hard copy for the following industry sectors:

- *Aerospace (EPA 310-R-98-001)*
- *Air transportation (EPA 310-R-97-001)*
- *Dry cleaning (EPA 310-R-05-001)*
- *Electronics and computer (EPA 310-R-95-002)*
- *Fossil fuel electronic power generation (EPA 310-R-97-007)*
- *Ground transportation (EPA 310-R-97-002)*
- *Inorganic chemical (EPA 310-R-95-004)*
- *Iron and steel (EPA 310-R-95-005)*
- *Lumber and wood products (EPA 310-R-95-006)*
- *Metal casting (EPA 310-R-97-004)*
- *Metal fabrication (EPA 310-R-95-007)*
- *Metal mining (EPA 310-R-95-008)*
- *Motor vehicle assembly (EPA 310-R-95-009)*
- *Nonferrous metals (EPA 310-R-95-010)*
- *Non-fuel, non-metal mining (EPA 310-R-95-011)*
- *Organic chemical (EPA 310-R-95-012)*
- *Petroleum refining (EPA 310-R-95-013)*
- *Pharmaceutical (EPA 310-R-97-005)*
- *Plastic resins and man-made fibers (EPA 310-R-97-006)*
- *Printing (EPA 310-R-95-014)*
- *Pulp and paper (EPA 310-R-95-015)*
- *Rubber and plastic (EPA 310-R-95-016)*
- *Shipbuilding and repair (EPA 310-R-97-008)*
- *Stone, clay, glass, and concrete (EPA 310-R-95-017)*
- *Textiles (EPA 310-R-97-009)*
- *Transportation equipment cleaning (EPA 310-R-95-018)*
- *Water transportation (EPA 310-R-97-003)*
- *Wood furniture and fixtures (EPA 310-R-95-003)*

EPA Region 3 Industry Profile Fact Sheets
View on line at <http://www.epa.gov/reg3hwmd/brownfld/industry.htm>
Developed by EPA Region 3, the fact sheets are designed to assist in the initial planning and evaluation of sites that are under consideration for remediation, redevelopment, or reuse. The fact sheets provide general descriptions of site conditions and contaminants commonly found at selected industrial sites. Each fact sheet provides information about the processes conducted in the industry; raw materials characteristic of the industry; environmental media that could be affected; sampling strategies; and suggested parameters for analysis. Fact sheets on the following subjects are available on line:

- *Abandoned chemical facilities*
- *Abandoned laboratories*
- *Abandoned oil facilities*
- *Asbestos pile*
- *Auto body facilities*
- *Battery reclamation facilities*
- *Bethlehem-asbestos/tailing mine*
- *Drum recycling facility*
- *Dye facilities*
- *Electroplating*
- *Glass manufacturing facilities*
- *Gas stations*
- *Infectious wastes*
- *Manufactured gas plants/coal tar sites*
- *Municipal landfill*
- *Ordnance*
- *Paint industry*
- *Pesticide facilities*
- *Petroleum recycling facility*
- *Plastics*
- *Print shops*
- *Quarry sites*
- *Radiation*
- *Rail yard facilities*
- *Salvage yards*
- *Scrap metal*
- *Steel manufacturing - electric arc/coke*
- *Tanning facility*
- *Tire fires*
- *Wood treating facility*

What Technologies Are Available?

The table presented below identifies examples of technologies that may be used during the site assessment phase to screen for potential contaminants. Because a site assessment focuses on determining the likelihood of contamination, technologies that detect contamination that may be in the air as vapor or particulate matter are listed. If other data indicate that contamination in soil or groundwater may exist, the use of analytical sampling techniques should be considered (as discussed in the next chapter). The information in the table was developed from data in the EPA REACH IT on-line searchable database.

Specific information about the technologies, their effectiveness, and a summary of the contaminants monitored by the technologies can be found in EPA REACH IT. See *Appendix B, List of Acronyms and Glossary of Key Terms,* for descriptions of the technologies.

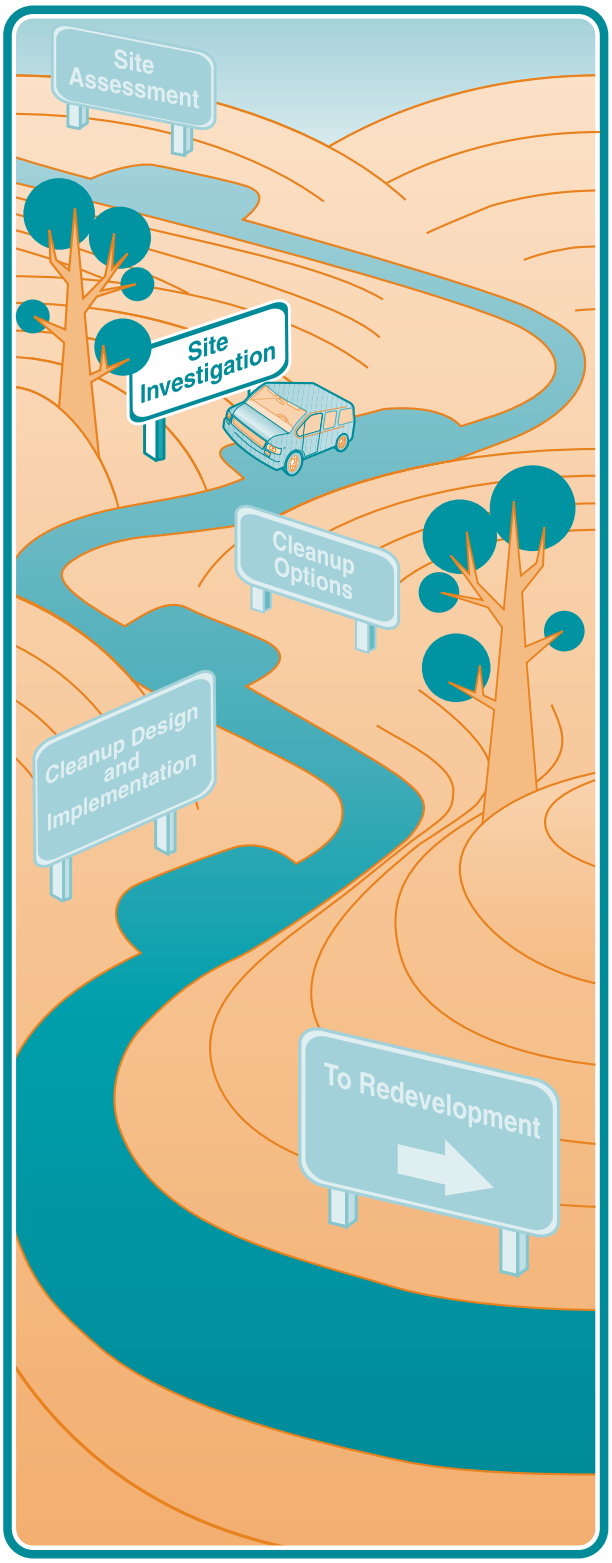
Contaminants Monitored	Applicable Technologies
Ammonia	Colorimetric Detector Tubes; Gas Monitors
Carbon Monoxide	Colorimetric Detector Tubes; Gas Monitors
Chlorine	Colorimetric Detector Tubes; Gas Monitors
Cyanide Compounds	Colorimetric Detector Tubes; Gas Monitors
Explosives, such as Hydrazine	Colorimetric Detector Tubes; Gas Monitors
Hydrogen Sulfide	Colorimetric Detector Tubes; Gas Monitors
Mercury	Mercury Vapor Analyzers; Immunoassay Test Kits
Metals/Lead-Based Paints	X-ray Fluorescence Analyzers
Methane	Gas Monitors
Nitrous Oxides	Gas Monitors
Pesticides	Gas Monitors
Radiation	Radiation Meters
Various Volatile Organic Compounds (VOC)	Colorimetric Detector Tubes; Hand-held Photoionization Detectors (PID) or Flame Ionization Detectors (FID); Immunoassay Test Kits

Where Do We Go From Here?

After completing an initial assessment and survey of the environmental conditions at the site, one of the following courses of action may be taken:

Result of Site Assessment	Course of Action
No apparent contamination is found and there is no reason to suspect other media are contaminated. Concerns of stakeholders have been addressed adequately.	*Discuss results with appropriate regulatory officials before proceeding with redevelopment activities.*
Contamination is found that poses a significant risk to human health or the environment.	*Contact the appropriate federal, state, local, or tribal government agencies responsible for hazardous waste. Based on feedback of government agency, determine what cleanup levels are required for redevelopment, and proceed to the SITE INVESTIGATION phase.*
Contamination possibly exists.	*Proceed to the SITE INVESTIGATION phase.*
Contamination definitely exists, BUT no site investigation has been conducted.	*Proceed to the SITE INVESTIGATION phase.*
Contamination definitely exists, AND a site investigation has been performed.	*Proceed to the SITE INVESTIGATION phase if additional investigation is needed; otherwise, proceed to the CLEANUP OPTIONS phase.*

SITE INVESTIGATION



Identify the Source, Nature, and Extent of Contamination

OBJECTIVE

This phase focuses on confirming whether any contamination exists at a site, locating any existing contamination, and characterizing the nature and extent of that contamination. It is essential that an appropriately detailed study of the site be performed to identify the cause, nature, and extent of contamination and the possible threats to the environment or to any people living or working nearby. For brownfields sites, the results of such a study can be used in determining goals for cleanup, quantifying risks, determining acceptable and unacceptable risk, and developing effective cleanup plans that do not cause unnecessary delays or costs in the redevelopment and reuse of property. To ensure that sufficient information supporting future activities is obtained, the type of data to be collected during this phase should be determined by the proposed cleanup measures and the proposed end use of the site.

A site investigation is based on the results of the site assessment, which is discussed in the preceding section of the Road Map. The site investigation phase may include the analysis of samples of soil and soil gas, groundwater, surface water, and sediment. The migration pathways of contaminants also are examined during this phase, and a baseline risk assessment may be needed to calculate risk to human health and the environment.

What Do We Need to Know?

KEY QUESTIONS

Factors that should be considered during the site investigation, if there is evidence of potential or actual contamination include:

1. Will the site be entered into a VCP? If so, will the investigation plan be reviewed through the VCP? If not, are there federal, state, local, and tribal regulatory requirements applicable to the site investigation? What agency will be responsible for managing oversight of this phase? What is to be done if the appropriate agency has not developed standards or guidelines that are suitable for the proposed redevelopment?
2. What technologies are available to facilitate site investigation and to support data collection relevant to the goals of the project? Has the technical team explored the full range of technologies that can produce data of the quality necessary? Can the technologies selected limit the number of mobilizations at the site?

3. Can the need for cleanup be assessed fully and accurately from the information gathered during the site assessment or from a previous site investigation?
4. What issues has the community raised that may affect the site investigation?
5. What are the potential exposure pathways? Who or what could be affected by the contamination or the efforts to clean up the contamination?
6. What happens if significant contamination is found? What happens if contamination poses a "significant threat" to local residents?
7. What happens if the contamination is originating from an adjacent or other off-site source? What happens if background sampling indicates that contamination is originating from a naturally occurring source?
8. Are the infrastructure systems (roads, buildings, sewers, and other facilities) contaminated? Could they be affected by efforts to clean up contamination?

How Do We Find the Answers?*

Typical activities that may be conducted during the site investigation phase include:

- Identify the proper mix of technologies (such as field measurement technologies that characterize the physical and chemical aspects of the site and fixed laboratory sampling methods) that can facilitate site investigations and meet the required level of data quality (see the definition of DQO in *Appendix B, List of Acronyms and Glossary of Key Terms*):
  - *Ensure that the laboratory has appropriate detection limits for analytes*
- Determine the environmental conditions at the site (for example, by performing an ASTM Phase II environmental site assessment or equivalent investigation that includes tests to confirm the locations and identities of environmental hazards):
  - *Conduct sampling and analysis to determine the nature, extent, source, and significance of the contamination that may be present at the site*
  - *Conduct sampling and analysis to fully assess the physical and geophysical conditions and characteristics of the site*
  - *Interpret the results of the analysis to characterize site conditions*
  - *Determine whether and how (if applicable) the infrastructure systems (including existing structures) are affected by contamination*
- Assess the risk the site may pose to human health and the environment. Consider the following exposure pathways:
  - *For soil and dust, direct contact, ingestion, or inhalation*
  - *For water, ingestion and inhalation*
  - *For air, inhalation or ingestion*
- Consider the use of a site-specific risk assessment to identify cleanup levels when that approach may result in more reasonable cleanup standards or when cleanup standards have not been developed
- Examine unacceptable environmental conditions in terms of initial costs for site improvement and long-term costs for annual operation and maintenance — include potential cleanup options and constraints that may affect redevelopment requirements, such as project schedules, costs, and potential for achieving the desired reuse
- Revise assumptions about the site based on data collected at the site
- Begin consideration of sources of funding for site investigation and cleanup activities such as state Brownfields programs and federal tax credits:
  - *Contact the EPA regional brownfields coordinator to identify and determine the availability of EPA support programs and federal financial incentives*
- Continue to work with appropriate regulatory agencies to ensure that regulatory requirements are being properly addressed:
  - *Identify and consult with the appropriate federal, state, local, and tribal agencies to include them as early as possible in the decision-making process*
- Educate members of the community about the site investigation process and actively involve them in decision making; consider risk communication techniques to facilitate those activities

** Please note that the Road Map seeks to answer technology selection questions and is not intended to provide a response to each procedural question identified.*

Where Do We Find Help To Our Technology Questions?

Listed below are examples of resources that assist in identifying the environmental condition of a site. Information about the availability of electronic resources — whether the item is found on the Road Map's accompanying Tool Kit CD-ROM or on various Web sites — also is provided. *Appendix D, How to Order Documents*, provides complete ordering information for documents that are not available on the CD-ROM or on the Internet.

A. Technology Resources

The documents listed below are resources that provide general information about the availability of technology resources in the form of bibliographies, status reports, and user guidelines. PC-based and on-line searchable databases also are included.

ASTM Standard Guide for Accelerated Site Characterization for Confirmed or Suspected Petroleum Releases (E1912-98)

Order on line at <http://www.astm.org/>

Developed by ASTM, the guide describes accelerated site characterization (ASC), a process used to rapidly and accurately characterize confirmed or suspected releases of petroleum. The guide provides a framework that responsible parties, contractors, consultants, and regulators can use to streamline and accelerate site characterization. The guide is available at $35 per copy and can be downloaded from the ASTM Web site or ordered by telephone at 610-832-9585 or by facsimile at 610-832-9555.

ASTM Standard Guide for Environmental Site Assessments: Phase II Environmental Site Assessment Process (E1903-97)

Order on line at <http://www.astm.org/>

Developed by ASTM, the guide discusses the framework for employing good commercial and customary practices in the U.S. when conducting Phase II environmental site assessments of commercial property with respect to the potential presence of a range of contaminants within the scope of CERCLA, as well as petroleum products. The practice, available at $35 per copy, can be downloaded from the ASTM Web site or ordered by telephone at 610-832-9585 or by facsimile at 610-832-9555.

Cost Estimating Tools and Resources for Addressing the Brownfields Initiatives (EPA 625-R-99-001)

Order on line at <http://www.epa.gov/ncepihom>

The guide is one in a series of publications designed to assist communities, states, municipalities, and the private sector to address brownfields sites more effectively. The guide, which is designed to be used with the three guides for specific types of sites — *Technical Approaches to Characterizing and Cleaning Up Automotive Repair Sites Under the Brownfields Initiative, Technical Approaches to Characterizing and Cleaning Up Iron and Steel Mill Sites Under the Brownfields Initiative, and Technical Approaches to Characterizing and Cleaning Up Metal Finishing Sites Under the Brownfields Initiative* — provides information about cost estimating tools and resources for addressing cleanup costs at brownfields sites. Many decision makers at brownfields sites may choose to assign the preparation of cost estimates to consultants who are experienced in the cleanup of hazardous waste sites; however, it benefits those decision makers to be able to provide guidance to their consultants and to understand the process sufficiently well to provide an informed review of the estimates prepared. The guide provides general information about the cost estimation process and includes summaries of various types of estimates. The guide also outlines the process of developing "order of magnitude" cost estimates. Information about resources, databases, and models also is provided.

EPA REACH IT On-line Searchable Database

View on line at <http://www.epareachit.org>

The EPA REACH IT on-line searchable database provides users comprehensive, up-to-date information about more than 150 characterization technologies which may be applicable during the site investigation phase. The guided and advanced search capabilities of the system can be used to gather information about innovative technology solutions and service providers. The information is based upon data submitted by project managers for EPA, DoD, DOE, and state agencies. EPA REACH IT is accessible only through the Internet.

Evaluation of Selected Environmental Decision Support Software

View or download pdf file on the Tool Kit CD-ROM

Developed by DOE's Office of Environmental Management, the report evaluates decision support software (DSS), computer-based systems that facilitate the use of data, models, and structured decision processes in making decisions related to environmental management. The report evaluates 19

such systems through the application of a rating system that favors software that simulates a wide range of environmental problems. It includes a glossary of terms and a statement of the rationale for the selection of various aspects of the performance of the DSS for evaluation.

Field Sampling and Analysis Technologies Matrix, Version 1.0

View on line at <http://www.frtr.gov/site/>

The matrix, an on-line tool, will assist brownfields stakeholders to obtain information about and screen technologies applicable for site investigation. Each site characterization technology is rated in a number of performance categories, such as detection limits, applicable media, selectivity, and turnaround time. Other useful information provided includes technology descriptions; data on commercial status, cost, and certification; and evaluation reports. The matrix is extremely helpful to users who are not familiar with specific characterization technologies, but who know baseline information about a site, such as contaminants and media; for such users, the matrix can identify and screen technologies for potential use at a site.

Guideline for Dynamic Workplans and Field Analytics, A: The Keys to Cost-Effective Site Characterization and Cleanup

View or download pdf file on the Tool Kit CD-ROM

Developed by Tufts University in cooperation with EPA, the document provides users with information about the many factors that are to be considered in incorporating field analytical instruments and methods into an adaptive sampling and analysis program for expediting the site investigation process. The guidance is intended to assist federal and state regulators, site owners, consulting engineers, and remediation companies understand how to develop, maintain, and update a dynamic workplan.

Hazardous Waste Site Characterization CD-ROM (EPA 600-C-96-001; PB96-503792INC)

Order on line at <http://www.ntis.gov>

The CD-ROM, developed by EPA's NERL - Las Vegas, Characterization Research Division, compiles guidance documents and related software to aid environmental professionals in the complex, multidisciplinary characterizing of hazardous waste sites. The CD-ROM, a compilation of computer programs and documents developed by EPA, includes more than 3,200 pages of documents related to EPA's RCRA and Superfund programs that can be printed, as well as searched by key words. The CD-ROM can be purchased from the NTIS for $135 *(see Appendix D, How to Order Documents)*. The CD-ROM contains the following documents and software:

- *Bibliography of Groundwater Sampling Methods*
- *Compendium of Superfund Program Publications (EPA 540-8-91-014)*
- *Data Quality Objectives Process for Superfund (EPA 540-R-93-071)*
- *Description and Sampling of Contaminated Soils: A Field Pocket Guide (EPA 625-12-91-002)*
- *Field Screening Methods Catalog (EPA 540-2-8-005)*
- *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (EPA 540-G-89-004)*
- *Guidance for Performing Preliminary Assessments Under CERCLA (EPA 540-G-91-013)*
- *Handbook of Suggested Practices for the Design and Installation of Groundwater Monitoring Wells (EPA 600-4-89-034)*
- *Preliminary Assessment Guidance for FY88 (OSWER 9345.0-01)*
- *Preparation Aids for the Development of Category I Quality Assurance Project Plans (EPA 600-8-91-003)*
- *Preparation of Soil Sampling Protocols: Sampling Techniques and Strategies (EPA 600-R-92-129)*
- *RCRA Groundwater Monitoring Technical Enforcement Guidance Document (OSWER 9950.1)*
- *Soil Sampling Quality Assurance User's Guide (EPA 600-8-89-046)*
- *Superfund Exposure Assessment Manual (EPA 540-1-88-001)*
- *Vadose Zone Monitoring for Hazardous Waste Sites (EPA 600-X-83-064)*
- *ASSESS Version 1.1A (PB93-505154).* ASSESS is an interactive QA/QC program designed to assist the user in statistically determining the quality of data from soil samples.
- *DEFT Version 4.0.* The DEFT software allows a decision maker or member of a planning team to quickly generate cost information about several sampling designs based on DQOs. A user's guide is available on the CD-ROM.
- *Geo-EAS Version 1.2.1 (PB93-504967).* Geo-EAS offers environmental scientists an interactive tool for performing two-dimensional geostatistical analyses of spatially distributed data. Extensive use of screen graphics such as maps, histograms, scatter plots, and variograms helps the user search for patterns, correlations, and problems in a data set. A user's guide also is available on the CD-ROM.

- *Geophysics Advisor Expert System Version 2.0 (PB93-505162).* The program considers several geophysical methods of determining the location of contamination and providing site characterization to make recommendations on the best methods to use at a specific site. Version 2.0 also includes a database of the physical and chemical properties of 94 substances selected from EPA's NPL.
- *Scout Version 2.0.* Scout is a user-friendly and menu-driven program that provides a graphical display of data in a multidimensional format that allows visual inspection of data, accentuates obvious outliers, and provides an easy means of comparing one data set with another. A user's guide also is available on the CD-ROM.

Innovations in Site Characterization Case Study Series
View or download pdf files on the Tool Kit CD-ROM
The case studies provide cost and performance information about innovative technologies that support less costly and more representative site characterization. The purpose of the case studies is to analyze and document the effectiveness of new technologies proposed for site cleanup. They present information about the capability of the technologies in analyzing and monitoring cleanup, as well as information about costs associated with the use of the technologies. The following case studies are available:

- *Hanscom Air Force Base, Operable Unit 1 (EPA 542-R-98-006)*
- *Dexsil L2000 PCB/Chloride Analyzer for Drum Surfaces (EPA 542-R-99-003)*

Site Characterization and Monitoring Technologies: Bibliography of EPA Information Resources (EPA 542-B-98-003)
View on line at <http://clu-in.org>
The bibliography lists information resources, both publications and electronic databases, that focus on evaluation and use of innovative site characterization and monitoring technologies. The document also provides information on obtaining copies of the documents.

Site Characterization Library, Volume 1, Release 2.0 (EPA 600-C-98-001)
Order on line at <http://www.epa.gov/ncepihom>
The CD-ROM, developed by EPA NERL, contains the following documents and software:

- *ASSESS Version 1.1A (PB93-505154)* is an interactive QA/QC program designed to assist the user in statistically determining the quality of data from soil samples.
- *BIOPLUME II* is a model for two-dimensional transport of contaminants under the influence of oxygen-limited biodegradation in groundwater.
- *CalTox* is a multimedia total exposure model for hazardous waste.
- *CHEMFLO* enables users to simulate water movement and chemical transport in unsaturated soils.
- *DEFT* is a software package that allows a decision maker to quickly generate cost information about several sampling designs based on DQOs.
- *FEMWATER/LEWASTE* is software which can be used to delineate wellhead protection areas in agricultural regions by using a criterion that considers environmental factors that reduce the concentration of contaminants transported to wells.
- *Geo-EAS Version 1.2.1 (PB93-504957)* is an interactive tool for performing two-dimensional geostatistical analyses of spatially-distributed data.
- *GEOPACK* is a comprehensive geostatistical software package that allows both novices and advanced users to conduct geostatistical analyses of spatially-correlated data.
- *Geophysics Advisor Expert System Version 2.0 (PB93-505162)* is a program that considers several geophysical methods of determining the location of contamination and providing site characterization to make recommendations about the best methods to use at a specific site.
- *GEOS* software facilitates the collection and analysis of geoenvironmental data.
- *GRITS/STAT* is a comprehensive database system for storing, analyzing, and reporting information from groundwater monitoring programs at RCRA, CERCLA, and other regulated facilities and sites.
- *HELP* is a two-dimensional modeling program that simulates water movement into and out of landfills on the basis of a waste management system.
- *IMES* offers a computer-based tool for matching site characteristics with an appropriate exposure assessment model or models.
- *MOFAT*, a two-dimensional, finite element model for simulating coupled multiphase flow and multicomponent transport in planar or radically symmetric vertical sections, can be used to evaluate flow and transport for water, NAPLs, and gas.

- *MULTIMED* is a one-dimensional, steady-state model used to predict the concentrations of contaminants migrating from a waste disposal facility through the subsurface, surface water, and air pathways to receptor sites.
- *PESTAN* assists users in estimating the vertical migration of dissolved organic solutes through the vadose zone to groundwater.
- *PRZM-2* is a pesticide flow-and-transport model for the root zone and vadose zone.
- *RETC* is a program used in analyzing the hydraulic conductivity properties of unsaturated soil.
- *Scout Version 2.0* is a user-friendly and menu-driven program that provides a graphical display of data in a multidimensional format that allows visual inspection of data, accentuates obvious outliers, and provides an easy measure for comparing data.
- *STF (VIP + RITZ)* consists of three components that provide information about the behavior of chemicals in soil environments. The models simulate the movement and fate of hazardous chemicals during treatment of oily wastes.
- *Subsurface Characterization and Monitoring Techniques* is an interactive, multimedia version of the two-volume EPA publication titled *Subsurface Characterization and Monitoring Techniques*. The documents include descriptions of more than 280 site characterization and field monitoring methods of detecting groundwater contamination and other aspects of the subsurface at hazardous waste sites. Geological and hydrogeological characterization topics covered include surface and borehole approaches, geophysical methods, and sampling of solids; drilling; aquifer tests and groundwater sampling; water-state measurement and monitoring; measurement of hydraulic conductivity and flux in the vadose zone; water budget characterization; soil-solute sampling and gas monitoring in the vadose zone; and field chemical analytical methods. The electronic version of the guide includes graphic support with animation and hypertext links that make all text readily accessible.
- *Total Human Exposure Risk database and Advanced Simulation Environment (THERdbASE), Version 1.2*, is an integrated database and analytical and modeling software system for use in exposure assessment calculations and studies. It provides a prototype for smoothly and efficiently linking communication between databases and exposure assessment models.
- *VLEACH* provides users a one-dimensional, finite difference model for making preliminary assessments of the effects on groundwater of leaching of volatile, sorbed contaminants through the vadose zone.
- *WhAEM* is a computer-based tool used in decision-making processes related to the protection of wellheads.
- *WHPA*, a semi-analytical groundwater flow simulation program, can be used for delineating capture zones in a wellhead protection area.

Superfund Innovative Technology Evaluation (SITE) Program Demonstration Reports

View or download reports at <http://www.epa.gov/ord/SITE/reports/> or on the Tool Kit CD-ROM

An extensive inventory of reports of the evaluation of measurement and monitoring technologies in the SITE program is available to assist decision makers in reviewing technology options and assessing a technology's applicability to a particular site. The reports evaluate all information about a technology; provide an analysis of its overall applicability to site characteristics, waste types, and waste matrices; and present testing procedures, performance and cost data, and QA/QC standards. The Demonstration Bulletins provide summarized descriptions of technologies and announcements of demonstrations. The Innovative Technology Evaluation Reports provide full reports of the demonstration results, including technical data useful to decision makers. A complete list of the reports is provided on the Tool Kit CD-ROM.

Test Methods for Evaluating Waste, Physical/Chemical Methods (SW-846)

View on line at <http://www.epa.gov/epaoswer/hazwaste/test/sw846.htm>

Developed by EPA's Office of Solid Waste (OSW), the Internet site provides users access to the third edition of the SW-846 base manual, as well as updates I, II, IIA, IIB, and III. The manual is a compendium of analytical and sampling methods that have been evaluated and approved for use in complying with RCRA regulations, and includes periodic updates to SW-846 to support changes in the regulatory program and to improve method performance and cost effectiveness. To date, EPA has finalized Updates I, II, IIA, IIB, and III to the SW-846 manual.

B. Site-Specific Resources

Listed below are survey reports on the application of innovative technologies to specific contaminants and site types.

Contaminants and Remedial Options at Pesticide Sites (EPA 600-R-94-202, PB95-183869)

Order on line at <http://www.epa.gov/ncepihom>

The document provides information about treatment technologies and the selection of services at pesticide sites to meet acceptable levels of cleanliness as required by applicable regulations. It is targeted primarily for the use of federal, state, or private site removal and remediation managers. The document does not identify or establish cleanup levels.

Contaminants and Remedial Options at Selected Metal-Contaminated Sites (EPA 540-R-95-512, PB95-271961)

Order on line at <http://www.epa.gov/ncepihom>

The report provides information on site characterization and the selection of treatment technologies capable of meeting site-specific cleanup levels at sites contaminated with metal. It is targeted to federal, state, and private site removal and remediation managers. The report focuses primarily on metalloid arsenic and metals, including cadmium, chromium, lead, and mercury. The report does not identify or establish cleanup levels.

EPA ORD Brownfields Guides

Order on line at <http://www.epa.gov/ncepihom>

The series of publications are designed to assist communities, states, municipalities, and the private sector to address brownfields sites more effectively. The guides provide decision makers, such as city planners, private sector developers, and others who are involved in redeveloping brownfields, with a better understanding of the technical issues involved in assessing and cleaning up automotive repair sites, iron and steel mill sites, and metal finishing sites. After reading the guides, the user will have a better understanding of activities commonly carried out at such sites and how those activities might cause the release of contaminants into the environment. The guides also provide information about the types of contaminants often found at such sites; a discussion of site assessment, screening and cleanup levels, and cleanup technologies; a conceptual framework for identifying potential contaminants; information about developing a cleanup plan; and a discussion of issues and special factors that should be considered when developing plans and selecting technologies. The following guides are available:

- *Technical Approaches to Characterizing and Cleaning Up Automotive Repair Sites Under the Brownfields Initiative (EPA 625-R-98-008)*
- *Technical Approaches to Characterizing and Cleaning Up Iron and Steel Mill Sites Under the Brownfields Initiative (EPA 625-R-98-007)*
- *Technical Approaches to Characterizing and Cleaning Up Metal Finishing Sites Under the Brownfields Initiative (EPA 625-R-98-006)*

Expedited Site Assessment Tools for Underground Storage Tank Sites: A Guide for Regulators (EPA 510-B-97-001)

View or download pdf file on the Tool Kit CD-ROM

Produced by EPA's OUST, this guide is designed to help state and federal regulators with responsibility for USTs to evaluate conventional and new site assessment technologies and promote the use of expedited site assessments. The manual covers five major issues related to UST site assessments: the expedited site assessment process; surface geophysical methods for UST site investigations; soil-gas surveys; direct push technologies; and field analytical methods for the analysis of petroleum hydrocarbons. The equipment and methods presented in the manual are evaluated in terms of applicability, advantages, and limitations for use at petroleum UST sites.

C. Technology-Specific Resources

The documents listed below provide detailed information about specific innovative technologies and the application of those processes to specific contaminants and media in the form of engineering analyses, application reports, technology verification and evaluation reports, and technology reviews.

California Environmental Technology Certification Program - California Certified Technologies List

View on line at <http://www.calepa.ca.gov/programs/EnviroTech/encertpg.htm>

The California Environmental Protection Agency's (Cal/EPA) Environmental Technology Certification program Internet site provides the user access to the California Certified Technologies List. The document provides a list of technologies and their respective vendors that have been certified by the state of California. Certification is granted to technologies on the basis of an independent, third-party verification of the technology's performance and ability to meet regulatory specifications and requirements. Developers and manufacturers define quantitative performance claims for their technologies and provide supporting documentation. Cal/EPA reviews that information and, when necessary, conducts

additional testing to verify the claims. Technologies, equipment, and products that are proven to work as claimed receive official state certification.

Environmental Technology Verification Reports
View or download pdf files at <http://www.epa.gov/etv>
Produced by EPA's ORD, the Environmental Technology Verification (ETV) program reports provide extensive information about the performance of commercial-ready, private sector technologies. The reports, intended for buyers of technologies, developers of technologies, consulting engineers, and state and federal agencies, verify the environmental performance characteristics of those technologies through the conduct of pilots. The reports, as well as other information about the ETV program, are available on the ETV site. ETV reports and verification statements about the following technologies are available:

- *Cone penetrometer-deployed sensor*
- *Field-portable gas chromatograph/mass spectrometer*
- *Field-portable x-ray fluorescence analyzer*
- *Polychlorinated biphenyl (PCB) analysis technologies*
- *Well-head monitoring for VOCs*
- *Soil sampling technologies*

Federal Facilities Forum Issue: Field Sampling and Selecting On-Site Analytical Methods for Explosives in Soil (EPA 540-R-97-501)
View or download pdf file on the Tool Kit CD-ROM
This paper was prepared by members of the Federal Facilities Forum, a group of EPA scientists and engineers representing EPA regional offices and committed to the identification and resolution of issues affecting federal facility Superfund and RCRA sites. The purpose of the paper is to provide guidance to remedial project managers (RPM) about field sampling and on-site analytical methods for detecting and quantifying secondary explosive contaminants in soil. The paper is divided into the following sections: (1) background information; (2) overview of sampling and analysis of explosives; (3) data quality objectives; (4) unique sampling and design considerations for dealing with contaminants from explosives; (5) a summary of on-site analytical methods; and, (6) a summary of the EPA reference analytical methods.

Field Validation of a Penetrometer-Based Fiber Optic Petroleum, Oil, and Lubricant (POL) Sensor: Project Summary (EPA 600-SR-97-055)
View on line at <http://www.epa.gov/ncepihom/nepishom/>
The report provides comprehensive comparisons of in situ measurements from a cone penetrometer-deployed laser induced fluorescence (LIF) petroleum, oil, and lubricant (POL) sensor with traditional field screening methods. The report includes an introduction that describes the system and indicates the technology constraints. In addition to conclusions and recommendations, the report also provides information about methods and materials, such as calibration and sampling procedures, analytical methods, and methods of data reproduction and analysis. Two case studies help illustrate the concepts discussed.

Hydrogeologic Characterization of Fractured Rock Formations: A Guide for Groundwater Remediators; Project Summary (EPA 600-S-96-001)
View or download pdf file on the Tool Kit CD-ROM
This report describes the conduct and findings of a hydrogeologic characterization study of a saturated fractured, granitic rock aquifer in the foothills of the Sierra Nevada mountains in California. First, the report presents an overview of the problems associated with remediating fractured aquifers, referring to case histories as examples. Brief descriptions of the methods and results of the characterization effort at the experimental field site then are presented. The remaining chapters present particular phases of the characterization effort and a general strategy for hydrogeologic characterization, with each tool and method described in detail. In addition, the report discusses issues related to the effect of incorrect characterization of flow properties on prediction of the behavior of a contaminant.

What Technologies Are Available?

The table presented below identifies some of the field analytical technologies that may be used during the site investigation phase.

The information in the table was developed from information in the EPA REACH IT on-line searchable database. Specific information about the technologies, their effectiveness, and their applicability in relation to detection limits, as well as a summary of the contaminants monitored, can be obtained from the system. See *Appendix B, List of Acronyms and Glossary of Key Terms,* for a description of the technologies.

Contaminants Monitored	Examples of Field Analytical Technologies*
Benzene, Toluene, Ethylbenzene, and Xylene (BTEX)	Colorimetric Test Kits; Immunoassay Test Kits; Laser-induced Fluorescence/Cone Penetrometer; Portable Gas Chromatography/ Mass Spectrometry
Buried Objects	Ground-Penetrating Radar (GPR); Infrared Monitors; High-Frequency Electromagnetic (EM) Sounding; Subsurface EM; Subsurface Magnetrometry; Transient EM Geophysical Instruments
Dioxins and Furans	Gas Chromatography/Mass Spectrometry
Explosives	Colorimetric Test Kits; Immunoassay Test Kits; Gas Chromatography/Mass Spectrometry
Geophysical Characteristics of Soil and Bedrock	In Situ Geophysics; Borehole Technologies; Downhole Sensors; Seismic Reflection/ Refraction; GPR; Electromagnetic Sounding
Mercury	Immunoassay Test Kits
Metals	X-ray Analyzers; Electrochemical Detector Kits; Graphite Furnace Atomic Absorption Spectroscopy
Pentachlorophenol (PCP)	Immunoassay Test Kits; Portable Gas Chromatography/Mass Spectrometry
Pesticides	Immunoassay Test Kits; Colorimetric Test Kits; Gas Chromatography/Mass Spectrometry
PCBs	Colorimetric Test Kits; Immunoassay Test Kits
Polynuclear Aromatic Hydrocarbons (PAH)	Immunoassay Test Kits; Colorimetric Test Kits; Gas Chromatography/Mass Spectrometry
Total Petroleum Hydrocarbons (TPH)	Colorimetric Test Kits; Immunoassay Test Kits; Laser-induced Fluorescence/Cone Penetrometer; Infrared Monitors; Gas Chromatography/Mass Spectrometry
VOCs, Semi-Volatile Organic Compounds (SVOC)	Portable Gas Chromatography/Mass Spectrometry; Colorimetric Test Kits; Immunoassay Test Kits; Infrared Monitors

** See the table to the right for more information about field analytical technologies and mobile laboratories.*

Highlights of Field Analytical Technologies and Mobile Laboratories

Field Analytical Technologies: Field analytical technologies, often referred to as "field analytics," can be used onsite without the absolute need for a mobile laboratory. Some field analytical technologies are very sophisticated and can yield quantitative results that are comparable to those obtained by analysis in mobile or off-site laboratories. Some field analytical measurements can be made quickly, allowing a high rate of sampling. Under certain conditions, data can be collected in a short period of time. Field analytical technologies are implemented through the use of hand-held instruments, such as the portable gas chromatography and mass spectrometry and the x-ray fluorescence analyzer, as well as the use of bench procedures, such as colorimetric and immunoassay tests.

Mobile Laboratories: A variety of technologies can be used in a mobile laboratory. Such technologies differ from field analytical technologies because they may require more controlled conditions (such as temperature, humidity, and source of electricity) or complex sample preparation that uses solvents or reagents that require special handling or protective equipment that require the handling and storage of chemical standards. Technologies adaptable to mobile laboratories include those used to analyze soil and water samples for inorganic analytes (such as anodic stripping voltammetry) and organic compounds (such as gas chromatography with a variety of detectors). When operated properly and with adequate QA/QC, the technologies can achieve quantitative results equal to those achieved by off-site analytical laboratories.

Where Do We Go From Here?

After you have completed your investigation of the environmental conditions at the site, you may take one of the following courses of action:

Results of the Site Investigation	Course of Action
No contamination is found.	*Consult with appropriate regulatory officials before proceeding with redevelopment activities.*
Contamination is found BUT does not pose a significant risk to stakeholders' human health or the environment.	*Consult with appropriate regulatory officials before proceeding with redevelopment activities.*
Cleanup of the contamination found probably will require a small expenditure of funds and time.	*Proceed to the CLEANUP OPTIONS phase.*
Cleanup of the contamination found probably will require a significant expenditure of funds and time. However, contamination does not pose a significant threat to local residents.	*Determine whether redevelopment continues to be practicable as planned, or whether the redevelopment plan can be altered to fit the circumstances; if so, proceed to the CLEANUP OPTIONS phase.*
Contamination is found that poses a significant threat to local residents.	*Contact the appropriate federal, state, local, or tribal government agencies responsible for hazardous waste. If contamination exists at considerable levels, compliance with other programs, such as RCRA and Superfund, may be required.*

CLEANUP OPTIONS

Evaluate Applicable Cleanup Alternatives for the Site

OBJECTIVE

The review and analysis of cleanup alternatives rely on the data collected during the site assessment and investigation phases, which are discussed in the preceding sections of the Road Map. The purpose of evaluating various technologies is to identify those technologies for their capability to meet specific cleanup and redevelopment objectives. For brownfields sites, it also is important to consider budget requirements and to maintain a work schedule so that the project remains financially viable.

The role of institutional controls, such as zoning and deed restrictions; posting of safety signs; and efforts to increase community awareness of the environmental conditions and cleanup activities at the site, also are important considerations during this phase.

What Do We Need to Know?

KEY QUESTIONS

Factors that should be considered during the evaluation of cleanup options include:

1. How do we determine the appropriate and feasible level of cleanup? Are there federal, state, local, and tribal requirements for cleanup? Should risk-based approaches be considered as an option for assessing exposure (see the definition of risk-based corrective action [RBCA] in *Appendix C, List of Acronyms and Glossary of Key Terms*)? Are there prescribed standards for cleanup? Are there provisions for using presumptive remedies?

2. What factors are associated with the implementation of cleanup options? Will the cleanup facilitate or hinder the planned redevelopment? How long will cleanup take? What will cleanup cost? What are the short-term and long-term effects of the cleanup technologies under consideration?

3. Are the cleanup options compatible with regional or local planning and development goals and requirements? Can redevelopment activities (such as construction or renovation of buildings) be conducted concurrently with cleanup?

4. How can the community participate in the review and selection of cleanup options? Are the options acceptable in light of community

concerns about protection during cleanup and reuse of the site? What environmental standards should be considered to ensure that community stakeholders are satisfied with the outcome and process of cleanup, given the intended reuse?

5. Is there a need for institutional controls after cleanup? Are proposed institutional controls appropriate in light of community concerns and access to and use of the property? Will institutional controls facilitate or hinder development? What plans, including financial assurances, are being made to ensure that institutional controls remain in place as long as contamination is present?
6. What options are available to monitor the performance of cleanup technologies?

How Do We Find the Answers?*

The process of reviewing and analyzing cleanup options and technology alternatives usually follows these steps:

- Establish goals for cleanup that consider the end use and use either published state or federal guidelines, RBCAs, or site-specific risk assessment results
- Educate members of the community about the site cleanup selection process and actively involve them in decision making
- Review general information about cleanup technologies to become familiar with those that may be applicable to a particular site:
  - *Use the resources in this publication*
  - *Conduct searches of existing literature that further describes the technology alternatives*
  - *Analyze detailed technical information about the applicability of technology alternatives*
- Narrow the list of potential technologies that are most appropriate for addressing the contamination identified at the site and that are compatible with the specific conditions of the site and the proposed reuse of the property:
  - *Network with other brownfields stakeholders and environmental professionals to learn about their experiences and to tap their expertise*
  - *Determine whether sufficient data are available to support identification and evaluation of cleanup alternatives*
  - *Evaluate the options against a number of factors, including toxicity levels, exposure pathways, associated risk, future land use, and economic considerations*
  - *Analyze the applicability of a particular technology to the contamination identified at a site*
  - *Determine the effects of various technology alternatives on redevelopment objectives*
- Continue to work with appropriate regulatory agencies to ensure that regulatory requirements are addressed properly:
  - *Consult with the appropriate federal, state, local, and tribal regulatory agencies to include them in the decision-making process as early as possible*
  - *Contact the EPA regional brownfields coordinator to identify and determine the availability of EPA support programs*
- Integrate cleanup alternatives with reuse alternatives to identify potential constraints on reuse and time schedules and to assess cost and risk factors
- To provide a measure of certainty and stability to the project, investigate environmental insurance policies, such as protection against cost overruns, undiscovered contamination, and third-party litigation, and integrate their cost into the project financial package
- Select an acceptable remedy that not only addresses the risk of contamination, but also best meets the objectives for redevelopment and reuse of the property and is compatible with the needs of the community
- Communicate information about the proposed cleanup option to brownfields stakeholders, including the affected community

Where Do We Find Help To Our Technology Questions?

Examples of resources that will assist in reviewing and analyzing cleanup options are listed below. Information about the availability of electronic resources — whether the item is found on the Road Map's accompanying Tool Kit CD-ROM or on various Web sites — also is provided. *Appendix D, How to Order Documents*, provides complete ordering information for documents that are not available on the CD-ROM or on the Internet.

** Please note that the Road Map seeks to answer technology selection questions and is not intended to provide a response to each procedural question identified.*

A. Technology Resources

The documents listed below are resources that provide general information about the availability of technology resources in the form of bibliographies, status reports, and user guides. PC-based and on-line searchable databases also are included.

ASTM Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites (E1739-95e1)

Order on line at <http://www.astm.org>

The purpose of the guide is to define RBCA as a process for assessing and responding to a petroleum release in a manner that ensures the protection of human health and the environment. The guide will assist brownfields decision makers who wish to become familiar with another approach that can be used to assess environmental risk at a site, in conformity with applicable federal, state, local, and tribal regulations. The diversity and flexibility of a RBCA approach is defined and discussed, and the tiered approach of the process is summarized. Although the RBCA process is not limited to a particular site, the guide emphasizes the use of RBCA in response to releases of petroleum. Examples of RBCA applications also are provided. The guide, available at $45 per copy, can be downloaded from the ASTM Web site or ordered by telephone at 610-832-9585 or by facsimile at 610-832-9555.

Bibliography for Innovative Site Clean-Up Technologies (EPA 542-B-99-004)

View or download pdf file on the Tool Kit CD-ROM

The bibliography is a comprehensive listing of information resources available for innovative site cleanup technologies. The bibliography lists resources by categories including: technology survey reports; EPA program information; groundwater (in situ) treatment; thermal treatment; bioremediation; soil vapor extraction and enhancements; physical and chemical treatment; site characterization; other conferences and international surveys; technical support; community relations; bulletin board systems, databases, software, and the Internet; technology newsletters; and innovative site remediation engineering technology monographs. The document also provides titles, document numbers, and ordering information.

Citizen's Guides to Understanding Innovative Treatment Technologies

View or download pdf files on the Tool Kit CD-ROM

The guides are prepared by EPA to provide site managers with nontechnical outreach materials, in English and Spanish, that they can share with communities in the vicinity of a site. The guides present information on innovative treatment technologies that have been selected or applied at some cleanup sites, provide overviews of innovative treatment technologies, and present success stories about sites at which innovative treatment technologies have been applied. The guides contain information on the following subjects:

- *Bioremediation*
- *Chemical dehalogenation*
- *In situ soil flushing*
- *Innovative treatment technologies for contaminated soils, sludges, sediments, and debris*
- *Natural attenuation*
- *Phytoremediation*
- *SVE and air sparging*
- *Soil washing*
- *Solvent extraction*
- *Thermal desorption*
- *Treatment walls*
- *Understanding presumptive remedies*

Clean-Up Information Home Page on the World Wide Web

View on line at <http://clu-in.org>

The Internet site provides information about innovative treatment technologies and site characterization technologies to the hazardous waste remediation community. CLU-IN describes programs, publications, and other tools for EPA and other federal and state personnel, consulting engineers, technology developers and vendors, remediation contractors, researchers, community groups, and individual citizens. Information about issues related to site remediation also is provided: technology descriptions and status reports; technology selection tools; programs and organizations; TIO perspectives; and publications.

Completed North American Innovative Technology Demonstration Projects and Associated Database (EPA 542-B-96-002, PB96-153127)

View or download pdf files on the Tool Kit CD-ROM

The report and searchable database summarizes more than 300 innovative technology field demonstration projects that have been completed in North America. The demonstration projects listed include those

performed, co-sponsored, or funded through programs developed by EPA, the military services, DOE, the U.S. Department of Interior (DOI), the government of Canada, and the State of California. The report summarizes key information from available demonstration projects in a single document and presents that information in a manner that enables project managers and other interested persons to easily identify innovative technologies that may be appropriate to their particular site remediation needs. The report highlights key features of the demonstrations, including contaminants treated, site types, technology types, technology vendors, project sponsors, and technical reports available.

Cost Estimating Tools and Resources for Addressing the Brownfields Initiatives (EPA 625-R-99-001)
Order on line at <http://www.epa.gov/ncepihom>
The guide is one in a series of publications designed to assist communities, states, municipalities, and the private sector to address brownfields sites more effectively. The guide, which is designed to be used with the three guides for specific types of sites — *Technical Approaches to Characterizing and Cleaning Up Automotive Repair Sites Under the Brownfields Initiative, Technical Approaches to Characterizing and Cleaning Up Iron and Steel Mill Sites Under the Brownfields Initiative, and Technical Approaches to Characterizing and Cleaning Up Metal Finishing Sites Under the Brownfields Initiative* — provides information about cost estimating tools and resources for addressing cleanup costs at brownfields sites. Many decision makers at brownfields sites may choose to assign the preparation of cost estimates to consultants who are experienced in the cleanup of hazardous waste sites; however, it benefits those decision makers to be able to provide guidance to their consultants and to understand the process sufficiently well to provide an informed review of the estimates prepared. The guide provides general information about the cost estimation process and includes summaries of various types of estimates. The guide also outlines the process of developing "order of magnitude" cost estimates. Information about resources, databases, and models also is provided.

EPA REACH IT On-line Searchable Database
View on line at <http://www.epareachit.org>
EPA REACH IT will assist those involved in brownfields projects to evaluate and select applicable remediation technologies, as well as to gather detailed information about the providers of those technologies. An on-line searchable database, EPA REACH IT provides comprehensive, up-to-date information about more than 1,300 remediation technologies that can be accessed through the guided and advanced search capabilities of the system. Examples of sites at which a particular type of technology has been implemented also are presented. The information is based upon data submitted by project managers for EPA, DoD, DOE, and state agencies, as well as information provided by suppliers of innovative technologies. EPA REACH IT is accessible only through the Internet.

Evaluation of Selected Environmental Decision Support Software (DSS)
View or download pdf file on the Tool Kit CD-ROM
Developed by DOE's Office of Environmental Management, the report evaluates DSS, computer-based systems that facilitate the use of data, models, and structured decision processes in making decisions related to environmental management. The report evaluates 19 such systems through the application of a rating system that favors software that simulates a wide range of environmental problems. It includes a glossary of terms and a statement of the rationale for the selection of various aspects of the performance of the DSS for evaluation.

Evaluation of Subsurface Engineered Barriers at Waste Sites (EPA 542-R-98-005)
View or download pdf file on the Tool Kit CD-ROM
The report provides a national retrospective analysis of the field performance of barrier systems, as well as information that could be useful in developing guidance on the use and evaluation of such systems. The report contains information about the design, application, and performance of subsurface engineered barriers.

Federal Remediation Technologies Roundtable (FRTR) Case Studies
View on line at <http://www.frtr.gov/cost>
The case studies provide the user information about specific remedial technology applications. FRTR case studies are developed by DoD, the U.S. Army Corps of Engineers (USACE), the U.S. Navy, the U.S. Air Force (USAF), DOE, DOI, and EPA. The case studies focus on full-scale and large field demonstration projects and include information on site background, description of the technology, cost and performance of technology application, and lessons learned. Technologies include innovative and conventional treatment technologies for contaminated soil, groundwater, and solid media. Visit FRTR's Internet Site at *<http://www.frtr.gov/search>* to search the case studies by groups of contaminants, media, waste management practices that contribute to contamination, and treatment systems.

Guide to Documenting and Managing Cost and Performance Information for Remediation Projects (EPA 542-B-98-007)
View or download pdf file on the Tool Kit CD-ROM
The document recommends the types of data that should be collected to document the performance and cost of future cleanups. The guide specifies data elements for 13 conventional and innovative cleanup technologies: soil bioventing, soil flushing, soil vapor extraction, groundwater sparging, in situ groundwater remediation, pump-and-treat technologies, composting, incineration, land treatment, slurry-phase soil bioremediation, soil washing, stabilization, and thermal desorption. The document provides site managers with a standard set of parameters for documenting completed remediation projects. A number of federal agencies have made commitments to using the guidance to collect data for full-scale cleanups, demonstrations, and treatability studies.

In Situ Remediation Technology Status Reports
View or download pdf files on the Tool Kit CD-ROM
The series of six documents describes more than 90 field demonstrations or full-scale applications of in situ abiotic technologies for treatment of nonaqueous phase liquids (NAPL) and groundwater. The documents provide information on the following subjects:

- *Cosolvents (EPA 542-K-94-006)*
- *Electrokinetics (EPA 542-K-94-007)*
- *Hydraulic and Pneumatic Fracturing (EPA 542-K-94-005)*
- *Surfactant Enhancements (EPA 542-K-94-003)*
- *Thermal Enhancements (EPA 542-K-94-009)*
- *Treatment Walls (EPA 542-K-94-004)*

Rapid Commercialization Initiative (RCI) Final Report for an Integrated In Situ Remediation Technology (Lasagna™) (DOE/OR/22459-1)
View on line at <http://clu-in.org/pub1.htm>
This report describes demonstration results for the Lasagna™ process, a process which uses established geotechnical methods to install degradation zones in contaminated soil and electrosmosis to move the contaminants back and forth through these zones until treatment is completed.

Remediation Technologies Screening Matrix and Reference Guide, Version 3.0 (PB98-108590)
View on line at <http://www.frtr.gov/matrix/top_page.html>
The document is intended to assist site remediation project managers to narrow the field of remediation alternatives and identify potentially applicable technologies for more detailed assessment and evaluation before remedy selection. The document summarizes the strengths and weaknesses of innovative and conventional technologies for remediation of soils, sediments, sludges, groundwater, surface water, and air emissions and off-gases; it focuses primarily on demonstrated technologies. Treatment, containment, separation of wastes, and enhanced recovery technologies are covered. Additional references and information resources also are included.

Site Remediation Technology InfoBase: A Guide to Federal Programs, Information Resources, and Publications on Contaminated Site Cleanup Technologies, First Edition (EPA 542-B-98-006)
View or download pdf file on the Tool Kit CD-ROM
Prepared by the member agencies of the FRTR, the guide identifies programs, resources, and publications of the federal government related to technologies for the cleanup of contaminated sites.

Superfund Innovative Technology Evaluation (SITE) Program: Technology Profiles, Ninth Edition (EPA 540-R-97-502)
View on line at <http://www.epa.gov/ORD/SITE/profiles.html>
The document provides profiles of more than 150 demonstration, emerging, and monitoring and measurement technologies currently being evaluated. Each technology profile identifies the developer and process name of the technology, describes the technology, discusses its applicability to waste, and provides a project status report and contact information. The profiles also include summaries of demonstration results, if available.

Synopses of Federal Demonstrations of Innovative Site Remediation Technologies, Third Edition (EPA 542-B-93-009, PB94-144565)
Order on line at <http://www.epa.gov/ncepihom>
The document is a compilation of abstracts that describe field demonstrations of innovative technologies that treat hazardous waste at contaminated sites. The abstracts are information resources that hazardous waste site project managers can use to assess the availability and practicability of

innovative technologies for treating contaminated groundwater, soils, and sludge. The document describes more than 110 demonstrations, sponsored by federal agencies, in six different technology categories, involving the use of innovative technologies to treat soil and groundwater. A matrix that lists the demonstration categories, the type of contaminant, media that can be treated, and the treatment setting for each innovative technology demonstrated also is provided in the document.

Tank RACER Software Program

View on line at <http://www.epa.gov/swerust1/tnkracr1.htm>

Tank Remedial Action Cost Engineering and Requirements (RACER) is a Windows™-based system that provides fast, accurate, and comprehensive cost estimates for cleanups at petroleum and UST sites. The software estimates costs for cleanups on a site-specific basis for all phases of remediation, including site assessment, remedial design, remedial action, operation and maintenance, tank closure, and site work and utilities, as well as the costs of using alternative technologies, such as air sparging, bioremediation, bioventing, groundwater extraction wells, land farming, natural attenuation, SVE, and thermal desorption. The software was developed under an interagency agreement between the USAF and EPA. A newer version, Tank RACER 99, is now available. Visit the Web site identified above for more information.

TechKnow™ Database

View on line at <http://www.techknow.org>

Developed by the Global Network of Environment & Technology (GNET), TechKnow is an on-line, interactive database which allows users to gain access to and provide information about innovative and sustainable technologies. For each technology profiled, a summary, development information, status, and cost is provided. The Internet site also provides contact information for the technologies. Users may access the TechKnow database at the Internet site identified above. There is no cost to use TechKnow, but users are required to register on GNET.

Treatment Technologies for Site Cleanup: Annual Status Report, Ninth Edition (EPA 542-R-99-001)

View on line at <http://clu-in.org/pub1.htm>

The report documents, as of the summer of 1998, the status of treatment technology applications at more than 900 soil and groundwater cleanup projects in the Superfund program, selected RCRA corrective action sites, and DOE and DoD sites. The report updates the projects included in the Annual Status Report (eighth edition) and information on projects derived from 79 RODs signed in 1996 and 1997. It also now includes information on 217 incineration and solidification/stabilization projects not previously covered. For the most frequently selected technologies, the report analyzes selection trends over time, contaminant groups addressed, quantities of soil treated, and project implementation status. Specific site information for each technology application has been incorporated into the EPA REACH IT on-line database.

B. Site-Specific Resources

Listed below are survey reports on the application of innovative technologies to specific contaminants and site types.

EPA ORD Brownfields Guides

Order on line at <http://www.epa.gov/ncepihom>

The series of publications are designed to assist communities, states, municipalities, and the private sector to address brownfields sites more effectively. The guides provide decision makers, such as city planners, private sector developers, and others who are involved in redeveloping brownfields, with a better understanding of the technical issues involved in assessing and cleaning up automotive repair sites, iron and steel mill sites, and metal finishing sites. After reading the guides, the user will have a better understanding of activities commonly carried out at such sites and how those activities might cause the release of contaminants into the environment. The guides also provide information about the types of contaminants often found at such sites; a discussion of site assessment, screening and cleanup levels, and cleanup technologies; a conceptual framework for identifying potential contaminants; information about developing a cleanup plan; and a discussion of issues and special factors that should be considered when developing plans and selecting technologies. The following guides are available:

- *Technical Approaches to Characterizing and Cleaning Up Automotive Repair Sites Under the Brownfields Initiative (EPA 625-R-98-008)*
- *Technical Approaches to Characterizing and Cleaning Up Iron and Steel Mill Sites Under the Brownfields Initiative (EPA 625-R-98-007)*
- *Technical Approaches to Characterizing and Cleaning Up Metal Finishing Sites Under the Brownfields Initiative (EPA 625-R-98-006)*

Evaluation of Technologies for In Situ Cleanup of DNAPL Contaminated Sites (EPA 600-R-94-120, PB94-195039)
View on line at <http://clu-in.org>
The document provides a review and technical evaluation of in situ technologies for the remediation of dense nonaqueous phase liquid (DNAPL) contamination that has occurred below the groundwater tables. It reviews several in situ technologies and provides information about the evaluation of the technologies on the basis of theoretical background, field implementation, level of demonstration and performance, waste, technical and site applicability and limitations, and cost and availability.

How To Evaluate Alternative Cleanup Technologies for Underground Storage Tank Sites: A Guide for Corrective Action Plan Reviewers (EPA 510-B-94-003, S/N 055-000-00499-4)
Order on line at <http://www.epa.gov/ncepihom>
The guide was developed to assist state regulators in efficiently and confidently evaluating corrective action plans (CAP) that incorporate alternative technologies. The guide, written in nontechnical language, takes the reader through the steps involved in reviewing a CAP. Each chapter presents a comprehensive description of the technology, an explanation of how it works, and a flow chart that illustrates the decision points in the process; information that will help the regulator evaluate whether a given technology will clean up a given site successfully; discussion and instruction to help the regulator evaluate whether a CAP is technically sound; a check list to assist the regulator in determining whether or not the CAP includes all the steps necessary; and a list of references.

Innovative Measures for Subsurface Chromium Remediation: Source Zone, Concentrated Plume, and Dilute Plume; Environmental Research Brief (EPA 600-S-97-005)
View or download pdf file on the Tool Kit CD-ROM
This report describes innovative measures for addressing chromium contamination in each of the three areas described in the title. For the source zone, surfactant-enhanced chromium extraction is evaluated; for the concentrated plume, polyelectrolyte-enhanced ultrafiltration is evaluated; and for the dilute plume, the effectiveness of the permeable barrier wall is evaluated.

In Situ Treatment of Metal-Contaminated Soils (EPA 542-R-96-001)
View or download pdf file on the Tool Kit CD-ROM
The document provides information about four in situ technologies for treating metal-contaminated soils: electrokinetic remediation; phytoremediation; soil flushing; and solidification/stabilization. The report is intended to assist in screening new technologies early in the remedy evaluation and selection process. It identifies vendors, summarizes performance data, and discusses technology attributes that should be considered during the early screening of potential remedies for metal-contaminated soils. The document outlines the relatively few alternative methods for in situ treatment of metals.

MTBE Fact Sheet #2: Remediation of MTBE-Contaminated Soil and Groundwater (EPA 510-F-98-002)
View or download pdf file on the Tool Kit CD-ROM
Developed by EPA's OUST, the fact sheet describes the physical and chemical characteristics of methyl tert butyl ether (MTBE) and identifies alternative technologies for remediating it.

Pay-For-Performance Cleanups: Effectively Managing Underground Storage Tank Cleanups (EPA 510-B-96-002)
View on line at <http://www.epa.gov/ncepihom/nepishom/>
Pay-for-performance cleanup agreements allow users to pay contractors a fixed price as measurable environmental goals are reached, rather than paying using a more typical time-and-materials contract. This document focuses on the experience of the UST Bureau of the New Mexico Environment Department and is supplemented by the experience and ideas of representatives of other states, contractors, and EPA. The document is intended as a starting point for owners of USTs to use in designing pay-for-performance cleanup programs. The document first identifies the advantages of pay-for-performance cleanup agreements, such as cost and time savings. It then explains how to implement a pay-for-performance cleanup program. Many tips for ensuring the success of pay-for-performance agreement programs are provided. It also presents information about enlisting the support of stakeholders, such as that of state technical and funding staff, government auditors, legislators and legislative staff, and cleanup contractors. In addition to providing instructions for constructing such an agreement, the document provides an example of how to calculate performance payments.

Presumptive Response Strategy and Ex-Situ Treatment Technologies for Contaminated Ground Water at CERCLA Sites (EPA 540-R-96-023)
Order on line at <http://www.epa.gov/ncepihom>
Produced by EPA's Office of Emergency and Remedial Response (OERR), the guidance defines EPA's presumptive response strategy and discusses technologies for the ex situ treatment component of a groundwater remedy. It also explains how EPA intends to exercise its discretion in implementing the National Contingency Plan (NCP).

Recent Developments for In Situ Treatment of Metal-Contaminated Soils (EPA 542-R-97-004)
View or download pdf file on the Tool Kit CD-ROM
The document provides hazardous waste cleanup professionals with an update on the status of four available and promising technologies for in situ remediation of soil contaminated with heavy metals: electrokinetics; phytoremediation; soil flushing; and solidification and stabilization. The report is intended to assist in screening new technologies early in the remedy evaluation and selection process.

Treatment Technology Performance and Cost Data for Remediation of Wood Preserving Sites (EPA 625-R-97-005)
Order on line at <http://www.epa.gov/ttbnrmrl/625/R-97/005.htm>
The document presents information about applicable treatment alternatives for the remediation of soil and groundwater at wood preserving sites. The document provides decision makers with a better understanding of technologies suitable for cleaning up such sites. Background information about the wood preserving industry in general is presented, as well as information about contaminants commonly found at wood preserving sites, such as PCPs, PAHs, dioxins and furans, and inorganic compounds. The document describes a number of technologies that have been used to remediate wood preserving sites; treatability and case studies also are presented. Additional sources of information are provided.

Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites
View or download pdf file on the Tool Kit CD-ROM
The policy directive, issued April 21, 1999, provides guidance to the staff of EPA, the public, and the regulated community on how EPA intends to exercise its discretion in implementing national policy on the use of monitored natural attenuation for the remediation of contaminated soil and groundwater at sites regulated under the programs of EPA's OSWER.

C. Technology-Specific Resources

The documents listed below provide detailed information about specific innovative technologies and the application of those processes to specific contaminants and media in the form of engineering analyses, application reports, technology verification and evaluation reports, and technology reviews. PC-based searchable databases also are included.

Anaerobic Biodegradation of BTEX in Aquifer Material; Environmental Research Brief (EPA 600-S-97-003)
View or download pdf file on the Tool Kit CD-ROM
The study focuses on anaerobic biodegradation of BTEX isomers in aquifer material from two petroleum-contaminated aquifers. Two different techniques were used to evaluate the ability of indigenous microorganisms to anaerobically degrade BTEX and to estimate the rate of degradation.

Analysis of Selected Enhancements for Soil Vapor Extraction (EPA 542-R-97-007)
View or download pdf file on the Tool Kit CD-ROM
The report provides an engineering analysis of, and status report on, selected enhancements for SVE treatment technologies. The report is intended to assist project managers who are considering an SVE treatment system by providing then with an up-to-date report on the status of enhancement technologies; an evaluation of each technology's applicability to various site conditions; a presentation of cost and performance information; a list of vendors that specialize in the technologies; a discussion of the relative strengths and limitations of the technologies; recommendations of factors to be kept in mind when considering the enhancements; and a compilation of references. The five enhancement technologies discussed in the report are air sparging, dual-phase extraction, directional drilling, pneumatic and hydraulic fracturing, and thermal enhancement.

Assessment and Remediation of Contaminated Sediments (ARCS) Program: Guidance for In Situ Subaqueous Capping of Contaminated Sediments (EPA 905-B-96-004)
View on line at <http://www.epa.gov/glnpo/sediment/iscmain/index.html>
Published by EPA's Great Lakes National Program Office, the document provides technical guidance for subaqueous, in situ capping as a remediation technique for contaminated sediments. Descriptions of the processes, identification of the design requirements, and a recommended sequence for design also are provided.

Bibliography of Phytoremediation Resources
View on line at <http://clu-in.org/pub1.htm>
Produced by EPA's Phytoremediation Handbook Team, in conjunction with the Remediation Technologies Development Forum (RTDF) Phytoremediation Action Team, the list of more than 865 citations includes articles published in peer-reviewed journals, newspaper stories, presentations and posters from conferences, and chapters excerpted from books.

Bioremediation in the Field Search System (BFSS) Version 2.1
View or download database on the Tool Kit CD-ROM
The PC-based searchable database provides information about sites at which bioremediation is being tested or implemented or at which cleanup by bioremediation has been completed. The database covers sites being addressed under CERCLA, RCRA, TSCA, as well as those being addressed under the UST Program. Information is available about location, media, contaminants, technology, cost, and performance.

Bioremediation of Chlorinated Solvent Contaminated Groundwater
View or download pdf file on the Tool Kit CD-ROM
The report is intended to provide a basic summary of in situ treatment technologies for groundwater contaminated with chlorinated solvents. It includes information gathered from a range of currently available sources, including project documents, reports, periodicals, Internet searches, and personal communication with parties involved in the use of the technologies.

California Environmental Technology Certification Program - California Certified Technologies List
View on line at <http://www.calepa.ca.gov/programs/EnviroTech/encertpg.htm>
The Cal/EPA Environmental Technology Certification program Internet site provides the user access to the California Certified Technologies List. The document provides a list of technologies and their respective vendors that have been certified by the state of California. Certification is granted to technologies on the basis of an independent, third-party verification of the technology's performance and ability to meet regulatory specifications and requirements. Developers and manufacturers define quantitative performance claims for their technologies and provide supporting documentation. Cal/EPA reviews that information and, when necessary, conducts additional testing to verify the claims. Technologies, equipment, and products that are proven to work as claimed receive official state certification.

EPA Engineering Bulletins
View on line at <http://www.epa.gov/ncepihom/nepishom/>
The bulletins, developed by EPA's National Risk Management Research Laboratory, are a series of documents that summarize the latest information about specific treatment and remediation processes. Limitations of the technologies, the latest performance data, site requirements, and the status of the technologies also are discussed. The bulletins provide detailed information about several physical and chemical treatment processes, including:

- *Composting (EPA 540-S-96-502)*
- *In Situ Biodegradation Treatment (EPA 540-S-94-502)*
- *In Situ Vitrification Treatment (EPA 540-S-94-504)*
- *Separation/Concentration Technology Alternatives for the Remediation of Pesticide Contaminated Soil (EPA 540-S-97-503)*
- *Technology Alternatives for the Remediation of Soils Contaminated with As, Cd, Cr, Hg, and Pb (EPA 540-S-97-500)*
- *Thermal Desorption Treatment (EPA 540-S-94-501, PB94-160603)*

EPA Region 5 Monitored Natural Attenuation Report
View or download pdf file on the Tool Kit CD-ROM
The report describes a natural attenuation field study conducted jointly by EPA Region 5, the Wisconsin Department of Natural Resources, the Illinois Environmental Protection Agency, and Amoco Corporation that has been underway since October 1994.

Field Applications of In Situ Remediation Technologies: Chemical Oxidation (EPA 542-R-98-008)
View or download pdf file on the Tool Kit CD-ROM
The document describes recent pilot demonstrations and full-scale applications of chemical oxidation processes that treat soil and groundwater in place or increase the solubility and mobility of contaminants to improve their removal by other remediation technologies.

Field Applications of In Situ Remediation Technologies: Ground-Water Circulation Wells (EPA 542-R-98-009)
View or download pdf file on the Tool Kit CD-ROM
The report is one in a series of reports that document recent pilot demonstrations and full-scale applications that treat soil and groundwater in situ or increase the

solubility and mobility of contaminants to improve their removal by other remediation technologies. It is hoped that the information provided will facilitate more frequent consideration of new, less costly, and more effective technologies to address the problems associated with hazardous waste sites and petroleum contamination.

Field Applications of In Situ Remediation Technologies: Permeable Reactive Barriers (EPA 542-R-99-002)
View or download pdf file on the Tool Kit CD-ROM
One of a series of reports that summarize pilot demonstrations and full-scale applications of technologies that treat soil and groundwater, the document presents profiles of a number of applications of permeable reactive barriers (PRB). Each profile identifies, to the extent the information is available, the name of the site, its location, its characteristics, the principal contaminants present, the installation date of the PRB, the type of construction, the costs of design and construction, the reactive materials used, and the results achieved. The profiles also discuss lessons learned and lists a point of contact for obtaining further information. A bibliography of articles and documents related to PRBs also is included.

Ground Water Issue Paper: Steam Injection for Soil and Aquifer Remediation (EPA 540-S-97-505)
View or download pdf file on the Tool Kit CD-ROM
The document contains detailed information on how steam injection can be used to recover organic contaminants from the subsurface, the contaminant and subsurface conditions for which the process may be appropriate, and general design and equipment considerations.

Ground-Water Remediation Technologies Analysis Center (GWRTAC) Technology Reports
View or download reports at <http://www.gwrtac.org/html/techdocs.html> or on the Tool Kit CD-ROM
Developed by the Ground-Water Remediation Technologies Analysis Center (GWRTAC), a variety of reports about groundwater technologies and how they work are available to assist decision makers in reviewing technology options and assessing a technology's applicability to a particular site. The Technical Overview Reports are intended to provide a general overview and introduction to selected groundwater technologies. More detailed information and technical analyses is provided in the Technical Evaluation Reports which provide, for specific technologies, comprehensive descriptions of the technology and performance information; information about its applicability and cost; discussion of regulatory and policy requirements and issues; and a summary of lessons learned. The Technology Status Reports are summary documents which provide information about the status of specific groundwater technologies or topics. Examples of some of the topics covered include: air sparging; bioslurping; electrokinetics; in situ bioremediation; in situ chemical treatment; phytoremediation; and surfactants and cosolvents. Each of the reports, as well as abstract descriptions of each, can be downloaded from the GWRTAC site. A complete list of the reports is provided on the Tool Kit CD-ROM.

In Situ Treatment of Contaminated Sediments
View or download pdf file on the Tool Kit CD-ROM
The document provides a technology assessment about in situ treatment technologies applicable for cleanup of contaminated sediments. It is intended to provide federal agencies, states, consulting engineering firms, private industries, and technology developers with information on the current status of this technology.

Leak Detection for Landfill Liners: Overview of Tools for Vadose Zone Monitoring (EPA 542-R-98-019)
View or download pdf file on the Tool Kit CD-ROM
The report provides a basic summary of tools in current use for detection of leaks in landfill liners. It includes information gathered from a range of currently available sources, including project documents, reports, periodicals, Internet searches, and personal communication with parties involved in such efforts.

Michigan Soil Vapor Extraction Remediation (MISER) Model: A Computer Program to Model Soil Vapor Extraction and Bioventing of Organic Chemicals in Unsaturated Geologic Material (EPA 600-R-97-009)
View on line at <http://www.epa.gov/ncepihom/nepishom/>
The report describes the formulation, numerical development, and use of a multiphase biodegradation model designed to simulate physical, chemical, and biological interactions that occur primarily in field-scale SVE and bioventing systems. The report is divided into the following six sections: (1) an overview of SVE and bioventing systems and a review of existing models; (2) a presentation of the conceptual formulation of MISER and the associated mathematical representation for flow, transport, and biotransformation processes; (3) a description of the numerical solution approach; (4) a presentation of the results of model verification analyses; (5) a description and usage of the model; and (6) example simulations.

Monitored Natural Attenuation of Chlorinated Solvents (EPA 600-F-98-022)
View or download pdf file on the Tool Kit CD-ROM
The fact sheet, written for a nonscientific audience

and intended to assist federal, state, and local regulators in educating the public about complex environmental issues, explains what the term "monitored natural attenuation" (MNA) means when it is used to describe a potential strategy for remediating a contaminated site. It also describes the various physical, chemical, and biological processes of natural attenuation that may take place at a site contaminated with chlorinated solvents and explains how decision makers evaluate the role of MNA at a contaminated site.

Monitored Natural Attenuation of Petroleum Hydrocarbons (EPA 600-F-98-021)
View or download pdf file on the Tool Kit CD-ROM
The fact sheet, written for a nonscientific audience and intended to assist federal, state, and local regulators in educating the public about complex environmental issues, explains what the term "MNA" means when it is used to describe a potential strategy for remediating a contaminated site. It also describes the various physical, chemical, and biological processes of natural attenuation that may take place at a site contaminated with petroleum hydrocarbons and explains how decision makers evaluate the role of MNA at a contaminated site.

Multi-Phase Extraction: State of the Practice (EPA 542-R-99-004)
View or download pdf file on the Tool Kit CD-ROM
The report describes the use of multi-phase extraction (MPE) for the remediation of contaminated soil and groundwater, focusing primarily on the application of MPE at sites at which contamination with halogenated VOCs is present. The report describes MPE technology and the various configurations used for it, indicates the types of site conditions to which MPE is applicable, and discusses the advantages and potential limitations of the use of MPE at such sites. In addition, the report provides information about vendors of MPE and case studies that summarize cost and performance data on applications of the technology at three sites.

Permeable Reactive Barriers Technologies for Contaminant Remediation (EPA 600-R-98-125)
View or download pdf file on the Tool Kit CD-ROM
The document provides information about treatable contaminants, design, feasibility studies, and construction options. Summaries of several current installations also are provided.

Permeable Reactive Subsurface Barriers for the Interception and Remediation of Chlorinated Hydrocarbon and Chromium (VI) Plumes in Ground Water (EPA 600-F-97-008)
View or download pdf file on the Tool Kit CD-ROM
Prepared by EPA's ORD, the document discusses the use of barrier walls employing zero-valent iron as the reactive substrate for treating groundwater contaminated with chlorinated hydrocarbons or chromium.

Phytoremediation Resource Guide (EPA 542-B-99-003)
View or download pdf file on the Tool Kit CD-ROM
The document aids decision makers in reviewing the applicability of phytoremediation extraction treatment technologies. The document also provides access information on electronic resources and hotlines; cites relevant federal regulations; and provides abstracts of more than 100 pertinent resources, such as bibliographies, guidance documents, workshop proceedings, overview documents, study and test results, and test designs and protocols. Included is a phytoremediation treatment technology resource matrix that compares the documents by technology type, affected media, and contaminants. The guide also provides detailed information on how to obtain the publications listed.

Phytoremediation of TCE in Groundwater Using Populus
View or download pdf file on the Tool Kit CD-ROM
The document provides a basic understanding of phytoremediation for shallow groundwater and reports on the status of the technology.

Presumptive Remedy: Supplemental Bulletin, Multi-Phase Extraction Technology for VOCs in Soil and Groundwater (EPA 540-F-97-004)
View or download pdf file on the Tool Kit CD-ROM
Produced by EPA and the USAF, this fact sheet provides an explanation of the technology and explains how to determine whether multi-phase extraction is applicable to a site contaminated with VOCs in soil and groundwater. The fact sheet also recommends MPE as a potential enhancement for SVE in the presumptive remedy for sites with VOCs in soil.

Pump and Treat Ground-Water Remediation: A Guide for Decision Makers and Practitioners (EPA 625-R-95-005)
View on line at <http://www.epa.gov/ORD/WebPubs/pumptreat/>
The guide provides an introduction to pump-and-treat groundwater remediation by addressing such questions as, "When is pump-and-treat an appropriate remediation approach?" and "How can the design and operation of a pump-and-treat system be optimized and its performance measured?" The guide is intended to provide decision makers with a foundation for evaluating the appropriateness of conventional or innovative approaches.

Soil Vapor Extraction (SVE) Treatment Technology Resource Guide (EPA 542-B-94-007)
View or download pdf file on the Tool Kit CD-ROM
The document aids decision makers in reviewing the applicability of SVE treatment technologies. The document also provides access information on electronic resources and hotlines; cites relevant federal regulations; and provides abstracts of pertinent print resources, such as bibliographies, guidance documents, workshop proceedings, overview documents, study and test results, and test designs and protocols. Included is an SVE treatment technology resource matrix that compares the documents by technology type, affected media, and contaminants. The guide also provides detailed information on how to obtain the publications listed.

Technical and Regulatory Requirements for Enhanced In Situ Bioremediation of Chlorinated Solvents in Groundwater
View or download pdf file on the Tool Kit CD-ROM
The report describes enhanced in situ bioremediation (EISB) and examines the circumstances under which its application is appropriate. It also discusses related regulatory and policy issues, such as the ban under RCRA on land disposal and technical requirements for implementation of EISB. The report was prepared by the Interstate Technology and Regulatory Cooperation Workgroup.

Testing and Demonstration Sites for Innovative Ground-Water Remediation Technologies (EPA 542-R-97-002)
View or download pdf file on the Tool Kit CD-ROM
The report identifies and describes 15 publicly-sponsored facilities available for testing and demonstration of groundwater technologies.

What Technologies Are Available?

As discussed in the Background and Before You Begin sections, technologies available for remediating brownfields sites include both innovative and established technologies (see the definition of the two types of technologies in the Background section). The table below identifies which types of technologies are appropriate for specific types of contaminant groups.

The information in the table is based on data in the EPA REACH IT system as well as other EPA sources. See *Appendix B, List of Acronyms and Glossary of Key Terms,* for descriptions of the technologies.

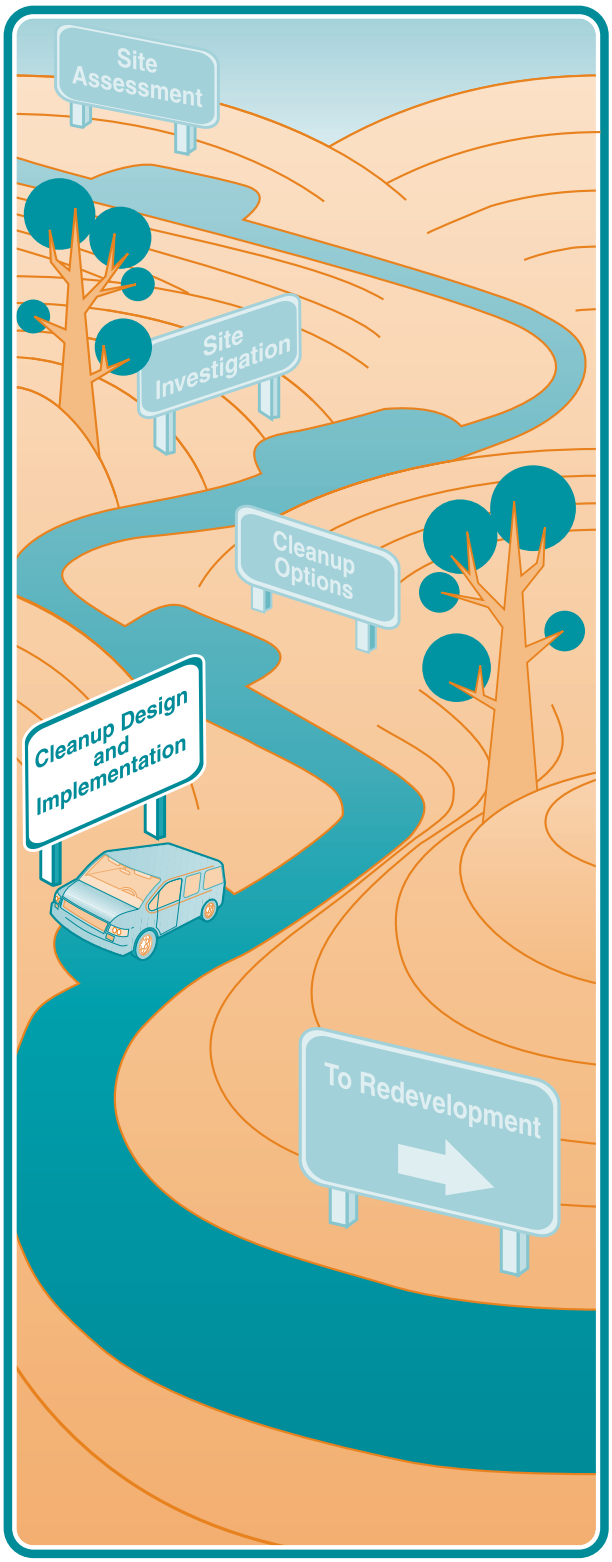
Contaminants Treated	Examples of Technologies
Soils, Sediments, and Sludges	
VOCs	Ex Situ Bioremediation; In Situ Bioremediation (Biodegradation); In Situ Soil Flushing; SVE; Thermal Desorption; In Situ Vitrification
SVOCs	Thermally Enhanced SVE; Soil Washing; Solvent Extraction; Thermal Desorption
Inorganic Compounds	Soil Flushing; Soil Washing; Electrokinetic Separation; Solvent Extraction; Chemical Treatment
Fuels	Ex Situ Bioremediation; In Situ Bioremediation; Soil Washing; SVE; Thermal Desorption
Explosives	Ex Situ Bioremediation; In Situ Bioremediation; Soil Washing; Solvent Extraction; Thermal Desorption
Groundwater, Surface Water, and Leachate	
VOCs	Air Sparging; Dual-Phase Extraction; Fluid/Vapor Extraction; In Situ Bioremediation; Bioreactors; Permeable Reactive Barriers
SVOCs	In Situ Bioremediation; Bioslurping; Permeable Reactive Barriers
Inorganic Compounds	Adsorption; Permeable Reactive Barriers; Phytoremediation
Fuels	Air Sparging; Dual-Phase Extraction; In Situ Bioremediation; Bioreactor; Bioslurping; Fluid/Vapor Extraction
Explosives	Bioreactor; Permeable Reactive Barriers; Phytoremediation

Where Do We Go From Here?

After you have reviewed options for cleanup, you may take any of the following courses of action:

Result of the Review of Cleanup Options		Course of Action
The proposed cleanup option appears feasible.	➡	*Proceed to the CLEANUP DESIGN AND IMPLEMENTATION phase.*
No cleanup option appears feasible in light of the proposed redevelopment and land reuse needs (such as project milestones and cost and intended reuse).	➡	*Determine whether revising the redevelopment plan remains a practicable option; if so, proceed to the CLEANUP DESIGN AND IMPLEMENTATION phase. If contamination exists at considerable levels, compliance with other programs, such as RCRA and Superfund, may be required.*

CLEANUP DESIGN AND IMPLEMENTATION



Develop and Carry Out Detailed Cleanup Plans for the Site

OBJECTIVE

This phase focuses on the design and implementation of a cleanup plan to prepare the property for redevelopment and reuse. The design of the cleanup plan and implementation of the technology options selected in the previous phase involves close coordination with all other redevelopment efforts in the immediate vicinity of the site.

What Do We Need to Know?

KEY QUESTIONS

Factors that should be considered during the design and implementation of cleanup activities include:

1. Are there federal, state, local, and tribal requirements for the design, installation, and monitoring of cleanup activities?
2. How will cleanup be monitored so that work can be stopped when cleanup goals are reached?
3. How best can the community participate in the design and implementation of the cleanup plan?
4. What can be done to protect the community and other property during cleanup?
5. What are the tradeoffs between cost and meeting redevelopment project deadlines? Can redevelopment activities (such as renovation of existing buildings and construction of roads and sewage systems) be performed concurrently with cleanup activities?
6. What are the long-term effects of the selected technology on the liability or on the future use of the site? What are the effects of a catastrophic change to the environment (for example, a hurricane or changes to the subsurface)?
7. Will long-term monitoring be required? If so, how will it be managed?
8. Will institutional controls facilitate or hinder redevelopment? Now? In the future?

How Do We Find the Answers?*

Typical activities that may be conducted during this phase include:

- Review all applicable federal, state, local, and tribal regulatory guidelines and regulations to determine all specific requirements, including guidelines for state VCPs
- Continue to work with the appropriate regulatory agencies to ensure that regulatory requirements are being properly addressed:
  - *Consult with the appropriate federal, state, local, and tribal regulatory agencies to include them in the decision-making process as early as possible*
  - *Contact the EPA regional brownfields coordinator to identify and determine the availability of EPA support programs*
- Develop conceptual plans for cleanup and subsequent monitoring that incorporate technology options and consider the effect of any cleanup activities on the proposed reuse of the property and the schedule for project design or construction:
  - *Develop or review the schedule for completion of the project*
  - *Obtain a final amount for the funds available for project development*
  - *Coordinate the renovation and construction of infrastructure with cleanup activities*
  - *Coordinate activities with developers, financiers, construction firms, and members of the local community*
- Establish contingency plans to address the discovery of additional contamination during cleanup, including tools such as environmental insurance policies
- Develop procedures for community participation, for example, by working with community advisory boards or local redevelopment authorities
- Implement and monitor the cleanup plan and performance of the technology selected
- Work with the state VCP program, if applicable, and or county or local officials to facilitate the placement and implementation of institutional controls

Where Do We Find Help To Our Technology Questions?

Listed below are examples of technology resources that provide information about applicable regulatory guidelines and regulations and community outreach materials. In addition, technologies identified during the site investigation phase may be appropriate to monitor cleanup performance and close-out. Information about the availability of electronic resources — whether the item is found on the Road Map's accompanying Tool Kit CD-ROM or on various Web sites — also is provided. *Appendix D, How to Order Documents*, provides complete ordering information for documents that are not available on the CD-ROM or on the Internet.

A. Technology Resources

The documents listed below are resources that provide general information about the availability of technology resources in the form of bibliographies and status reports. On-line searchable databases also are included.

Citizen's Guides to Understanding Innovative Treatment Technologies

View or download pdf files on the Tool Kit CD-ROM

The guides are prepared by EPA to provide site managers with nontechnical outreach materials, in English and Spanish, that they can share with communities in the vicinity of a site. The guides present information on innovative treatment technologies that have been selected or applied at some cleanup sites, provide overviews of innovative treatment technologies, and present success stories about sites at which innovative treatment technologies have been applied. The guides contain information on the following subjects:

- *Bioremediation*
- *Chemical dehalogenation*
- *In situ soil flushing*
- *Innovative treatment technologies for contaminated soils, sludges, sediments, and debris*
- *Natural attenuation*
- *Phytoremediation*
- *SVE and air sparging*
- *Soil washing*
- *Solvent extraction*
- *Thermal desorption*
- *Treatment walls*
- *Understanding presumptive remedies*

** Please note that the Road Map seeks to answer technology selection questions and is not intended to provide a response to each procedural question identified.*

EPA Directive: Initiatives to Promote Innovative Technology in Waste Management Programs (OSWER Directive 93800-25, EPA 540-F-96-012)
View or download pdf file on the Tool Kit CD-ROM
The policy directive, issued April 29, 1996, describes several initiatives to facilitate the testing, demonstration, and use of innovative cleanup and field measurement technologies and stresses EPA's commitment to promoting the development and commercialization of environmental technologies. The initiatives under the directive place a high priority on selecting innovative treatment and characterization technologies, reducing impediments to the development and use of innovative technologies, and sharing the risks of using innovative treatment technologies.

EPA REmediation And CHaracterization Innovative Technologies (REACH IT) On-line Searchable Database
View on line at <http://www.epareachit.org>
EPA REACH IT is an on-line searchable database that assists brownfields stakeholders in obtaining comprehensive information about technologies useful for monitoring cleanup of brownfields sites. Specific information about applicable technologies and their service providers can be accessed readily using the guided and advanced search capabilities of the system. EPA REACH IT is accessible only through the Internet.

Federal Remediation Technologies Roundtable (FRTR) Case Studies
View on line at <http://www.frtr.gov/cost>
The case studies provide the user information about specific remedial technology applications. FRTR case studies are developed by DoD, USACE, the U.S. Navy, USAF, DOE, DOI, and EPA. The case studies focus on full-scale and large field demonstration projects and include information on site background, description of the technology, cost and performance of technology application, and lessons learned. Technologies include innovative and conventional treatment technologies for contaminated soil, groundwater, and solid media. Visit FRTR's Internet Site at *<http://www.frtr.gov/search>* to search the case studies by groups of contaminants, media, waste management practices that contribute to contamination, and treatment systems.

WASTECH® Series of Innovative Site Remediation Technology Engineering Monographs
See Appendix D, How to Order Documents, for a WASTECH order form, or view the order form on the Tool Kit CD-ROM
The WASTECH® project generates authoritative, consensus-based engineering monographs for remediation of hazardous waste sites and contaminated soils and groundwater. WASTECH® is funded by EPA, DoD, DOE, and the American Academy of Environmental Engineers®. During Phase I of the project, eight monographs were published in 1994 and 1995 covering the basics of these technologies, i.e., identification and description, potential applications, process evaluations, and limitations. During 1997 and early 1998, an additional seven volumes covering the design and applications, including actual case studies, were produced. Copies of the individual monographs (by technology type) or the entire series may be purchased by contacting the American Academy of Environmental Engineers® by telephone at 410-266-3390 or by facsimile at 410-266-7653.

The volumes contain information on the following technologies:

- *Bioremediation*
- *Chemical treatment*
- *Soil washing/soil flushing*
- *Solidification/stabilization*
- *Solvent/chemical extraction*
- *Thermal desorption*
- *Thermal destruction*
- *Vacuum vapor extraction*

B. Technology-Specific Resources

The documents listed below provide detailed information about specific innovative technologies and the application of those processes to specific contaminants and media in the form of engineering analyses, application reports, technology verification and evaluation reports, and technology reviews.

Best Management Practices (BMPs) for Soil Treatment Technologies: Suggested Operational Guidelines to Prevent Cross-Media Transfer of Contaminants During Clean-Up Activities (EPA 530-R-97-007)
View or download pdf file on the Tool Kit CD-ROM
The document provides guidance for designing and conducting soil remediation activities at RCRA and other hazardous waste sites so that cross-contamination is minimal. The document is expected to assist in reducing exposure of workers to contaminants by identifying the potential for transfer from medium to medium and recommending control mechanisms that could be applied during implementation of treatment technologies for soil. The BMPs are provided for seven technology categories: containment technologies; soil washing; thermal treatment; vapor extraction; bioremediation; incineration; and other physical and chemical treatments. The document also provides case studies and information about field validation activities that EPA undertook at soil remediation sites in 1996 and 1997.

State Policy and Regulatory Barriers to In Situ Ground Water Remediation (EPA 542-R-96-001)
View or download pdf file on the Tool Kit CD-ROM
The report identifies specific state regulatory and policy barriers to the use of techniques that enhance in situ groundwater treatment technologies through the subsurface injection of surfactants, cosolvents, and nutrients. The report also describes the experiences and policies of each state and provides contact information for obtaining additional assistance.

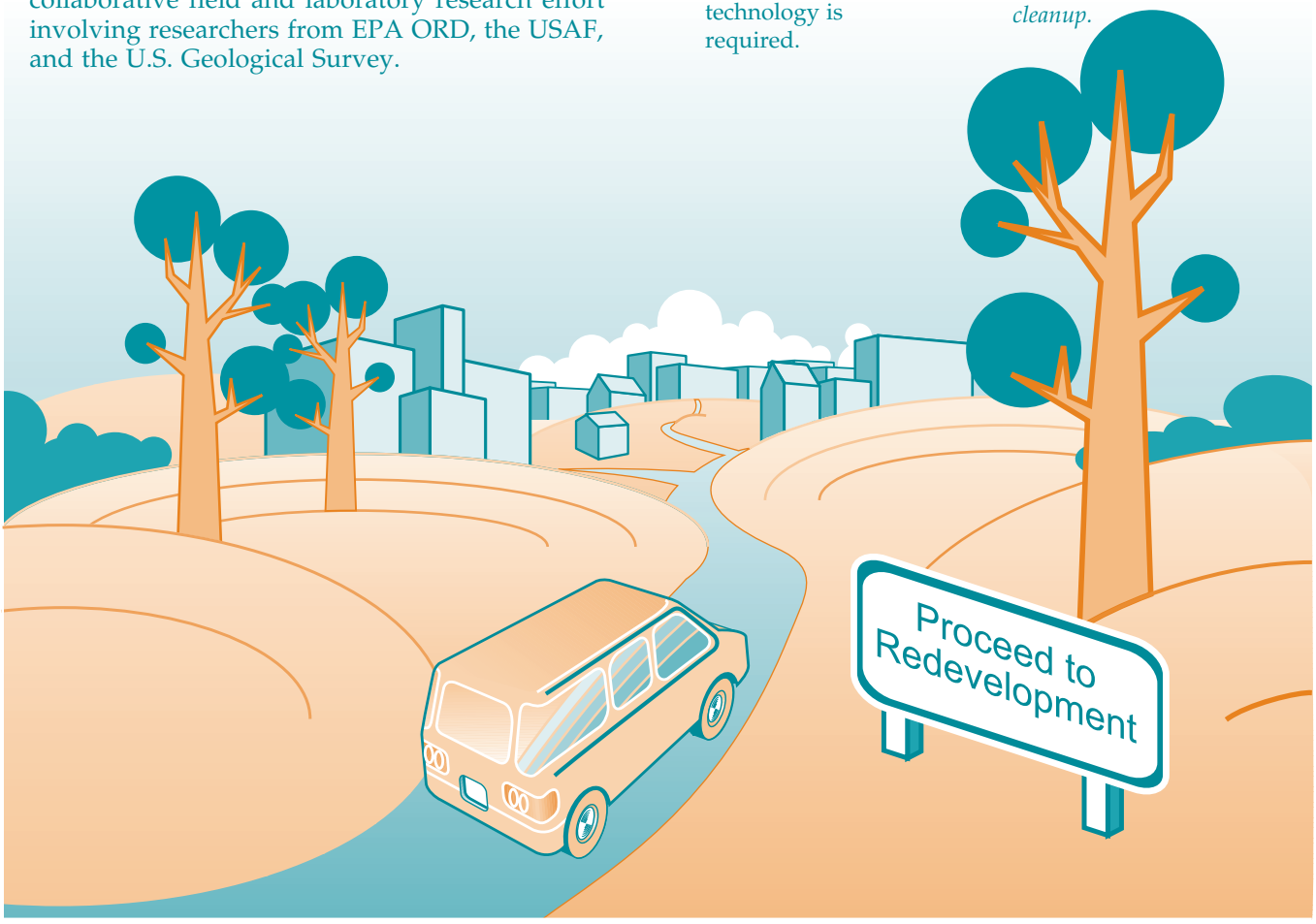
Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water (EPA 600-R-98-128)
View or download pdf file on the Tool Kit CD-ROM
The report provides guidance for environmental managers about the steps that must be taken to understand the rate and extent to which natural processes are reducing contaminant concentrations at sites that are contaminated by chlorinated solvents. Data collected with this protocol can be used to evaluate natural attenuation through biological processes as part of a protective overall site remedy. The protocol is the result of a collaborative field and laboratory research effort involving researchers from EPA ORD, the USAF, and the U.S. Geological Survey.

Where Do We Go From Here?

NEXT STEPS

After you have completed cleanup, you may take one of the following courses of action:

Result of Cleanup	Course of Action
Contamination has been removed, contained, or controlled.	*Consult with the appropriate regulatory officials before proceeding with redevelopment activities.*
Additional contamination has been discovered.	*Continue cleanup activities. However, you may have to return to the SITE INVESTIGATION phase to determine the extent and nature of the contamination.*
Long-term monitoring of cleanup and performance of the technology is required.	*Return to the SITE INVESTIGATION phase to collect after-performance samples for monitoring cleanup.*



APPENDICES

APPENDIX A

Appendix A

GUIDE TO CONTAMINANTS FOUND AT TYPICAL BROWNFIELDS SITES

The following table identifies activities that may have caused contamination at brownfields sites. The table summarizes contaminants that are related to such activities and identifies sources for the contaminants. However, it is not an exhaustive list of contaminants that can be found at a brownfields site. Identifying contaminants that may be present should be determined on a site-by-site basis. Such a determination should be conducted thoroughly and carefully. Information for this table was compiled from several sources, including various EPA *Guides to Pollution Prevention* for selected industries. A list of the specific citations used is provided on page A-2.

Past Activities Typically Conducted at Brownfields Sites	Typical Contaminants
Agriculture	VOCs, arsenic, copper, carbon tetrachloride, ethylene dibromide and methylene chloride, pesticides, insecticides, herbicides, grain fumigants
Automotive refinishing and repair	Some metals and metal dust, various organic compounds, solvents, paint and paint sludges, scrap metal, waste oils
Battery recycling and disposal	Lead, cadmium, acids, nickel, copper, zinc, arsenic, chromium
Chloro-alkali manufacturing	Chlorine compounds, mercury
Coal gasification	PAHs, sulfur compounds, cyanide, aluminum, iron, lead, nickel, chromium
Cosmetics manufacturing	Heavy metals, dusts, solvents, acids
Dry cleaning activities	VOCs such as chloroform and tetrachloroethane, various solvents, spot removers, fluorocarbon 113, perchloroethylene
Dye facilities	2-naphthylamine, 4-aminobiphenyl, benzidine
Electroplating operations	Various metals such as cadmium, chromium, cyanide, copper, and nickel
Glass manufacturing	Arsenic, lead
Herbicide manufacturing and use	Dioxin, metals, herbicides
Hospitals	Formaldehyde, radionuclides, photographic chemicals, solvents, mercury, ethylene oxide, chemotherapy chemicals
Incinerators	Dioxin, various municipal and industrial waste, ash, ordnance compounds, metals
Landfills—municipal and industrial	Metals, VOCs, PCBs, ammonia, methane, household products and cleaners, pesticides, various wastes, hydrogen sulfide
Leather manufacturing	Toluene, benzene
Machine shops/metal fabrication	Metals, VOCs, dioxin, beryllium, degreasing agents, solvents, waste oils
Marine maintenance industry sludges, degreasers	Solvents, paints, cyanide, acids, VOC emissions, heavy metal
Munitions manufacturing	Lead, explosives, copper, antimony, unexploded ordnance (UXO)
Paint/ink manufacturing	Metals (such as chromium, cadmium, lead, and zinc), VOCs, chloroform, ethyl benzene, solvents, paints, inks
Pesticide manufacturing	VOCs, arsenic, copper, pesticides, insecticides, herbicides, fungicides, xylene, chlorinated organic compounds, solvents
Petroleum refining and reuse	Petroleum hydrocarbons, BTEX, fuels, oil and grease
Pharmaceutical manufacturing	Lead, various organic chemicals, organic solvents

Past Activities Typically Conducted at Brownfields Sites (continued)	Typical Contaminants
Photographic manufacturing and uses	Silver bromide, methylene chloride, solvents, photographic products
Plastics manufacturing	Polymers, phthalates, cadmium, solvents, resins, chemical additives, VOCs
Printing industry	Silver, solvents, acids, waste oils, inks and dyes, photographic chemicals
Railroad yards	Petroleum hydrocarbons, VOCs, BTEX, solvents, fuels, oil and grease, lead, PCBs
Research and educational institutions	Inorganic acids, organic solvents, metals and metal dust, photographic waste, waste oil, paint, heavy metals, pesticides
Scrap metal operations	Various metals (such as lead and nickel), PCBs, dioxin, transformers
Semiconductor manufacturing	Metals, VOCs, carbon tetrachloride, degreasing agents, solvents
Smelter operations	Metals (such as lead, copper, and arsenic)
Underground storage tanks	Solvents, metals, POLs, BTEX, gasoline, diesel fuel
Wood pulp and paper manufacturing	Chlorinated organic compounds, dioxin, furans, chloroform, resin acids
Wood preserving	Creosote, PCP, arsenic, chromium, copper, PCBs, PAHs, beryllium, dioxin, wood preservatives, zinc

LIST OF CITATIONS USED TO IDENTIFY COMMON CONTAMINANTS

Bioremediation of Hazardous Waste: Research Development, and Field Evaluation (EPA 540-R-95-532)

Contaminants and Remedial Options at Selected Metal-Contaminated Sites (EPA 540-R-95-512, PB95-271961)

Dry Cleaning and Laundry Plants, Fact Sheet (EPA 530-SW-90-027b)

EPA Region 3 Industry Profile Fact Sheets

EPA REmediation And CHaracterization Innovative Technologies (EPA REACH IT)

Guidelines for Waste Reduction and Recycling: Metal Finishing, Electroplating, Printed Circuit Board Manufacturing, Hazardous Waste Reduction Program, Oregon Department of Environmental Quality (No document number)

Guides to Pollution Prevention:

- *Research and Educational Institutions (EPA 625-7-90-010)*
- *Selected Hospital Waste Streams (EPA 625-7-90-009)*
- *The Automotive Refinishing Industry (EPA 625-7-91-016)*
- *The Automotive Repair Industry (EPA 625-7-91-013)*
- *The Commercial Printing Industry (EPA 625-7-90-008)*
- *The Fiberglass-Reinforced and Composite Plastics Industry (EPA 625-7-91-014)*
- *The Marine Maintenance and Repair Industry (EPA 625-7-91-015)*
- *The Mechanical Equipment Repair Industry (EPA 625-R-92-008)*
- *The Pesticide Formulating Industry (EPA 625-7-90-004)*
- *The Pharmaceutical Industry (EPA 625-7-91-017)*

Low-Level Mixed Waste: A RCRA Perspective for NRC Licenses (EPA 530-SW-90-057)

Pollution Prevention Technologies for the Bleached Kraft Segment of the U.S. Pulp and Paper Industry (EPA 600-R-93-110)

Solving the Hazardous Waste Problem: EPA's RCRA Program (EPA 530-SW-86-037)

Treatment Technologies for Site Cleanup: Annual Report, Ninth Edition (EPA 542-R-99-001)

Waste Minimization Audit Report: Case Studies of Minimization of Mercury-Bearing Wastes at a Mercury Cell Chloralkali Plant; Project Summary (EPA 600-S2-88-011)

Waste Minimization Opportunity Assessment: Philadelphia Naval Shipyard; Project Summary (EPA 600-S2-90-046)

Waste Reduction for the Aerospace Industry: Fact Sheet, California Department of Health Services Technology Clearinghouse (No document number)

APPENDIX B

Appendix B

LIST OF ACRONYMS and GLOSSARY OF KEY TERMS

ARAR	Applicable or Relevant and Appropriate Requirement
ASTM	American Society for Testing and Materials
BDAT	Best Demonstrated Achievable Technology
BTEX	Benzene, Toluene, Ethylbenzene, and Xylene
CAA	Clean Air Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CERCLIS	Comprehensive Environmental Response, Compensation, and Liability Information System
CERI	Center for Environmental Research Information
CLU-IN	EPA Hazardous Waste Clean-up Information Web Site
CMS	Corrective Measure Study
CWA	Clean Water Act
DNAPL	Dense Nonaqueous Phase Liquid
DQO	Data Quality Objective
EPA	U.S. Environmental Protection Agency
EPA REACH IT	EPA REmediation And CHaracterization Innovative Technologies On-Line Searchable Database
EPCRA	Emergency Planning and Community Right-to-Know Act
ESA	Environmental Site Assessment
FDIC	Federal Deposit Insurance Corporation
HRS	Hazard Ranking System
HSWA	Hazardous and Solid Waste Amendments
IRIS	Integrated Risk Information System
ITT	Innovative Treatment Technology
LDR	Land Disposal Restrictions
LNAPL	Light Nonaqueous Phase Liquid
LUST	Leaking Underground Storage Tank
NAPL	Nonaqueous Phase Liquid
NCP	National Contingency Plan
NERL	National Exposure Research Laboratory
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NRC	National Response Center
O&M	Operation and Maintenance
ORD	Office of Research and Development
OSWER	Office of Solid Waste and Emergency Response
PAH	Polynuclear Aromatic Hydrocarbon
PA/SI	Preliminary Assessment and Site Inspection
PBMS	Performance-Based Measurement System
PCB	Polychlorinated Biphenyl
PCP	Pentachlorophenol
PRP	Potentially Responsible Party
QA/QC	Quality Assurance and Quality Control
RBCA	Risk-Based Corrective Action
RCRA	Resource Conservation and Recovery Act
RD/RA	Remedial Design and Remedial Action
RFA	RCRA Facility Assessment
RFI	RCRA Facility Investigation
RI/FS	Remedial Investigation and Feasibility Study
ROD	Record of Decision
RQ	Reportable Quantity
SARA	Superfund Amendments and Reauthorization Act
SITE	Superfund Innovative Technology Evaluation
SVE	Soil Vapor Extraction
SVOC	Semi-Volatile Organic Compound
TCE	Trichloroethylene
TCLP	Toxicity Characteristic Leaching Procedure
TIO	Technology Innovation Office
TPH	Total Petroleum Hydrocarbon
TSCA	Toxic Substances Control Act
TSDF	Treatment, Storage, and Disposal Facility
UST	Underground Storage Tank
VCP	Voluntary Cleanup Program
VOC	Volatile Organic Compound

The following is a list of specialized terms used during the cleanup of brownfields sites.

Absorption
Absorption is the passage of one substance into or through another.

Adsorption
Adsorption is the adhesion of molecules of gas, liquid, or dissolved solids to a surface. The term also refers to a method of treating wastes in which activated carbon removes organic matter from wastewater.

Air Sparging
In air sparging, air is injected into the ground below a contaminated area, forming bubbles that rise and carry trapped and dissolved contaminants to the surface where they are captured by a soil vapor extraction system. Air sparging may be a good choice of treatment technology at sites contaminated with solvents and other VOCs. *See also Soil Vapor Extraction and Volatile Organic Compound.*

Air Stripping
Air stripping is a treatment system that removes or "strips" VOCs from contaminated groundwater or surface water as air is forced through the water, causing the compounds to evaporate. *See also Volatile Organic Compound.*

American Society for Testing and Materials (ASTM)
The ASTM sets standards for many services, including methods of sampling and testing of hazardous waste and media contaminated with hazardous waste.

Applicable or Relevant and Appropriate Requirement (ARAR)
As defined under CERCLA, ARARs are cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limits set forth under federal or state law that specifically address problems or situations present at a CERCLA site. ARARs are major considerations in setting cleanup goals, selecting a remedy, and determining how to implement that remedy at a CERCLA site. ARARs must be attained at all CERCLA sites unless a waiver is attained. ARARs are not national cleanup standards for the Superfund program. *See also Comprehensive Environmental Response, Compensation, and Liability Act and Superfund.*

Aquifer
An aquifer is an underground rock formation composed of such materials as sand, soil, or gravel that can store groundwater and supply it to wells and springs.

Aromatics
Aromatics are organic compounds that contain 6-carbon ring structures, such as creosote, toluene, and phenol, that often are found at dry cleaning and electronic assembly sites.

Baseline Risk Assessment
A baseline risk assessment is an assessment conducted before cleanup activities begin at a site to identify and evaluate the threat to human health and the environment. After remediation has been completed, the information obtained during a baseline risk assessment can be used to determine whether the cleanup levels were reached.

Bedrock
Bedrock is the rock that underlies the soil; it can be permeable or non-permeable. *See also Confining Layer and Creosote.*

Best Demonstrated Achievable Technology (BDAT)
A BDAT is a technology that has demonstrated the ability to reduce a particular contaminant to a lower concentration than other currently available technologies. BDATs can change with time as technologies evolve.

Bioremediation
Bioremediation refers to treatment processes that use microorganisms (usually naturally occurring) such as bacteria, yeast, or fungi to break down hazardous substances into less toxic or nontoxic substances. Bioremediation can be used to clean up contaminated soil and water. In situ bioremediation treats the contaminated soil or groundwater in the location in which it is found. For ex situ bioremediation processes, contaminated soil must be excavated or groundwater pumped to the surface before they can be treated.

Bioreactor
Bioreactors degrade contaminants in water with microorganisms through attached or suspended biological systems. In suspended growth systems, such as activated sludge, fluidized beds, or sequencing batch reactors, contaminated groundwater is circulated in an aeration basin where a microbial

population aerobically degrades organic matter and produces carbon dioxide, water, and new cells. In attached systems, such as rotating biological contactors (RBC) and trickling filters, microorganisms are established on an inert support matrix. The cells form a sludge, which is settled out in a clarifier and is recycled to the aeration basin or disposed of. In attached growth systems, such as upflow fixed-film bioreactors, RBCs, and trickling filters, microorganisms are established on an inert support matrix to aerobically degrade contaminants in water.

Biosensor
A biosensor is a portable device that uses living organisms, such as enzymes, tissues, microbes, and antibodies, to produce reactions to specific chemical contaminants.

Bioslurping
Bioslurping is the adaptation and application of vacuum-enhanced dewatering technologies to remediate hydrocarbon-contaminated sites. Bioslurping combines elements of both bioventing and free-product recovery to simultaneously recover free product and bioremediate soils in the vadose zone. Bioventing stimulates the aerobic bioremediation of hydrocarbon-contaminated soils and vacuum-enhanced free-product recovery extracts light nonaqueous phase liquids (LNAPL) from the capillary fringe and the water table.

Bioventing
Bioventing is an in situ remediation technology that combines soil vapor extraction methods with bioremediation. It uses vapor extraction wells that induce air flow in the subsurface through air injection or through the use of a vacuum. Bioventing can be effective in remediating releases of petroleum products, such as gasoline, jet fuels, kerosene, and diesel fuel. *See also Bioremediation and Soil Vapor Extraction.*

Borehole
A borehole is a hole cut into the ground by means of a drilling rig.

Borehole Geophysics
Borehole geophysics are nuclear or electric technologies used to identify the physical characteristics of geologic formations that are intersected by a borehole.

Brownfields
Brownfields sites are abandoned, idled, or under-used industrial and commercial facilities where expansion or redevelopment is complicated by real or perceived environmental contamination.

BTEX
BTEX is the term used for benzene, toluene, ethylbenzene, and xylene-volatile aromatic compounds typically found in petroleum products, such as gasoline and diesel fuel.

Cadmium
Cadmium is a heavy metal that accumulates in the environment. *See also Heavy Metal.*

Carbon Adsorption
Carbon adsorption is a treatment system that removes contaminants from groundwater or surface water as the water is forced through tanks containing activated carbon.

Chemical Dehalogenation
Chemical dehalogenation is a chemical process that removes halogens (usually chlorine) from a chemical contaminant, rendering the contaminant less hazardous. The chemical dehalogenation process can be applied to common halogenated contaminants such as PCBs and dioxins, which may be present in soil and oils. Dehalogenation can be effective in removing halogens from hazardous organic compounds, such as dioxins, PCBs, and certain chlorinated pesticides. The treatment time is short, energy requirements are moderate, and operation and maintenance costs are relatively low. This technology can be brought to the site, eliminating the need to transport hazardous wastes. *See also Polychlorinated Biphenyl and Dioxin.*

Chemical Treatment
Chemical treatments typically involve reduction/oxidation (redox) reactions that chemically convert hazardous contaminants to nonhazardous or less toxic compounds that are more stable, less mobile, or inert. Redox reactions involve the transfer of electrons from one compound to another. Specifically, one reactant is oxidized (loses electrons) and one is reduced (gains electrons). The oxidizing agents most commonly used for treatment of hazardous contaminants are ozone, hydrogen peroxide, hypochlorites, chlorine, and chlorine dioxide. In cyanide oxidation, organic cyanides are oxidized to less hazardous compounds through chemical reactions.

Chlorinator
A chlorinator is a device that adds chlorine, in gas or liquid form, to water or sewage to kill bacteria.

Clean Air Act (CAA)
The CAA is a federal law passed in 1970 that requires EPA to establish regulations to control the release of contaminants to the air to protect human health and environment.

Cleanup
Cleanup is the term used for actions taken to deal with a release or threat of release of a hazardous substance that could affect humans and or the environment. The term sometimes is used interchangeably with the terms remedial action, removal action, response action, or corrective action.

Clean Water Act (CWA)
CWA is a 1977 amendment to the Federal Water Pollution Control Act of 1972, which set the basic structure for regulating discharges of pollutants to U.S. waters. This law gave EPA the authority to set wastewater discharge standards on an industry-by-industry basis and to set water quality standards for all contaminants in surface waters.

Colorimetric
Colorimetric refers to chemical reaction-based indicators that are used to produce reactions to individual, or classes of compounds. The reactions, such as visible color changes or other easily noted indications, are used to detect and quantify contaminants.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)
CERCLA is a federal law passed in 1980 that created a special tax that funds a trust fund, commonly known as Superfund, to be used to investigate and clean up abandoned or uncontrolled hazardous waste sites. CERCLA required for the first time that EPA step beyond its traditional regulatory role and provide response authority to clean up hazardous waste sites. EPA has primary responsibility for managing cleanup and enforcement activities authorized under CERCLA. Under the program, EPA can pay for cleanup when parties responsible for the contamination cannot be located or are unwilling or unable to perform the work, or take legal action to force parties responsible for contamination to clean up the site or reimburse the federal government for the cost of the cleanup. *See also Superfund.*

Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS)
CERCLIS is a database that serves as the official inventory of Superfund hazardous waste sites. CERCLIS also contains information about all aspects of hazardous waste sites, from initial discovery to deletion from the NPL. The database also maintains information about planned and actual site activities and financial information entered by EPA regional offices. CERCLIS records the targets and accomplishments of the Superfund program and is used to report that information to the EPA Administrator, Congress, and the public. *See also National Priorities List and Superfund.*

Cone Penetrometer
The cone penetrometer is a truck-mounted device that rapidly penetrates the ground to collect samples. It has been used for approximately the last 50 years for geotechnical applications, but its use for site characterization is relatively new.

Confining Layer
A "confining layer" is a geological formation characterized by low permeability that inhibits the flow of water. *See also Bedrock and Permeability.*

Contaminant
A contaminant is any physical, chemical, biological, or radiological substance or matter present in any media at concentrations that may result in adverse effects on air, water, or soil.

Corrective Measure Study (CMS)
If the potential need for corrective measures is verified during a RCRA Facility Investigation (RFI), the owner or operator of a facility is then responsible for performing a CMS. A CMS is conducted to identify, evaluate, and recommend specific corrective measures based on a detailed engineering evaluation. Using data collected during the RFI, the CMS demonstrates that proposed measures will be effective in controlling the source of contamination, as well as problems posed by the migration of substances from the original source into the environment. The measures also must be assessed in terms of technical feasibility, ability to meet public health protection requirements and protect the environment, possible adverse environmental effects, and institutional constraints. *See also RCRA Facility Investigation.*

Corrosivity
Corrosive wastes include those that are acidic and capable of corroding metal such as tanks, containers, drums, and barrels.

Creosote
Creosote is an oily liquid obtained by the distillation of wood that is used as a wood preservative and disinfectant and often is found at wood preserving sites. *See also Aromatics and Light Nonaqueous Phase Liquid.*

Data Quality Objective (DQO)
DQOs are qualitative and quantitative statements specified to ensure that data of known and appropriate quality are obtained. The DQO process is a series of planning steps, typically conducted during site assessment and investigation, that is designed to ensure that the type, quantity, and quality of environmental data used in decision making are appropriate. The DQO process involves a logical, step-by-step procedure for determining which of the complex issues affecting a site are the most relevant to planning a site investigation before any data are collected.

Dechlorination
Dechlorination, the process used primarily to treat and destroy halogenated aromatic contaminants, is the chemical reaction that removes halogens (usually chlorine) from the primary structure of the contaminating organic chemical. Dechlorination can treat contaminated liquids, soils, sludges, and sediments, as well as halogenated organics and PCBs, pesticides, and some herbicides.

Dense Nonaqueous Phase Liquid (DNAPL)
A DNAPL is one of a group of organic substances that are relatively insoluble in water and more dense than water. DNAPLs tend to sink vertically through sand and gravel aquifers to the underlying layer.

Detection Limit
The lowest concentration of a chemical that can be distinguished reliably from a zero concentration.

Dioxin
A dioxin is any of a family of compounds known chemically as dibenzo-p-dioxins. They are chemicals released during combustion. Concern about them arises from their potential toxicity and the risk posed by contamination in commercial products. Boilers and industrial furnaces are among the sources of dioxins.

Disposal
Disposal is the final placement or destruction of toxic, radioactive or other wastes; surplus or banned pesticides or other chemicals; polluted soils; and drums containing hazardous materials from removal actions or accidental release. Disposal may be accomplished through the use of approved secure landfills, surface impoundments, land farming, deep well injection, or ocean dumping.

Dual-Phase Extraction
Dual-phase extraction is a technology that extracts contaminants simultaneously from soils in saturated and unsaturated zones by applying soil vapor extraction techniques to contaminants trapped in saturated zone soils. *See also Soil Vapor Extraction.*

Electrochemical Detector Kits
Electrochemical test kits use the electrical charges of ions that make up the target analyte(s) to identify and quantify the target analyte(s) in a sample. Typically, the ions are attracted to an anode or a cathode or both, depending on their charge, resulting in the generation of an electrical current that is measured and converted into a sample concentration by the unit's display or electronics. An analyte-specific catalyst can be used to aid in the reaction. The self-contained kits include all the equipment and supplies necessary to produce an analytical result.

Electrokinetic Separation
In electrokinetic separation, electrochemical and electrokinetic processes are used to desorb, and then remove, metals and polar organics. This in situ soil processing technology is primarily a separation and removal technique for extracting contaminants from soils. The principle of electrokinetic remediation relies upon application of a low-intensity direct current through the soil between ceramic electrodes that are separated into a cathode array and an anode array, mobilizing charged species and causing ions and water to move toward the electrodes. The current creates an acid front at the anode and a base front at the cathode. The generation of acidic condition in situ may help to mobilize sorbed metal contaminants to be transported to the collection system at the cathode.

Electromagnetic (EM) Geophysics
EM geophysics refers to technologies used to detect spatial (horizontal and vertical) differences in subsurface electromagnetic characteristics. The data collected provide information about subsurface environments.

Electromagnetic (EM) Induction
EM induction is a geophysical technology used to create a magnetic field beneath the earth's surface, which in turn causes a secondary magnetic field to form around nearby objects that have conductive properties, such as ferrous and nonferrous metals. The secondary magnetic field then is used to detect and measure buried debris.

Emergency Removal
An emergency removal is an action initiated in response to a release of a hazardous substance that requires on-site activity within hours of a determination that action is appropriate.

Emerging Technology
An emerging technology is an innovative technology that currently is undergoing bench-scale testing. During bench-scale testing, a small version of the technology is built and tested in a laboratory. If the technology is successful during bench-scale testing, it is demonstrated on a small scale at field sites. If the technology is successful at the field demonstrations, it often will be used full scale at contaminated waste sites. As the technology is used and evaluated at different sites, it is improved continually. *See also Established Technology and Innovative Technology.*

Enforcement Action
An enforcement action is an action undertaken by EPA under authority granted to it under various federal environmental statutes, such as CERCLA, RCRA, CAA, CWA, TSCA, and others. For example, under CERCLA, EPA may obtain voluntary settlement or compel potentially responsible parties (PRP) to implement removal or remedial actions when releases of hazardous substances have occurred. *See also Comprehensive Environmental Response, Compensation, and Liability Act; Potentially Responsible Party; and Removal Action.*

Engineered Control
An engineered control, such as barriers placed between a contaminated area and the rest of a site, is a method of managing environmental and health risks. Engineered controls can be used to limit exposure pathways.

Environmental Audit
An environmental audit usually refers to a review or investigation that determines whether an operating facility is in compliance with relevant environmental regulations. The audit may include checks for possession of required permits, operation within permit limits, proper reporting, and record keeping. The typical result is a corrective action or compliance plan for the facility.

Environmental Risk
Environmental risk is the chance that human health or the environment will suffer harm as the result of the presence of environmental hazards.

Environmental Site Assessment (ESA)
An ESA is the process that determines whether contamination is present at a site.

Established Technology
An established technology is a technology for which cost and performance information is readily available. Only after a technology has been used at many different sites and the results fully documented is that technology considered established. The most frequently used established technologies are incineration, solidification and stabilization, and pump-and-treat technologies for groundwater. *See also Emerging Technology and Innovative Technology.*

Exposure Pathway
An exposure pathway is the route of contaminants from the source of contamination to potential contact with a medium (air, soil, surface water, or groundwater) that represents a potential threat to human health or the environment. Determining whether exposure pathways exist is an essential step in conducting a baseline risk assessment. *See also Baseline Risk Assessment.*

Ex Situ
The term ex situ or "moved from its original place," means excavated or removed.

Ex Situ Bioremediation
Ex situ bioremediation uses microorganisms to degrade organic contaminants in excavated soil, sludge, and solids. The microorganisms break down contaminants by using them as a food source. The end products typically are carbon dioxide and water. Ex situ bioremediation includes slurry-phase bioremediation, in which the soils are mixed with water to form a slurry to keep solids suspended and microorganisms in contact with the soil contaminants; and solid-phase bioremediation, in which the soils are placed in a cell or building and tilled with added water and nutrients. Land farming and composting are types of solid-phase bioremediation.

Filtration
Filtration is a treatment process that removes solid matter from water by passing the water through a porous medium, such as sand or a manufactured filter.

Flame Ionization Detector (FID)
A FID is an instrument often used in conjunction with gas chromatography to measure the change of signal as analytes are ionized by a hydrogen-air flame. It also is used to detect phenols, phthalates, PAHs, VOCs, and petroleum hydrocarbons. *See also Portable Gas Chromatography.*

Fluid/Vapor Extraction
In fluid/vapor extraction, a high-vacuum system is applied to remove liquid and gas simultaneously from low-permeability or heterogeneous formations. The vacuum extraction well includes a screened section in the zone of contaminated soils and groundwater and is used to remove contaminants from above and below the water table. The system lowers the water table around the well, exposing more of the formation. Contaminants in the newly exposed vadose zone are then accessible for vapor extraction, which can remove contaminants more efficiently than pump-and-treat systems.

Fourier Transform Infrared Spectroscopy
A fourier transform infrared spectroscope is an analytical air monitoring tool that uses a laser system chemically to identify contaminants.

Fumigant
A fumigant is a pesticide that is vaporized to kill pests. They often are used in buildings and greenhouses.

Furan
Furan is a colorless, volatile liquid compound used in the synthesis of organic compounds, especially nylon.

Gas Chromatography
Gas chromatography is a technology used for investigating and assessing soil, water, and soil gas contamination at a site. It is used for the analysis of VOCs and SVOCs. The technique identifies and quantifies organic compounds on the basis of molecular weight, characteristic fragmentation patterns, and retention time. Recent advances in gas chromatography that are considered innovative are portable, weather-proof units that have self-contained power supplies.

Graphite Furnace Atomic Absorption (GFAA) Spectroscopy
Graphite furnace atomic absorption (GFAA) spectroscopy is a highly sensitive spectroscopic technique that provides excellent detection limits for measuring concentrations of metals in liquid sample media. Water samples may be analyzed directly, while soil samples first must undergo an extraction process to draw the contaminants into solution for analysis. The sample is vaporized in the graphite furnace, and light of a specific wavelength then is passed through the atomic vapor of an element of interest. The attenuation of the intensity of the light as a result of absorption is measured, and the amount of attenuation is converted into an estimate of the contaminant metal's concentration.

Ground-Penetrating Radar (GPR)
GPR is a technology that emits pulses of electromagnetic energy into the ground to measure its reflection and refraction by subsurface layers and other features, such as buried debris.

Groundwater
Groundwater is the water found beneath the earth's surface that fills pores between such materials as sand, soil, or gravel and that often supplies wells and springs. *See also Aquifer.*

Halogenated Organic Compound
A halogenated organic compound is a compound containing molecules of chlorine, bromine iodine, and fluorine. Halogenated organic compounds were used in high-voltage electrical transformers because they conducted heat well while being fire resistant and good electrical insulators. Many herbicides, pesticides, and degreasing agents are made from halogenated organic compounds.

Hazard Ranking System (HRS)
The HRS is the primary screening tool used by EPA to assess the risks posed to human health or the environment by abandoned or uncontrolled hazardous waste sites. Under the HRS, sites are assigned scores on the basis of the toxicity of hazardous substances that are present and the potential that those substances will spread through the air, surface, water, or groundwater, taking into account such factors as the proximity of the substance to nearby populations. Scores are used in determining which sites should be placed on the NPL. *See also National Priorities List.*

Hazardous Substance
As defined under CERCLA, a hazardous substance is any material that poses a threat to public health or the environment. The term also refers to hazardous wastes as defined under RCRA. Typical hazardous substances are materials that are toxic, corrosive, ignitable, explosive, or chemically reactive. If a certain quantity of a hazardous substance, as established by EPA, is spilled into the water or otherwise emitted into the environment, the release must be reported. Under the legislation cited above, the term excludes petroleum, crude oil, natural gas, natural gas liquids, or synthetic gas usable for fuel.

Hazardous and Solid Waste Amendments (HSWA)
HSWA are 1984 amendments to RCRA which required phasing out land disposal of hazardous waste and added minimum technology requirements. *See also Resource Conservation and Recovery Act.*

Heavy Metal
The term heavy metal refers to a group of toxic metals including arsenic, chromium, copper, lead, mercury, silver, and zinc. Heavy metals often are present at industrial sites at which operations have included battery recycling and metal plating.

Herbicide
A herbicide is a chemical pesticide designed to control or destroy plants, weeds, or grasses.

High-Frequency Electromagnetic (EM) Sounding
High-frequency EM sounding, the technology used for nonintrusive geophysical exploration, projects high-frequency electromagnetic radiation into subsurface layers to detect the reflection and refraction of the radiation by various layers of soil. Unlike ground-penetrating radar, which uses pulses, the technology uses continuous waves of radiation. *See also Ground-Penetrating Radar.*

Hot Air Injection
With hot air injection, hot air or steam is injected below the contaminated zones to heat contaminated soil. The heating enhances the release of contaminants from the soil matrix so they can be extracted and captured for further treatment and recycling.

Hydrazine
Hydrazine is a highly toxic liquid used in rocket propellant, agricultural chemicals, drugs, spandex fibers, antioxidants, plating metals on glass and plastic, explosives, and in boiler feedwater. The chemical compound causes a severe explosion hazard when exposed to heat.

Hydrocarbon
A hydrocarbon is an organic compound containing only hydrogen and carbon, often occurring in petroleum, natural gas, and coal.

Hydrogen Sulfide (HS)
HS is a gas emitted during decomposition of organic compounds. It also is a byproduct of oil refining and burning.

Hydrogeology
Hydrogeology is the study of groundwater, including its origin, occurrence, movement, and quality.

Hydrology
Hydrology is the science that deals with the properties, movement, and effects of water found on the earth's surface, in the soil and rocks beneath the surface, and in the atmosphere.

Ignitability
Ignitable wastes can create fires under certain conditions. Examples include liquids, such as solvents that readily catch fire, and friction-sensitive substances.

Immunoassay
Immunoassay is an innovative technology used to measure compound-specific reactions (generally colorimetric) to individual compounds or classes of compounds. The reactions are used to detect and quantify contaminants. The technology is available in field-portable test kits.

Incineration
Incineration is a treatment technology that involves the burning of certain types of solid, liquid, or gaseous materials under controlled conditions to destroy hazardous waste.

Infill Development
Infill development is new construction on previously developed land in cities or developed suburbs. The term often refers to redevelopment of small residential, commercial, or industrial properties. An important aspect of many infill development projects is the enhancement of the built environment with open space and parks.

Information Repository
An information repository is a location in a public building that is convenient for local residents, such as a public school, city hall, or library, that contains information about a Superfund site, including technical reports and reference documents.

Infrared Monitor
An infrared monitor is a device used to monitor the heat signature of an object, as well as to sample air. It may be used to detect buried objects in soil.

Inorganic Compound
An inorganic compound is a compound that generally does not contain carbon atoms (although carbonate and bicarbonate compounds are notable exceptions) and tends to be more soluble in water. Examples of inorganic compounds include various acids, potassium hydroxide, and metals.

Innovative Technology
An innovative technology is a process that has been tested and used as a treatment for hazardous waste or other contaminated materials, but lacks a long history of full-scale use and information about its cost and how well it works sufficient to support prediction of its performance under a variety of operating conditions. An innovative technology is one that is undergoing pilot-scale treatability studies that usually are conducted in the field or the laboratory and require installation of the technology, and provide performance, cost, and design objectives for the technology. Innovative technologies are being used under many federal and state cleanup programs to treat hazardous wastes that have been improperly released. For example, innovative technologies are being selected to manage contamination (primarily petroleum) at some leaking underground storage sites. *See also Emerging Technology and Established Technology.*

Ion Exchange
Ion exchange, a common method of softening water, depends on the ability of certain materials to remove and exchange ions from water. These ion exchange materials, generally composed of unsoluble organic polymers, are placed in a filtering device. Water softening exchange materials remove calcium and magnesium ions, replacing them with sodium ions.

Ionization
Ionization is the process which causes an atom to gain or lose electrons, which results in the atom having a negative or positive charge.

Insecticide
An insecticide is a pesticide compound specifically used to kill or control the growth of insects.

In Situ
The term in situ, "in its original place," or "on-site", means unexcavated and unmoved. In situ soil flushing and natural attenuation are examples of in situ treatment methods by which contaminated sites are treated without digging up or removing the contaminants.

In Situ Bioremediation
In situ bioremediation techniques stimulate and create a favorable environment for microorganisms to grow and use contaminants as a food and energy source. Generally, this means providing some combination of oxygen, nutrients, and moisture, and controlling the temperature and pH. Sometimes, microorganisms adapted for degradation of the specific contaminants are applied to enhance the process. Bioventing is a common form of in situ bioremediation. Bioventing uses extraction wells to circulate air with or without pumping air into the ground.

In Situ Oxidation
In situ oxidation is an innovative treatment technology that oxidizes contaminants that are dissolved in groundwater and converts them into insoluble compounds.

In Situ Soil Flushing
In situ soil flushing is an innovative treatment technology that floods contaminated soils beneath the ground surface with a solution that moves the contaminants to an area from which they can be removed. The technology requires the drilling of injection and extraction wells on site and reduces the need for excavation, handling, or transportation of hazardous substances. Contaminants considered for treatment by in situ soil flushing include heavy metals (such as lead, copper, and zinc), halogenated organic compounds, aromatics, and PCBs. *See also Aromatics, Halogenated Organic Compound, Heavy Metal, and Polychlorinated Biphenyl*.

In Situ Vitrification
In situ vitrification is a soil treatment technology that stabilizes metal and other inorganic contaminants in place at temperatures of approximately 3000°F. Soils and sludges are fused to form a stable glass and crystalline structure with very low leaching characteristics.

In Situ Well Aeration
For in situ well aeration, air is injected into a double screened well, allowing the VOCs in the contaminated groundwater to transfer from the dissolved phase to the vapor-phase by air bubbles. As the air bubbles rise to the water surface, the vapors are drawn off and treated by an SVE system.

Institutional Controls
An institutional control is a legal or institutional measure which subjects a property owner to limit activities at or access to a particular property. They are used to ensure protection of human health and the environment, and to expedite property reuse. Fences, posting or warning signs, and zoning and deed restrictions are examples of institutional controls.

Integrated Risk Information System (IRIS)
IRIS is an electronic database that contains EPA's latest descriptive and quantitative regulatory information about chemical constituents. Files on chemicals maintained in IRIS contain information related to both noncarcinogenic and carcinogenic health effects.

Joint and Several Liability
Under CERCLA, joint and several liability is a concept based on the theory that it may not be possible to apportion responsibility for the harm caused by hazardous waste equitably among potentially responsible parties (PRP). Joint liability means that more than one PRP is liable to the plaintiff. Several liability means that the plaintiff may choose to sue only one of the defendants and recover the entire amount. One PRP therefore can be held liable for the entire cost of cleanup, regardless of the share of waste that PRP contributed. Joint and several liability is used only when harm is indivisible. If defendants can apportion harm, there is no several liability. *See also Potentially Responsible Party and Strict Liability.*

Land Disposal Restrictions (LDR)
LDR is a RCRA program that restricts the land disposal of RCRA hazardous wastes and requires treatment to established treatment standards. LDRs may be an important ARAR for Superfund actions. *See also Applicable or Relevant and Appropriate Requirement and Resource Conservation and Recovery Act.*

Landfarming
Landfarming is the spreading and incorporation of wastes into the soil to initiate biological treatment.

Landfill
A sanitary landfill is a land disposal site for nonhazardous solid wastes at which the waste is spread in layers compacted to the smallest practical volume.

Laser-Induced Fluorescence/Cone Penetrometer
Laser-induced fluorescence/cone penetrometer is a field screening method that couples a fiber optic-based chemical sensor system to a cone penetrometer mounted on a truck. The technology can be used for investigating and assessing soil and water contamination.

Leachate
A leachate is a contaminated liquid that results when water collects contaminants as it trickles through wastes, agricultural pesticides, or fertilizers. Leaching may occur in farming areas and landfills and may be a means of the entry of hazardous substances into soil, surface water, or groundwater.

Lead
Lead is a heavy metal that is hazardous to health if breathed or swallowed. Its use in gasoline, paints, and plumbing compounds has been sharply restricted or eliminated by federal laws and regulations. *See also Heavy Metal.*

Leaking Underground Storage Tank (LUST)
LUST is the acronym for "leaking underground storage tank." *See also Underground Storage Tank.*

Light Nonaqueous Phase Liquid (LNAPL)
An LNAPL is one of a group of organic substances that are relatively insoluble in water and are less dense than water. LNAPLs, such as oil, tend to spread across the surface of the water table and form a layer on top of the water table.

Magnetrometry
Magnetrometry is a geophysical technology used to detect disruptions that metal objects cause in the earth's localized magnetic field.

Mass Spectrometry
Mass spectrometry is a method of chemical analysis in which the substance to be analyzed is heated and placed in a vacuum. The resulting vapor is exposed to a beam of electrons that causes ionization to occur, either of the molecules or their fragments. The ionized atoms are separated according to their mass and can be identified on that basis.

Mechanical Soil Aeration
Mechanical soil aeration agitates contaminated soil using tilling or other means to volatilize contaminants.

Medium
A medium is a specific environment–air, water, or soil–which is the subject of regulatory concern and activities.

Mercury
Mercury is a heavy metal that can accumulate in the environment and is highly toxic if breathed or swallowed. Mercury is a highly toxic substance found in thermometers, measuring devices, pharmaceutical and agricultural chemicals, chemical manufacturing, and electrical equipment. *See also Heavy Metal.*

Mercury Vapor Analyzer
A mercury vapor analyzer is an instrument that provides real-time measurements of concentrations of mercury in the air.

Methane
Methane is a colorless, nonpoisonous, flammable gas created by anaerobic decomposition of organic compounds.

Migration Pathway
A migration pathway is a potential path or route of contaminants from the source of contamination to contact with human populations or the environment. Migration pathways include air, surface water, groundwater, and land surface. The existence and identification of all potential migration pathways must be considered during assessment and characterization of a waste site.

Mixed Waste
Mixed waste is low-level radioactive waste contaminated with hazardous waste that is regulated under RCRA. Mixed waste can be disposed only in compliance with the requirements under RCRA that govern disposal of hazardous waste and with the RCRA land disposal restrictions, which require that waste be treated before it is disposed of in appropriate landfills.

Mobile Laboratory
A mobile laboratory refers to a collection of analytical instruments contained in a vehicle that can be deployed to a project site. A mobile laboratory offers many of the advantages of a fixed laboratory, such as protection from the elements, a power supply, and climate control, while still providing the advantages of analyzing samples on site while the project is in progress. A mobile laboratory may even allow the use of laboratory-grade instruments which otherwise could not be taken into the field. Configurations can vary in sophistication from a single instrument mounted in a sampling van, to large truck trailers and recreational vehicles equipped with multiple instruments and laboratory-grade support equipment.

Monitoring Well
A monitoring well is a well drilled at a specific location on or off a hazardous waste site at which groundwater can be sampled at selected depths and studied to determine the direction of groundwater flow and the types and quantities of contaminants present in the groundwater.

National Contingency Plan (NCP)
The NCP, formally the National Oil and Hazardous Substances Contingency Plan, is the major regulatory framework that guides the Superfund response effort. The NCP is a comprehensive body of regulations that outlines a step-by-step process for implementing Superfund responses and defines the roles and responsibilities of EPA, other federal agencies, states, private parties, and the communities in response to situations in which hazardous substances are released into the environment. *See also Superfund.*

National Pollutant Discharge Elimination System (NPDES)
NPDES is the primary permitting program under the Clean Water Act, which regulates all discharges to surface water. It prohibits discharge of pollutants into waters of the United States unless EPA, a state, or a tribal government issues a special permit to do so.

National Priorities List (NPL)
The NPL is EPA's list of the most serious uncontrolled or abandoned hazardous waste sites identified for possible long-term remedial response under Superfund. Inclusion of a site on the list is based primarily on the score the site receives under the HRS. Money from Superfund can be used for cleanup only at sites that are on the NPL. EPA is required to update the NPL at least once a year. *See also Hazard Ranking System and Superfund.*

National Response Center (NRC)
The NRC, staffed by the U.S. Coast Guard, is a communications center that receives reports of discharges or releases of hazardous substances into

the environment. The U.S. Coast Guard in turn, relays information about such releases to the appropriate federal agency.

Natural Attenuation
Natural attenuation is an approach to cleanup that uses natural processes to contain the spread of contamination from chemical spills and reduce the concentrations and amounts of pollutants in contaminated soil and groundwater. Natural subsurface processes, such as dilution, volatilization, biodegradation, adsorption, and chemical reactions with subsurface materials, are allowed to reduce concentrations of contaminants to acceptable levels. An in situ treatment method that leaves the contaminants in place while those processes occur, natural attenuation is being used to clean up petroleum contamination from LUSTs across the country.

Neutralization
Neutralization is a chemical reaction between an acid and a base. The reaction involves acidic or caustic wastes that are neutralized using caustic or acid additives.

Nitric Oxide
Nitric oxide is a gas formed by combustion under high temperature and high pressure in an internal combustion engine.

Nonaqueous Phase Liquid (NAPL)
NAPLs are organic substances that are relatively insoluble in water and are less dense than water. *See also Dense Nonaqueous Phase Liquid and Light Nonaqueous Phase Liquid.*

Non-Point Source
The term non-point source is used to identify sources of pollution that are diffuse and do not have a point of origin or that are not introduced into a receiving stream from a specific outlet. Common non-point sources are rain water, runoff from agricultural lands, industrial sites, parking lots, and timber operations, as well as escaping gases from pipes and fittings.

Operation and Maintenance (O&M)
O&M refers to the activities conducted at a site, following remedial actions, to ensure that the cleanup methods are working properly. O&M activities are conducted to maintain the effectiveness of the remedy and to ensure that no new threat to human health or the environment arises. Under the Superfund program, the state or PRP assumes responsibility for O&M, which may include such activities as groundwater and air monitoring, inspection and maintenance of the treatment equipment remaining on site, and maintenance of any security measures or institutional controls.

Organic Chemical or Compound
An organic chemical or compound is a substance produced by animals or plants that contains mainly carbon, hydrogen, and oxygen.

Ozone
Ozone is a form of oxygen found naturally which provides a protective layer in the stratosphere shielding the earth from the harmful health effects on human health and the environment from ultraviolet radiation. Ozone also is a chemical oxidant and a major component of smog in the troposphere, the earth's atmospheric layer below the stratosphere extending 7 to 10 miles from the earth's surface. Ozone within the troposphere can have a serious effect on the human respiratory system and is one of the most prevalent and widespread of all the criteria pollutants for which the Clean Air Act required EPA to set standards.

Pentachlorophenol (PCP)
PCP, a chemical compound containing carbon, chlorine, oxygen, and hydrogen, is a contaminant used in feed stock material and chemical manufacturing.

Performance-Based Measurement System (PBMS)
EPA defines PBMS as a set of processes through which the data needs or limitations of a program or project are specified and serve as criteria for selected appropriate methods to meet those needs in a cost-effective manner. EPA uses the term to convey what must be accomplished, but not prescriptively how to do it. The PBMS initiative places regulatory emphasis on obtaining analytical results that provide adequate information to support the regulatory decision, but leaves the choice of analytical procedures up to the user. The PBMS approach gives regulators and members of the regulated community increased flexibility in selecting technologies, while still meeting mandated monitoring requirements. The use of PBMS is intended to reduce barriers to the use of new monitoring technologies.

Permeability
Permeability is a characteristic that represents a qualitative description of the relative ease with which rock, soil, or sediment will transmit a fluid (liquid or gas).

Permeable Reactive Barriers
Permeable reactive barriers, also known as passive treatment walls, are installed across the flow path of a contaminated plume, allowing the water portion of the plume to flow through the wall. These barriers allow the passage of water while prohibiting the movement of contaminants by employing such agents as zero-valent metals, chelators, sorbents, and microbes. The contaminants are either degraded or retained in a concentrated form by the barrier material.

Pesticide
A pesticide is a substance or mixture of substances intended to prevent or mitigate infestation by, or destroy or repel, any pest. Pesticides can accumulate in the food chain and or contaminate the environment if misused.

Phase I Environmental Audit
A Phase I environmental audit is an initial environmental investigation that is limited to a historical records search to determine ownership of a site and to identify the kinds of chemical processes that were carried out at the site. A Phase I assessment includes a site visit, but does not include any sampling. If such an assessment identifies no significant concerns, Phase II and III audits are not necessary.

Phase II Environmental Audit
A Phase II environmental audit is an investigation that includes tests performed at the site to confirm the location and identity of environmental hazards. The assessment includes preparation of a report that includes recommendations for cleanup alternatives.

Phase III Environmental Audit
A Phase III environmental audit is the third step in the assessment that includes the removal of contaminated materials from a site and their legal disposal.

Phenols
A phenol is one of a group of organic compounds that are byproducts of petroleum refining, tanning, and textile, dye, and resin manufacturing. Low concentrations of phenols cause taste and odor problems in water; higher concentrations may be harmful to human health or the environment.

Photoionization Detector (PID)
A PID is a nondestructive detector, often used in conjunction with gas chromatography, that measures the change of signal as analytes are ionized by an ultraviolet lamp. The PID also is used to detect VOCs and petroleum hydrocarbons. *See also Portable Gas Chromatography.*

Physical Separation
Physical separation processes use different size sieves and screens to concentrate contaminants into smaller volumes. Most organic and inorganic contaminants tend to bind, either chemically or physically, to the fine fraction of the soil. Fine clay and silt particles are separated from the coarse sand and gravel soil particles to concentrate the contaminants into a smaller volume of soil that could then be further treated or disposed.

Phytoremediation
Phytoremediation is an innovative treatment technology that uses plants and trees to clean up contaminated soil and water. Plants can break down, or degrade, organic pollutants or stabilize metal contaminants by acting as filters or traps. Phytoremediation can be used to clean up metals, pesticides, solvents, explosives, crude oil, polyaromatic carbons, and landfill leachates. Its use generally is limited to sites at which concentrations of contaminants are relatively low and contamination is found in shallow soils, streams, and groundwater.

Plasma High-Temperature Metals Recovery
Plasma high-temperature metals recovery is a thermal treatment process that purges contaminants from solids and soils such as metal fumes and organic vapors. The vapors can be burned as fuel, and the metal fumes can be recovered and recycled. This innovative treatment technology is used to treat contaminated soil and groundwater.

Plume
A plume is a visible or measurable emission or discharge of a contaminant from a given point of origin into any medium. The term also is used to refer to measurable and potentially harmful radiation leaking from a damaged reactor.

Point Source
A point source is a stationary location or fixed facility from which pollutants are discharged or emitted or any single, identifiable discharge point of pollution, such as a pipe, ditch, or smokestack.

Polychlorinated Biphenyl (PCB)
PCBs are a group of toxic, persistent chemicals, produced by chlorination of biphenyl, that once were used in high voltage electrical transformers because they conducted

heat well while being fire resistant and good electrical insulators. These contaminants typically are generated from metal degreasing, printed circuit board cleaning, gasoline, and wood preserving processes. Further sale or use of PCBs was banned in 1979.

Polynuclear Aromatic Hydrocarbon (PAH)
A PAH is a chemical compound that contains more than one fused benzene ring. They are commonly found in petroleum fuels, coal products, and tar.

Potentially Responsible Party (PRP)
A PRP is an individual or company (such as owners, operators, transporters, or generators of hazardous waste) that is potentially responsible for, or contributing to, the contamination problems at a Superfund site. Whenever possible, EPA requires PRPs, through administrative and legal actions, to clean up hazardous waste sites they have contaminated. *See also Comprehensive Environmental Response, Compensation, and Liability Act and Superfund.*

Preliminary Assessment and Site Inspection (PA/SI)
A PA/SI is the process of collecting and reviewing available information about a known or suspected hazardous waste site or release. The PA/SI usually includes a visit to the site.

Presumptive Remedies
Presumptive remedies are preferred technologies for common categories of CERCLA sites that have been identified through historical patterns of remedy selection and EPA's scientific and engineering evaluation of performance data on technology implementation.

Pump and Treat
Pump and treat is a general term used to describe remediation methods that involve the pumping of groundwater to the surface for treatment. It is one of the most common methods of treating polluted aquifers and groundwater.

Quality Assurance (QA)
QA is a system of management activities that ensure that a process, item, or service is of the type and quality needed by the user. QA deals with setting policy and implementing an administrative system of management controls that cover planning, implementation, and review of data collection activities. QA is an important element of a quality system that ensures that all research design and performance, environmental monitoring and sampling, and other technical and reporting activities conducted by EPA are of the highest possible quality.

Quality Control (QC)
QC refers to scientific precautions, such as calibrations and duplications, that are necessary if data of known and adequate quality are to be acquired. QC is technical in nature and is implemented at the project level. Like QA, QC is an important element of a quality system that ensures that all research design and performance, environmental monitoring and sampling, and other technical and reporting activities conducted by EPA are of the highest possible quality.

Radioactive Waste
Radioactive waste is any waste that emits energy as rays, waves, or streams of energetic particles. Sources of such wastes include nuclear reactors, research institutions, and hospitals.

Radionuclide
A radionuclide is a radioactive element characterized according to its atomic mass and atomic number, which can be artificial or naturally occurring. Radionuclides have a long life as soil or water pollutants. Radionuclides cannot be destroyed or degraded; therefore, applicable technologies involve separation, concentration and volume reduction, immobilization, or vitrification. *See also Solidification and Stabilization.*

Radon
Radon is a colorless, naturally occurring, radioactive, inert gaseous element formed by radioactive decay of radium atoms. *See also Radioactive Waste and Radionuclide.*

RCRA Facility Assessment (RFA)
A RFA is performed at a facility to determine the existence of any continuous or non-continuous releases of wastes. During the RFA, EPA or state regulators gather information on solid waste management units and other areas of concern at RCRA facilities, evaluate this information to determine whether there are releases that warrant further investigation and action, and determine the need to proceed to a RCRA Facility Investigation. *See also Resource Conservation and Recovery Act.*

RCRA Facility Investigation (RFI)
The purpose of a RFI is to gather sufficient data at a facility to fully characterize the nature, extent, and rate of migration of contaminant releases identified in the RCRA Facility Assessment. The data generated during the RFI is used to determine the potential need for corrective measures and to aid in the selection and implementation of these measures. *See also Corrective Measure Study and Resource Conservation and Recovery Act.*

Reactivity
Reactive wastes are unstable under normal conditions. They can create explosions and or toxic fumes, gases, and vapors when mixed with water.

Record of Decision (ROD)
A ROD is a legal, technical, and public document that explains which cleanup alternative will be used at a Superfund NPL site. The ROD is based on information and technical analysis generated during the remedial investigation and feasibility study (RI/FS) and consideration of public comments and community concerns. *See also Preliminary Assessment and Site Investigation and Remedial Investigation and Feasibility Study.*

Release
A release is any spilling, leaking, pumping, pouring, emitting, emptying, discharging, injecting, leaching, dumping, or disposing into the environment of a hazardous or toxic chemical or extremely hazardous substance, as defined under RCRA. *See also Resource Conservation and Recovery Act.*

Remedial Design and Remedial Action (RD/RA)
The RD/RA is the step in the Superfund cleanup process that follows the RI/FS and selection of a remedy. An RD is the preparation of engineering plans and specifications to properly and effectively implement the remedy. The RA is the actual construction or implementation of the remedy. *See also Remedial Investigation and Feasibility Study.*

Remedial Investigation and Feasibility Study (RI/FS)
The RI/FS is the step in the Superfund cleanup process that is conducted to gather sufficient information to support the selection of a site remedy that will reduce or eliminate the risks associated with contamination at the site. The RI involves site characterization -- collection of data and information necessary to characterize the nature and extent of contamination at the site. The RI also determines whether the contamination presents a significant risk to human health or the environment. The FS focuses on the development of specific response alternatives for addressing contamination at a site.

Removal Action
A removal action usually is a short-term effort designed to stabilize or clean up a hazardous waste site that poses an immediate threat to human health or the environment. Removal actions include removing tanks or drums of hazardous substances that were found on the surface and installing drainage controls or security measures, such as a fence at the site. Removal actions also may be conducted to respond to accidental releases of hazardous substances. CERCLA places time and money constraints on the duration of removal actions. *See also Comprehensive Environmental Response, Compensation, and Liability Act.*

Reportable Quantity (RQ)
The RQ is the quantity of hazardous substances that, when released into the environment, can cause substantial endangerment to public health or the environment. Under CERCLA, the federal government must be notified when quantities equaling or exceeding RQs specified in regulations are released.

Resin
Resins are solids or semi-solids of plant origin used principally in lacquers, varnishes, inks, adhesives, synthetic plastics, and pharmaceuticals.

Resource Conservation and Recovery Act (RCRA)
RCRA is a federal law enacted in 1976 that established a regulatory system to track hazardous substances from their generation to their disposal. The law requires the use of safe and secure procedures in treating, transporting, storing, and disposing of hazardous substances. RCRA is designed to prevent the creation of new, uncontrolled hazardous waste sites.

Response Action
A response action is a short-term removal action or a long-term remedial response, authorized under CERCLA that is taken at a site to address releases of hazardous substances.

Risk-Based Corrective Action (RBCA)
As defined by EPA, RBCA is a streamlined approach through which exposure and risk assessment practices are integrated with traditional components of the corrective action process to ensure that appropriate and cost-effective remedies are selected and that limited resources are allocated properly . RBCA refers specifically to the standard *Guide for Risk-Based Corrective Action Applied At Petroleum Release Sites,* published by ASTM. The RBCA process can be tailored to applicable state and local laws and regulatory practices. *See also American Society for Testing and Materials.*

Risk Communication
Risk communication, the exchange of information about health or environmental risks among risk assessors, risk managers, the local community, news

media and interest groups, is the process of informing members of the local community about environmental risks associated with a site and the steps that are being taken to manage those risks.

Sanborn Map
A Sanborn map is a record kept for insurance purposes that shows, for a specific property, the locations of such items as USTs, buildings, and areas where chemicals have been used for certain industrial processes. A Phase I environmental audit includes a review of Sanborn maps. *See also Phase I Environmental Audit.*

Saturated Zone
The saturated zone is the area beneath the surface of the land in which all openings are filled with water.

Seismic Reflection and Refraction
Seismic reflection and refraction is a technology used to examine the geophysical features of soil and bedrock, such as debris, buried channels, and other features.

Semi-Volatile Organic Compound (SVOC)
SVOCs, composed primarily of carbon and hydrogen atoms, have boiling points greater than 200°C. Common SVOCs include PCBs and phenol. *See also Phenol and Polychlorinated Biphenyl.*

Significant Threat
The term refers to the level of contamination that a state would consider significant enough to warrant an action. The thresholds vary from state to state.

Sludge
Sludge is a semisolid residue from air or water treatment processes. Residues from treatment of metal wastes and the mixture of waste and soil at the bottom of a waste lagoon are examples of sludge, which can be a hazardous waste.

Slurry-Phase Bioremediation
Slurry-phase bioremediation, a treatment technology that can be used alone or in conjunction with other biological, chemical, and physical treatments, is a process through which organic contaminants are converted to innocuous compounds. Slurry-phase bioremediation can be effective in treating various SVOCs and nonvolatile organic compounds, as well as fuels, creosote, PCPs, and PCBs.

Soil Boring
Soil boring is a process by which a soil sample is extracted from the ground for chemical, biological, and analytical testing to determine the level of contamination present.

Soil Flushing
In soil flushing, large volumes of water, at times supplemented with treatment compounds, are applied to the soil or injected into the groundwater to raise the water table into the zone of contaminated soil. Contaminants are leached into the groundwater, and the extraction fluids are recovered from the underlying aquifer. When possible, the fluids are recycled.

Soil Gas
Soil gas consists of gaseous elements and compounds that occur in the small spaces between particles of the earth and soil. Such gases can move through or leave the soil or rock, depending on changes in pressure.

Soil Vapor Extraction (SVE)
SVE, the most frequently selected innovative treatment at Superfund sites, is a process that physically separates contaminants from soil in a vapor form by exerting a vacuum through the soil formation. SVE removes VOCs and some SVOCs from soil beneath the ground surface.

Soil Washing
Soil washing is an innovative treatment technology that uses liquids (usually water, sometimes combined with chemical additives) and a mechanical process to scrub soils, removes hazardous contaminants, and concentrates the contaminants into a smaller volume. The technology is used to treat a wide range of contaminants, such as metals, gasoline, fuel oils, and pesticides. Soil washing is a relatively low-cost alternative for separating waste and minimizing volume as necessary to facilitate subsequent treatment. It is often used in combination with other treatment technologies. The technology can be brought to the site, thereby eliminating the need to transport hazardous wastes.

Solidification and Stabilization
Solidification and stabilization are the processes of removing wastewater from a waste or changing it chemically to make the waste less permeable and susceptible to transport by water. Solidification and stabilization technologies can immobilize many heavy metals, certain radionuclides, and selected organic compounds, while decreasing the surface area and

permeability of many types of sludge, contaminated soils, and solid wastes.

Solvent
A solvent is a substance, usually liquid, that is capable of dissolving or dispersing one or more other substances.

Solvent Extraction
Solvent extraction is an innovative treatment technology that uses a solvent to separate or remove hazardous organic contaminants from oily-type wastes, soils, sludges, and sediments. The technology does not destroy contaminants, but concentrates them so they can be recycled or destroyed more easily by another technology. Solvent extraction has been shown to be effective in treating sediments, sludges, and soils that contain primarily organic contaminants, such as PCBs, VOCs, halogenated organic compounds, and petroleum wastes. Such contaminants typically are generated from metal degreasing, printed circuit board cleaning, gasoline, and wood preserving processes. Solvent extraction is a transportable technology that can be brought to the site. *See also Halogenated Organic Compound, Polychlorinated Biphenyl, and Volatile Organic Compound.*

Strict Liability
Strict liability is a concept under CERCLA that empowers the federal government to hold PRPs liable without proving that the PRPs were at fault and without regard to a PRP's motive. PRPs can be found liable even if the problems caused by the release of a hazardous substance were unforeseeable, the PRPs acted in good faith, and state-of-the-art hazardous waste management practices were used at the time the materials were disposed of. *See also Potentially Responsible Party.*

Subsurface
Underground; beneath the surface.

Surfactant Flushing
Surfactant flushing is an innovative treatment technology used to treat contaminated groundwater. Surfactant flushing of NAPLs increases the solubility and mobility of the contaminants in water so that the NAPLs can be biodegraded more easily in an aquifer or recovered for treatment aboveground. *See also Nonaqueous Phase Liquid.*

Surface Water
Surface water is all water naturally open to the atmosphere, such as rivers, lakes, reservoirs, streams, and seas.

Superfund
Superfund is the trust fund that provides for the cleanup of hazardous substances released into the environment, regardless of fault. The Superfund was established under CERCLA and subsequent amendments to CERCLA. The term Superfund also is used to refer to cleanup programs designed and conducted under CERCLA and its subsequent amendments. *See also Comprehensive Environmental Response, Compensation, and Liability Act.*

Superfund Amendment and Reauthorization Act (SARA)
SARA is the 1986 act amending CERCLA that increased the size of the Superfund trust fund and established a preference for the development and use of permanent remedies, and provided new enforcement and settlement tools. *See also Comprehensive Environmental Response, Compensation, and Liability Act.*

Superfund Innovative Technology Evaluation (SITE) Program
The SITE program is an effort established by EPA in 1986 to advance the development, evaluation, and commercialization of innovative treatment technologies for assessing and cleaning up hazardous waste sites. The program provides an opportunity for technology developers to demonstrate their technologies' ability to successfully process and remediate hazardous waste. The SITE program has four components—the Emerging Technology Program, the Demonstration Program, the Monitoring and Measurement Technologies Program, and the Technology Transfer Program.

Test Methods for Evaluating Waste, Physical/ Chemical Methods (SW-846)
SW-846 refers to an EPA guidance and reference document, *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*, which is intended to assist analytical chemists and other users in the RCRA and Superfund programs by suggesting procedures that analysts have found to be successful when applied to typical samples. The SW-846 methods are analytical and sampling methods that have been evaluated and approved for use in complying with RCRA regulations. The methods are not intended to be prescriptive, nor are all technologies or methods that may be used identified.

Thermal Desorption
Thermal desorption is an innovative treatment technology that heats soils contaminated with hazardous wastes to temperatures from 200 to 1,000°F so that contaminants that have low boiling points will vaporize and separate from the soil. The vaporized contaminants then are collected for further treatment or destruction, typically by an air emissions treatment system. The technology is most effective at treating VOCs, SVOCs and other organic contaminants, such as PCBs, PAHs, and pesticides. It is effective in separating organics from refining wastes, coal tar wastes, waste from wood treatment, and paint wastes. It also can separate solvents, pesticides, PCBs, dioxins, and fuel oils from contaminated soil. *See also Polyaromatic Hydrocarbon, Polychlorinated Biphenyl, Semivolatile Organic Compound, and Volatile Organic Compound*.

Toluene
Toluene is a colorless liquid chemical with a sweet, strong odor. It is used as a solvent in aviation gasoline and in making other chemicals, perfumes, medicines, dyes, explosives, and detergents.

Total Petroleum Hydrocarbon (TPH)
TPH refers to a measure of concentration or mass of petroleum hydrocarbon constituents present in a given amount of air, soil, or water.

Toxicity
Toxicity is a quantification of the degree of danger posed by a substance to animal or plant life.

Toxicity Characteristic Leaching Procedure (TCLP)
The TCLP is a testing procedure used to identify the toxicity of wastes and is the most commonly used test for degree of mobilization offered by a solidification and stabilization process. Under this procedure, a waste is subjected to a process designed to model the leaching effects that would occur if the waste was disposed of in a RCRA Subtitle D municipal landfill. *See also Solidification and Stabilization.*

Toxic Substance
A toxic substance is a chemical or mixture that may present an unreasonable risk of injury to health or the environment.

Toxic Substances Control Act (TSCA)
TSCA was enacted in 1976 to test, regulate, and screen all chemicals produced or imported into the U.S. TSCA requires that any chemical that reaches the consumer marketplace be tested for possible toxic effects prior to commercial manufacture. Any existing chemical that poses health and environmental hazards is tracked and reported under TSCA.

Treatment, Storage, and Disposal Facility (TSD)
TSDs are sites at which hazardous substances are treated, stored, or disposed. TSD facilities are regulated by EPA and states under RCRA. *See also Resource Conservation and Recovery Act.*

Treatment Wall (also Passive Treatment Wall)
A treatment wall is a structure installed underground to treat contaminated groundwater found at hazardous waste sites. Treatment walls, also called passive treatment walls, are put in place by constructing a giant trench across the flow path of contaminated groundwater and filling the trench with one of a variety of materials carefully selected for the ability to clean up specific types of contaminants. As the contaminated groundwater passes through the treatment wall, the contaminants are trapped by the treatment wall or transformed into harmless substances that flow out of the wall. The major advantage of using treatment walls is that they are passive systems that treat the contaminants in place so the property can be put to productive use while it is being cleaned up. Treatment walls are useful at some sites contaminated with chlorinated solvents, metals, or radioactive contaminants.

Trichloroethylene (TCE)
TCE is a stable, low-boiling colorless liquid that is used as a solvent, metal degreasing agent, and in other industrial applications.

Underground Storage Tank (UST)
USTs are tanks located entirely or partially underground that are designed to hold gasoline or other petroleum products or chemical solutions.

Unsaturated Zone
The unsaturated zone is the area between the land surface and the uppermost aquifer (or saturated zone). The soils in an unsaturated zone may contain air and water.

Vadose Zone
The vadose zone is the area between the surface of the land and the surface of the water table in which the moisture content is less than the saturation point and the pressure is less than atmospheric. The openings (pore spaces) also typically contain air or other gases.

Vapor
Vapor is the gaseous phase of any substance that is liquid or solid at atmospheric temperatures and pressures. Steam is an example of a vapor.

Vitrification
Vitrification uses an electric current to melt contaminated soil at elevated temperatures (1,600 to 2,000ºC or 2,900 to 3,650ºF). The vitrification product is a chemically stable, leach-resistant, glass and crystalline material similar to obsidian or basalt rock. The process destroys and/or removes organic materials. Radionuclides and heavy metals are retained within the vitrified product.

Volatile Organic Compound (VOC)
A VOC is one of a group of carbon-containing compounds that evaporate readily at room temperature. Examples of VOCs include trichloroethane; trichloroethylene; and BTEX. These contaminants typically are generated from metal degreasing, printed circuit board cleaning, gasoline, and wood preserving processes.

Volatilization
Volatilization is the process of transfer of a chemical from the aqueous or liquid phase to the gas phase. Solubility, molecular weight, and vapor pressure of the liquid and the nature of the gas-liquid affect the rate of volatilization.

Voltammetric Stripping
Voltammetric stripping is a field-portable technology that uses electrochemistry to detect and quantify metals in environmental samples. Specific metals can be targeted for detection and quantification by the technology, which generally is applied to water samples.

Voluntary Cleanup Program (VCP)
A VCP is a formal means established by many states to facilitate assessment, cleanup, and redevelopment of brownfields sites. VCPs typically address the identification and cleanup of potentially contaminated sites that are not on the Superfund NPL. Under VCPs, owners or developers of a site are encouraged to approach the state voluntarily to work out a process by which the site can be readied for development. Many state VCPs provide technical assistance, liability assurances, and funding support for such efforts. *See also National Priorities List.*

Wastewater
Wastewater is spent or used water from an individual home, a community, a farm, or an industry that contains dissolved or suspended matter.

Water Table
A water table is the boundary between the saturated and unsaturated zones beneath the surface of the earth, the level of groundwater, and generally is the level to which water will rise in a well. *See also Aquifer and Groundwater.*

X-Ray Fluorescence Analyzer
An x-ray fluorescence analyzer is a self-contained, field-portable instrument, consisting of an energy dispersive x-ray source, a detector, and a data processing system that detects and quantifies individual metals or groups of metals.

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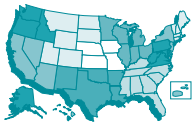
APPENDIX C

Appendix C

LIST OF BROWNFIELDS AND TECHNICAL SUPPORT CONTACTS

The lists included in this appendix identify contacts at the state and EPA regional levels, as well as EPA technical support staff in the Technology Innovation Office and the Office of Research and Development. The individuals are available to assist cleanup and redevelopment efforts at brownfields sites.



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EPA REGIONAL BROWNFIELDS COORDINATORS

REGION 1

Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont

<http://www.epa.gov/region01/remed/brnfld/>

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One Congress Street
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REGION 2

New Jersey, New York, Puerto Rico, Virgin Islands

<http://www.epa.gov/r02earth/superfnd/brownfld/bfmainpg.htm>

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290 Broadway
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REGION 3

Delaware, Washington, D.C., Maryland, Pennsylvania, Virginia, West Virginia

<http://www.epa.gov/reg3hwmd/brownfld/hmpage1.htm>

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MC 3HS 33
1650 Arch Street
Philadelphia, PA 19103
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E-mail: stolle.tom@epa.gov

REGION 4

Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee

<http://www.epa.gov/region4/wastepgs/brownfpgs/bf.htm>

Mickey Hartnett
U.S. EPA
Region 4
61 Forsyth Street
Atlanta, GA 30303
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Fax: (404) 562-8628
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REGION 5

Illinois, Indiana, Michigan, Minnesota, Ohio, Wisconsin

<http://www.epa.gov/R5Brownfields/>

Joe Dufficy
U.S. EPA
Region 5
77 West Jackson Boulevard
Chicago, IL 60604-3507
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REGION 6

Arkansas, Louisiana, New Mexico, Oklahoma, Texas

<http://www.epa.gov/earth1r6/6sf/bfpages/sfbfhome.htm>

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MC 6SF-P
1445 Ross Avenue, Suite 1200
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Fax: (214) 665-6660
E-mail: hitt.stan@epa.gov

REGION 7

Iowa, Kansas, Missouri, Nebraska

<http://www.epa.gov/region07/specinit/brown/brownfields.htm>

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REGION 8

Colorado, Montana, North Dakota, South Dakota, Utah, Wyoming

<http://www.epa.gov/region08/cross/brown/brownf.html>

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REGION 9

Arizona, California, Hawaii, Nevada, American Samoa, Guam

<http://www.epa.gov/region09/waste/brown/index.html>

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REGION 10

Alaska, Idaho, Oregon, Washington

<http://epainotes1.rtpnc.epa.gov:7777/r10/cleanup.nsf/webpage/Brownfields>

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REGULATORY INFORMATION

See page C-7 for information about EPA regional points of contact.

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BROWNFIELDS TECHNOLOGY SUPPORT CENTER

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EPA Contact: Dan Powell
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U.S. EPA
Phone: (703) 603-7196

APPENDIX D

Appendix D

HOW TO ORDER DOCUMENTS

Many of the EPA publications identified in this document are available through EPA's National Service Center for Environmental Publications (NSCEP). NSCEP is a central repository for all EPA documents, with more than 5,500 titles in paper and electronic format. The documents are available free of charge, but supplies may be limited. You may order one copy each of as many as five documents within any two-week period. Documents may be ordered on line, by telephone, by facsimile, or by using the order form provided on the following page. Please include the EPA document numbers of all publications ordered.

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5285 Port Royal Road
Springfield, VA 22161
Telephone: (703) 605-6000
Fax: (703) 605-6900
E-mail: orders@ntis.fedworld.gov
WWW: *http://www.ntis.gov*

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