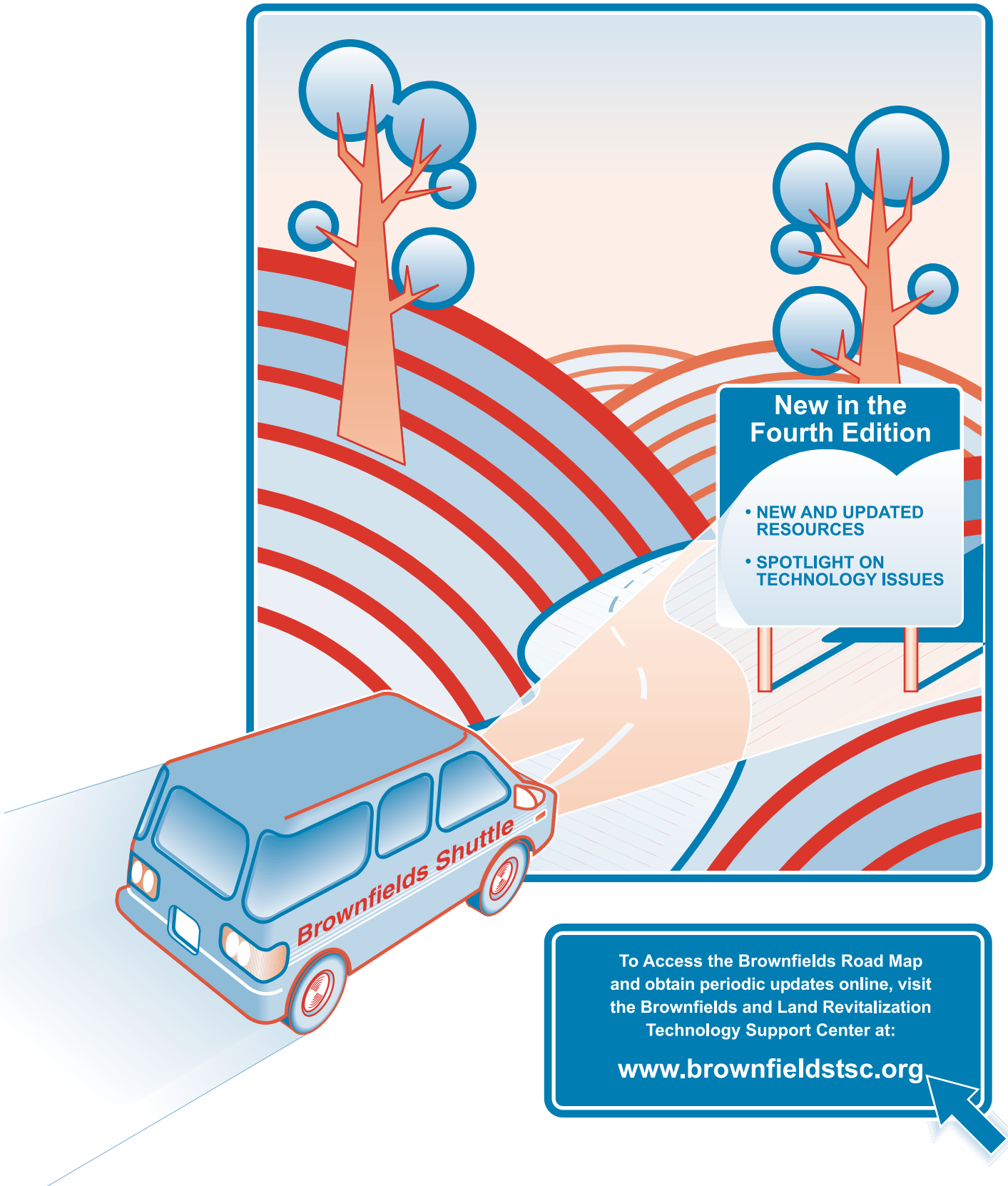
Road Map to Understanding Innovative Technology Options for Brownfields Investigation and Cleanup, Fourth Edition



To Access the Brownfields Road Map and obtain periodic updates online, visit the Brownfields and Land Revitalization Technology Support Center at:

www.brownfieldstsc.org

September 2005
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ROAD MAP TO UNDERSTANDING INNOVATIVE TECHNOLOGY OPTIONS FOR BROWNFIELDS INVESTIGATION AND CLEANUP, FOURTH EDITION

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

NOTICE

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ACKNOWLEDGMENTS

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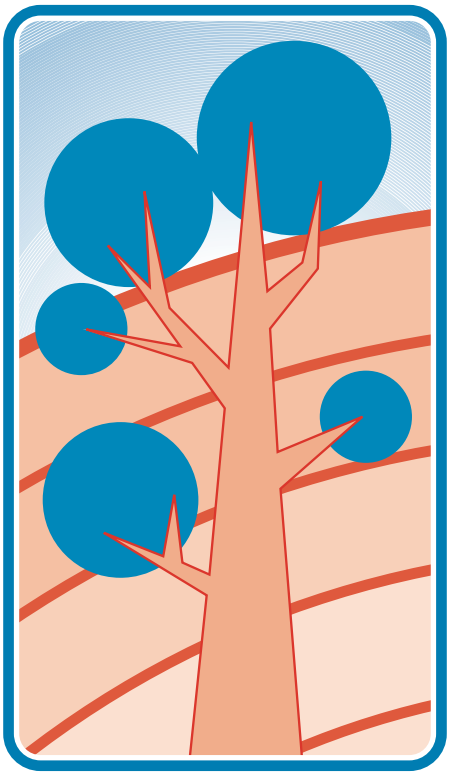
BACKGROUND

Section 101 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) defines brownfields sites as "real property, the expansion, redevelopment, or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant, or contaminant."

The U.S. Environmental Protection Agency (EPA) established its Brownfields Economic Revitalization Initiative to empower states, communities, and other stakeholders in economic revitalization to work together to accomplish the redevelopment of brownfields sites. With the enactment of the Small Business Liability Relief and Brownfields Revitalization Act in 2002, EPA assistance was expanded to provide greater support for brownfields cleanup and reuse (see the inset box on page 2). Many states and local jurisdictions also help businesses and communities adapt environmental cleanup programs to the special needs of brownfields sites.



Preparing brownfields sites for productive reuse requires 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 these 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 properties are transferred to new owners. At other sites, cleanup may take place simultaneously with construction and redevelopment activities.

Regardless of when and how cleanups are accomplished, the challenge to any brownfields program is to clean up sites in accordance with redevelopment goals. Such goals may include cost-effectiveness, timeliness, avoidance of adverse effects to site structures and neighboring communities, and redevelopment of land in a way that benefits communities and local economies.

Regulators and site managers are increasingly recognizing the value of implementing a more dynamic approach to streamline assessment and cleanup activities at brownfields sites. This approach, referred to as the Triad, is flexible and recognizes site-specific decisions and data needs.

Small Business Liability Relief and Brownfields Revitalization Act

Since its inception in 1995, EPA's Brownfields Program has grown into a proven, result-oriented initiative that has changed the way contaminated property is perceived, addressed, and managed. Through passage of the Small Business Liability Relief and Brownfields Revitalization Act (Public Law 107-118; H.R. 2869) in January 2002, effective policies that EPA had developed over the years were passed into law. The Brownfields Law expanded EPA's assistance by providing new tools that the public and private sectors could use to promote sustainable brownfields cleanup and reuse.

The law modified EPA's existing brownfields grants and technical assistance program by:

- Increasing the funding authority up to $200 million per year
- Providing grants for assessments, revolving loan funds, direct cleanups, and job training
- Expanding the entities, properties, and activities eligible for brownfields grants
- Expanding the Brownfields Program's applicability to sites with petroleum contamination such as abandoned gasoline stations
- Providing authority for brownfields training, research, and technical assistance
- Allowing up to 10 percent of the grant funds to be used to monitor the health of exposed populations and enforce any instutional controls

Brownfields grants continue to serve as the foundation of EPA's Brownfields Program by funding environmental assessment, cleanup, and job training activities. Brownfields Assessment Grants provide funding for brownfields inventories, planning, environmental assessments, and community outreach. Brownfields Revolving Loan Fund Grants provide funding to capitalize loans that are used to clean up brownfields sites. Brownfields Job Training Grants provide environmental training for residents of brownfields communities. Brownfields Cleanup Grants provide direct funding for cleanup activities at certain properties with planned green space, recreational, or other nonprofit uses.

The law changed and clarified Superfund liability:

- Clarified Superfund liability for prospective purchasers, innocent landowners, and contiguous property owners
- Provided liability protection for certain small-volume waste contributors and contributors of municipal solid waste

The law created a strong, balanced relationship between the federal government and state and tribal programs:

- Authorized up to $50 million per year for building and enhancing state and tribal response programs and expanded the activities eligible for funding
- Provided protection from Superfund liability at sites cleaned up under a state program
- Preserved the federal safety net by detailing the circumstances in which EPA can revisit a cleanup
- Clarified the state role in adding sites to the Superfund National Priorities List (NPL)

EPA's investment in the Brownfields Program has resulted in many accomplishments, and the momentum generated by the program is leaving an enduring legacy. EPA's Brownfields Program continues to look to the future by expanding the types of properties it addresses, forming new partnerships, and undertaking new initiatives to help revitalize communities across the nation. Additional information on the Brownfields Law is available at ***www.epa.gov/brownfields/sblrbra.htm***.

The Triad approach focuses on management of decision uncertainty by incorporating (1) systematic project planning; (2) dynamic work planning strategies; and (3) use of real-time measurement technologies, including innovative technologies, to accelerate and improve the cleanup process. The Triad approach can reduce costs, improve decision certainty, expedite site closeout, and positively affect regulatory and community acceptance. This approach is well aligned with brownfields site priorities, which are affected by the economics of redevelopment, community involvement, and liability considerations.

Numerous technology options are available to assist those involved in brownfields cleanup. EPA's Office of Superfund Remediation and Technology Innovation (OSRTI) encourages use of smarter solutions for characterizing and cleaning up contaminated sites by advocating more effective, less costly technological approaches. Use of innovative technologies to characterize and clean up brownfields sites provides opportunities for stakeholders to reduce cleanup costs and accelerate cleanup schedules. Often, innovative approaches are also more acceptable to communities.

EPA defines an innovative technology as one that has been used in the field but that does not yet have a long history of full-scale use. In addition, data about the cost and performance of innovative technologies may not be sufficient to encourage decision-makers to select those technologies over established technologies. A primary area of interest to EPA is documenting and disseminating information about the cost and performance of innovative technologies. EPA, through its work with the Federal Remediation Technologies Roundtable (FRTR), has seen significant progress in this area. Innovative technologies are being used in many cleanup programs to assess contamination and to clean up sites.

Comprehensive information about the range of innovative technologies and their use as well as technical expertise pertinent to them, is available from EPA's Brownfields and Land Revitalization Technology Support Center (BTSC). The BTSC is coordinated through OSRTI and is supported by EPA's Office of Research and Development (ORD). The center works closely with EPA's Office of Brownfields Cleanup and Redevelopment and in partnership with the U.S. Army Corps of Engineers (USACE) and Argonne National Laboratory (ANL). Established in 1999 as a pilot program, the BTSC 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 for communities, and providing demonstration support (see page 14 for more information about the BTSC).

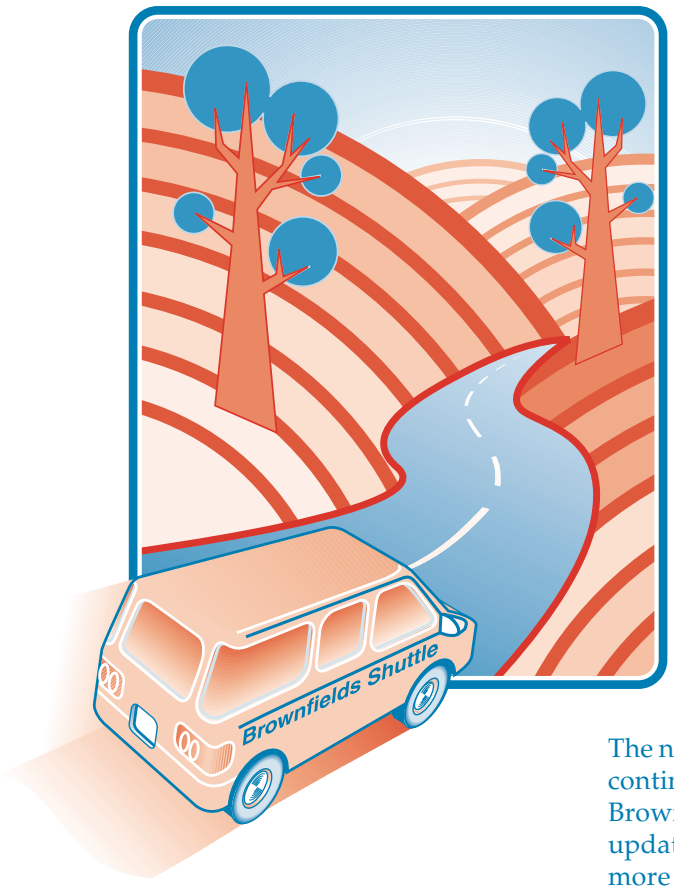
An **emerging technology** is an innovative technology that is currently undergoing bench-scale testing in which a small version of the technology is tested in a laboratory.

An **innovative technology** is a technology that has been field-tested and applied to a hazardous waste problem at a site but that 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 have been fully documented is that technology considered to be established.

INTRODUCTION

The "Road Map to Understanding Innovative Technology Options for Brownfields Investigation and Cleanup," Fourth Edition, includes new and updated resources to assist in identification and selection of innovative site characterization and cleanup technologies for brownfields redevelopment. The Road Map provides a general outline of the steps in the investigation and 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 provides valuable information for a wide range of stakeholders involved in or affected by redevelopment of brownfields sites, whether through public projects, private developments, or public-private partnerships. The Fourth Edition has been expanded significantly to include new and updated resources and supplemental information.



The First Edition of the Road Map, which was published in 1997, provided a broad overview of EPA's Brownfields Program and an outline of the steps involved in the cleanup of a brownfields site. Designed primarily for stakeholders who were unfamiliar with the elements of cleaning up a brownfields site, the Road Map built awareness of the advantages offered by innovative technologies. As the Brownfields Program matured, the Second and Third Editions were published in 1999 and 2001, respectively, to update information and resources associated with the program and innovative technologies. Those editions were accompanied by a CD-ROM to provide easier access to the wide range of information and resources included in the Road Map.

The new Fourth Edition has been developed to continue to serve audiences who are new to the Brownfields Program as well as provide new and updated technical information to audiences with more experience and technical qualifications. Updated with 71 new resources and one-page descriptions of technologies, processes, and initiatives that affect the consideration and use of innovative technologies, the newest edition of the Road Map will help:

- New and less experienced stakeholders learn about EPA's Brownfields Program and site cleanup in general.
- Decision-makers who are familiar with the Brownfields Program but are also interested in obtaining more detailed information about

technologies. The Road Map provides these users with up-to-date information about the applicability of innovative technologies and ready access to the latest resources that can assist them in making their technology decisions.

- Stakeholders who hire or oversee site cleanup professionals (such as environmental consultants, cleanup contractors, technology vendors, or analytical laboratories). The Road Map provides these stakeholders with a detailed understanding of the different phases of cleanup of a brownfields site and presents information about the role that cleanup professionals play in the process and about how to encourage consideration of use of innovative technologies.
- Regulators by increasing their understanding of the advantages that innovative technologies and approaches may provide throughout the cleanup process. The Road Map also serves as a resource that regulators can use to provide site owners, service providers, and other stakeholders with useful information about the Brownfields Program.
- Community members by providing information about the general site cleanup process as well as guidelines and mechanisms that ensure that they are involved in the decision-making process.
- Other stakeholders, such as financial institutions and insurance agencies, by providing information for their use in assessing and minimizing the risk associated with brownfields redevelopment.

It is important to understand that the site characterization and cleanup process may not occur in the sequence outlined in the following sections. At many sites, several activities may be undertaken concurrently, and some steps may recur throughout the process. For example, many technologies that are used for characterizing sites during the preliminary phases of a brownfields project may be appropriate for use in later stages of a site cleanup. Understanding the logical progression of the process is crucial to ensuring that the proper groundwork is laid for future phases and in determining whether activities can be combined or implemented concurrently.

The Road Map is not an official guidance document. Rather, it draws upon EPA's experiences with brownfields and 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 amounts 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.

New in the Fourth Edition

- Addition of 71 new resources identified with a "new resource" icon
- Updates of 18 resources identified with an "updated resource" icon
- Removal of approximately 40 resources that have been discontinued or are no longer available
- Updates and additions to the one-page spotlights on specific topics that identify and describe key technologies, processes, and initiatives that affect the use and consideration of innovative technologies at brownfields sites
- Updates to programmatic information and organizational changes resulting from the passage of the Small Business Liability Relief and Brownfields Revitalization Act
- Revision of Appendix A to provide additional information about typical contaminants found at brownfields sites and the technologies used to investigate and remediate these sites
- Expansion of Appendix B, List of Acronyms and Glossary of Key Terms
- Updates to brownfields and technical support contacts identified in Appendix C
- Updates to document ordering information included in Appendix D
- Elimination of the Road Map CD-Rom. With improved Internet access and the opportunity to provide more frequent updates, all publications and links are available online at ***www.brownfieldstsc.org***

How to Submit Comments

EPA invites comments from the members of the brownfields community to help ensure that any future versions of the Road Map meet their needs. Please submit comments to:

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Washington, DC 20460
E-mail: powell.dan@epa.gov
Telephone: (703) 603-7196

How to Obtain Additional Copies

Portable document format (pdf) and HTML versions of the Road Map are available for viewing or downloading at the Brownfields and Land Revitalization Technology Support Center Web site at ***www.brownfieldstsc.org***. A printed or hard copy version can also be ordered directly from that site.

If you do not have access to the Internet, a printed or hard copy version of this document can be obtained from the following source:

National Service Center for
Environmental Publications
U.S. Environmental Protection Agency
P.O. Box 42419
Cincinnati, OH 45242-0419
Telephone: (800) 490-9198 or (513) 489-8190
Fax: (513) 489-8695

When ordering the Road Map, refer to document number EPA 542-B-05-001.

How to Use the Road Map

The Road Map and the resources described in it have been organized into sections corresponding to the general phases of site characterization and cleanup, from early planning through implementation of the remedy.

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

The remaining four sections of the Road Map summarize the general phases of the characterization and cleanup of potentially contaminated sites: **Site Assessment**, **Site Investigation**, **Assessment of Cleanup Options**, and **Cleanup Design and Implementation**. Each section:

- Describes the objectives to be accomplished
- Outlines the key questions to be answered
- Summarizes the activities to be undertaken
- Lists information resources available to assist in selecting technologies. Within each section, the resources are listed in alphabetical order in three categories:
  - **A. Technology resources relevant to the phase** provide general information about technologies and their application in the four phases delineated in the Road Map.
  - **B. Site-specific resources** provide information about the application of innovative technologies to specific contaminants and site types.
  - **C. Technology-specific resources** present detailed information about specific technologies and their application to specific contaminants and media.
- Indicates specific actions to be taken at the completion of the phase

The graphic on page 18 provides an overview of the general phases of the site characterization and cleanup process, identifies some of the factors and questions potentially affecting the course of the process, and directs users to relevant sections of the Road Map.

• Before You Begin • Site Assessment • Site Investigation • Cleanup Options • Cleanup Design and Implementation

Resources: Components of Each Entry

Title of resource

Publication number

Title of resource

This icon denotes resources newly included in the Fourth Edition.

This icon denotes resources updated in the Fourth Edition.

Clarifying DQO Terminology Usage to Support Modernization of Site Cleanup Practices (EPA 542-R-01-014)

This report, which was developed by EPA, addresses the need to clarify DQO terminology use in order to support modernization of environmental restoration activities. The document presents a basic conceptual understanding of DQO-related terms in a way that facilitates systematic project planning in the context of site cleanups. A list of descriptions of DQO-related terms and concepts appears first in the report, followed by a more detailed discussion of the interrelationships among the concepts.

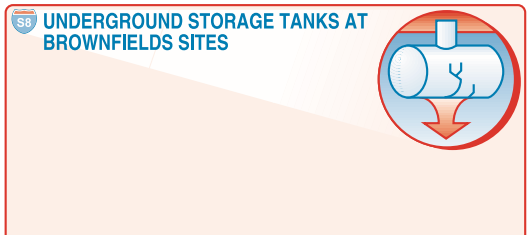
ASTM Standard Guide for Environmental Site Assessments: Phase II Environmental Site Assessment Process (E1903-97(2002))

Developed by ASTM, the guide discusses a framework for employing good commercial and customary practices in the United States during 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 guide, which is available at a cost, can be ordered online at *www.astm.org*.

Description of the resource

** Please note that in the Fourth Edition, the information about where to download the resource is no longer included with the entry. All resources may be accessed through *www.brownfieldstsc.org*

The Road Map is intended to identify and answer questions related to selection of technologies rather than questions related to other brownfields issues. Please note that the key questions and discussions of activities to be conducted are intended to guide the reader in identifying issues that should be addressed. To serve as guideposts in the cleanup process, the questions take the point of view of the various groups involved in the process. The questions ask what stakeholders as a group working together—the"we" of each question—must do as assessment and cleanup progress.



Spotlights

Like the previous edition, this edition of the Road Map includes brief descriptions that "spotlight" key technologies, processes, and initiatives that affect the use and consideration of innovative technologies for the characterization and cleanup of brownfields sites. The spotlights are included in the sections of the Road Map that are most relevant. Each spotlight also includes information about additional resources, as appropriate. The following spotlights have been updated for the Fourth Edition:

- "Other Redevelopment Initiatives"
- "Keys to Technology Selection and Acceptance"
- "The Triad Approach"
- "Data Quality and Representativeness"
- "State Dry Cleaner Remediation Programs"
- "Remediating Manufactured Gas Plant Sites"
- "Underground Storage Tanks at Brownfields Sites"
- "Phytoremediation Technology"
- "Cleanup of Dense Nonaqueous-Phase Liquids"
- "Understanding the Role of Institutional Controls at Brownfields Sites"

Six new spotlights have been added to the Fourth Edition of the Road Map:

- "Superfund Redevelopment Initiative"
- "All Appropriate Inquiry"
- "Sustainable Management Approaches and Revitalization Tools - electronic (SMARTe)"
- "Vapor Intrusion"
- "Innovative Approaches to Assessment and Cleanup of Mining Sites"
- "Supporting Tribal Revitalization Efforts"

Appendices

Four appendices are included in the Road Map to help stakeholders understand technical issues and terms related to site cleanup.

Appendix A, Guide to Contaminants and Technologies, identifies the types of contaminants found at brownfields sites and the range of technologies that may be appropriate for investigating and remediating those contaminants at brownfields sites.

Appendix B, List of Acronyms and Glossary of Key Terms, defines acronyms and specialized terms used in discussing and describing brownfields cleanup efforts. Because of the technical nature of the resources contained in this publication, acronyms are used throughout the Road Map. Consult Appendix B as necessary to identify acronyms and obtain definitions of unfamiliar terms.

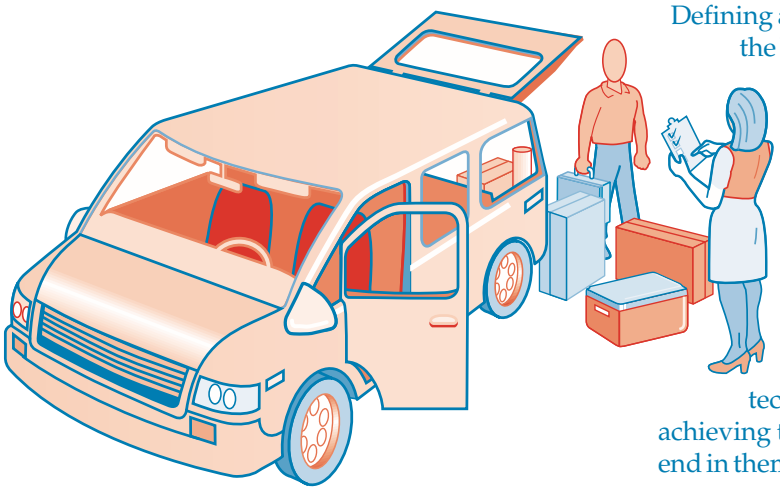
Appendix C, List of Brownfields and Technical Support Contacts, provides information about state and EPA regional and technical points of contact.

Appendix D, How to Order Documents, provides information about ordering the documents identified in the Road Map.

Index of Resources

The Index of Resources located at the back of the document provides a complete list of the resources in the Road Map sorted alphabetically by title. The Index is a useful tool for screening the list of resource titles and identifying new and updated resources.

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 long-term goals of the brownfields project and the decisions to be made throughout the project 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 prospective purchaser for development. 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, depending on state and local regulatory requirements, 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

The redevelopment of brownfields sites may be subject to a variety of federal, state, and local laws, regulations, policies, and guidelines with respect to the characterization and cleanup of the site. Such sites also may be governed by the standard practices of other government, nongovernment, and private institutions.

The applicable laws, regulations, policies, and guidelines will vary by site, depending on the regulatory authority that manages the cleanup. Therefore, it is important to research this information at the outset and to work closely with the regulatory authority throughout the cleanup process. For example, state or local regulatory authorities may manage the cleanup of brownfields sites. These agencies should be consulted to determine what, if any, site-specific requirements or permits are applicable.

Many of the standard practices 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.

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

Although compliance with regulations and official policy directives issued under other federal regulatory and cleanup programs such as Superfund may not be required, some of the information gathered under such programs may be useful in the investigation and cleanup of brownfields sites. For some sites, existing information provides a basis of understanding of site activities and conditions.

Additionally, lessons learned about site characterization strategies help to refine the process. 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 sites adequately. Additional sampling was necessary to assess 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 cleanup decisions with confidence. Streamlining the process may decrease costs and reduce the decision-making period for selecting options for site cleanups.

EPA has shown its support for the adoption of streamlined approaches to sampling, analysis, data review, and data evaluation during site assessment, characterization, and cleanup in a number of technical and guidance documents. Brownfields sites are well suited for use of the Triad approach (see Spotlight 7 on page 52), as limited funding and plans for reuse strongly influence decisions about cleanup. Inherent in the Triad approach is the need for cooperation and collaboration among the many stakeholders in the process. The Triad approach and the Brownfields Initiative reinforce each other in their emphasis on a common-sense approach in which barriers are removed and dollars are leveraged to provide the most cost-effective and streamlined strategy for monitoring and measurement activities. Use of real-time measurement technologies as well as a rigorous planning process to understand and control sources of uncertainty is inherent to the Triad approach and helps stakeholders improve the reliability of risk-related decisions.

Recognizing that rigorous planning is important, the approach should remain flexible and dynamic and should allow for adjustments in the field in light of actual site conditions observed and sample analytical results. Such a dynamic approach usually requires a well-rounded technical team that has a broad range of technical expertise and use of field analytical technologies, including an on-site mobile laboratory, to provide quick-turnaround analyses.

Seeking and Procuring External Professional Support

Most decision-makers for brownfields sites will require technical and legal assistance to fully understand the complexities of investigating and cleaning up contaminated sites. Depending upon the complexity of a particular site, decision-makers may

request the assistance of environmental consultants, cleanup contractors, technology vendors, or analytical laboratories in performing the many activities required to investigate and clean up the site. The inclusion of these professionals and other experts as members of the brownfields team is recommended.

Some states may require the participation of certified or licensed professionals to help guide the site investigation and cleanup process. To obtain the services of such professionals (individuals or a firm), a request for proposal (RFP) is often used as the procurement mechanism. The RFP addresses the approach, qualifications, and cost estimate for the services requested and includes specifications that encourage prospective bidders to think "outside the box" and consider nontraditional approaches. Selection criteria outlined in the RFP should include the demonstrated experience of the individuals or firm in developing valid options for using streamlined strategies and innovative technologies at brownfields sites and in successfully implementing the selected options.

To ensure that those individuals or firms responding to an RFP propose approaches that are valid for the site, the RFP also should include, or make readily available, all studies and reports that provide site-specific information that can be used as the basis for making technology decisions. Individuals preparing RFPs may wish to be proactive and provide suggestions for the use of specific strategies and technologies that appear to be valid for the particular site. When reviewing proposals and interviewing firms, the evaluation team must be prepared to ask pointed, detailed questions about the selection and use of technologies to be assured that the individual or firm chosen to perform the work is qualified to complete the project successfully. Described in this Road Map are many excellent resources that will assist brownfields decision-makers in preparing specifications to be included in RFPs, selecting the criteria for evaluating proposals, and developing questions for interviews of those responding to the RFP. For example, see EPA's Brownfields Technology Primer: Requesting and Evaluating Proposals That Encourage Innovative Technologies for Investigation and Cleanup on page 42 for more information.

Community Involvement

It is important that brownfields decision-makers encourage acceptance of redevelopment plans and cleanup alternatives by involving members of the community early in the decision-making process through community meetings, newsletters, or other outreach activities. For an individual site, the community should be informed about how the use of a proposed technology might affect redevelopment plans or the adjacent neighborhood. For example, the planting of trees for the use of phytoremediation may create aesthetic or visual improvements; on the other hand, the use of phytoremediation may bring about issues related to site security or long-term maintenance that could affect access to the site.

EPA can assist members of the brownfields community by 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 cleanup and technology options. As noted in the preceding section, EPA's Brownfields and Land Revitalization Technology Support Center is a valuable resource for brownfields decision-makers (see page 14 for more information).

Comparing Innovative Technologies to Other Characterization and Cleanup Options

In addition to innovative site characterization and cleanup technologies, the use of established treatment and containment technologies also should be considered. Examples of established treatment technologies include solidification/stabilization, soil vapor extraction, thermal desorption, incineration, and pump-and-treat. (For a complete list and description of the technologies, see the Treatment Technologies for Site Cleanup: Annual Status Report (Eleventh Edition). The document is available online at ***http://clu-in.org/asr/***.) Examples of containment include containing contaminated soil on site using a cap and limiting migration of contaminants using 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. When deciding between innovative and established technologies or between treatment and containment technologies, or other options, brownfields decision-makers should consider 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.

Selecting and Accepting Technologies

The successful cleanup of a brownfields site depends on the selection and acceptance of a specific technology or technology approach. Identified in the box below are the key elements to ensure that a proposed technology will be accepted by all stakeholders, whether site owners, potential buyers, financial service providers, investors, regulators, or affected citizens. Spotlight 6, Keys to Technology Selection and Acceptance, on page 51, describes in detail these key elements.

A Quick Look

- Focus on the decisions that support site goals
- Build consensus
- Understand the technology
- Allow flexibility

Information Centers, Training, and Other Resources

Described on the next four 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 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

Analysis of State Superfund Programs: 50-State Study, 2001 Update

The report, which was 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. 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 ***www.eli.org***; the report can be found under the topic "Contaminated Sites" under "Research Reports" in the ELI Store section of the site.

Brownfields: A Comprehensive Guide to Redeveloping Contaminated Property, Second Edition

The book, which was 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 of and background information about brownfields issues as well as 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 also is provided. Originally published in 1997, the Second Edition of this book was released in 2002. The book can be purchased through ABA's Web site at ***www.abanet.org*** or at bookstores across the country. The International Standard Book Number (ISBN) for the book is 1-57073-961-7.

Brownfields and Land Revitalization Technology Support Center

EPA established BTSC to ensure that brownfields decision-makers are aware of the full range of technologies available for conducting site assessments and cleanup actions and can make informed decisions for their sites. The center helps government decision-makers evaluate strategies to streamline the site assessment and cleanup process, identify and review information about complex technology options, evaluate contractor capabilities and recommendations, explain complex technologies to communities, and plan technology demonstrations. BTSC is coordinated through EPA's OSRTI and works through EPA's ORD laboratories. The center works closely with EPA's Office of Brownfields Cleanup and Redevelopment and in partnership with the U.S. Army Corps of Engineers (USACE) and Argonne National Laboratory (ANL). Localities can submit requests for assistance:

– Through their EPA Regional Brownfields Coordinator
– Online at ***www.brownfieldstsc.org***
– By calling 1 (877) 838-7220 (toll free)

For more information about BTSC, contact Dan Powell of EPA's OSRTI at (703) 603-7196 or powell.dan@epa.gov.

INFORMATION CENTERS, TRAINING, AND OTHER RESOURCES

Brownfields Handbook: How to Manage Federal Environmental Liability Risks (EPA 330-B-01-001)

In November 1998, EPA issued "The Handbook of Tools for Managing Federal Superfund Liability Risks at Brownfields and Other Sites." The handbook provided a compilation of tools and a discussion of how to use them for evaluating the benefits of reusing a brownfields property. The updated edition of the handbook published in November 2002 summarizes the tools available to clarify and address barriers to site cleanup and reuse posed by RCRA. In addition, the handbook summarizes the tools and initiatives that have been implemented since 1995. These include the Superfund Redevelopment Initiative (SRI), the UST-related initiatives, RCRA reforms, and improvements in the prospective purchaser agreement process. The handbook also provides updated lists of brownfields policies and guidance documents and EPA contacts. An electronic copy of the handbook is available at ***www.epa.gov/compliance/resources/publications/cleanup/brownfields/handbook***. In addition, this site contains policies and guidance documents issued since the publication of the 2002

CLU-IN Studio

CLU-IN Studio, which is coordinated by EPA's OSRTI, ITRC, and other partners, provides free and unlimited access to Internet technical seminars, live conference Webcasts, and videotapes. The three types of media provide information about and resources relevant to innovative site characterization and cleanup technologies. The 2-hour Internet seminars are live, Web-based slide presentations, each of which has a companion audio portion available by telephone line or RealAudio simulcast. The conference Webcasts are live events that combine Web-based presentation materials with a companion live audio stream. The videotapes, whose viewing time ranges from 6 to 28 minutes, may be viewed or ordered online. Descriptions and registration information for upcoming events as well as links to archived seminars and Webcasts are provided at ***www.clu-in.org/studio***.

EPA Brownfields Cleanup and Redevelopment Internet Site

This Internet site coordinated by EPA's Office of Brownfields Cleanup and Redevelopment provides extensive information about EPA's Brownfields Program, including the Brownfields Law, EPA brownfields grants, and technical tools and resources as well as information about brownfields projects across the country. Descriptions of EPA's brownfields pilot projects and points of contact in each of the EPA regional offices are provided, as are descriptions of publications, regulations, and other documents. Brownfields stakeholders involved in selection and use of technologies for environmental cleanup may have particular interest in learning more about EPA's brownfields grant programs, which offer assessment grants, revolving loan fund grants, cleanup grants, and job training grants. Information is also provided on EPA's Targeted Brownfields Assessments (TBA) Program as well as state and tribal response programs. The site also contains routinely updated announcements related to grants and information on pilot projects and success stories. The site provides links to the Web sites of different cleanup programs managed by offices within the EPA Office of Solid Waste and Emergency Response (OSWER). For additional information, visit the Web site at ***www.epa.gov/brownfields***.

EPA Dockets

Dockets, electronic dockets, and information centers serve as the repositories for information related to particular EPA actions. When a rulemaking or nonrulemaking action is announced, a docket is established in EPA Dockets (EDOCKET) with an assigned tracking number to accumulate materials throughout the process. Dockets may contain *Federal Register* documents, a variety of supporting documentation, and public comments. Publicly available docket materials are available either electronically in EDOCKET or on hard copy at the EPA Docket Center, EPA West Building, Room B102, 1301 Constitution Avenue, N.W., Washington, DC. This facility is open from 8:30 am to 4:30 pm, Monday through Friday, excluding federal holidays. The telephone number for the Public Reading Room is (202) 566-1744, and the telephone number for the OSWER Docket is (202) 566-0276. All documents in the docket are listed in the EDOCKET index at ***www.epa.gov/edocket***.

INFORMATION CENTERS, TRAINING, AND OTHER RESOURCES

Guidance for Preparing Standard Operating Procedures (EPA 240-B-01-004)

The document provides guidance on the preparation and use of a standard operating procedure (SOP) within a quality system. An SOP is a set of written instructions that document a routine or repetitive activity that an organization carries out. The development and use of SOPs are an integral part of a successful quality system because SOPs provide individuals with the information needed to perform a job properly and facilitate consistency in the quality and integrity of a product or end result. SOPs describe both technical and administrative operational elements of an organization that would be managed under a work plan, a quality assurance project plan, or a quality management plan. A copy of the guidance document can be viewed at the online version of the Road Map at ***www.brownfieldstsc.org***.

Hazardous Substance Research Centers

The Hazardous Substance Research Centers (HSRC) provide a national program of basic and applied research, technology transfer, and outreach. Five multi-university centers focus on different aspects of hazardous substance management and serve different regions of the country. The HSRCs receive financial support from EPA and additional funding from academia, industry, and other federal and state agencies. Research projects involve laboratory and field experiments as well as mathematical and physical modeling. Technology transfer and training activities facilitate information exchange with government agencies, industry, and other academic participants. The HSRCs operate three outreach programs that provide free, nonadvocacy technical assistance to communities. Technical Outreach Services for Communities (TOSC) uses university educational and technical resources to help community groups understand the technical issues associated with the hazardous waste sites in their midst. TOSC aims to empower communities to participate substantively in the decision-making process regarding their hazardous substance problems. An affiliate of TOSC is Technical Outreach Services for Native American Communities (TOSNAC), which provides technical assistance to Native Americans dealing with hazardous substance issues. Technical Assistance to Brownfields Communities (TAB) helps communities to clean up and redevelop properties that have been damaged or undervalued because of environmental contamination. The main audiences for TAB assistance are community groups, municipal officials, developers, and community leaders, with lending institutions constituting a secondary audience. More information on the HSRCs and their brownfields initiatives is available at ***www.hsrc.org***.

Hazardous, Toxic and Radioactive Waste Center of Expertise

Coordinated through USACE, the Hazardous, Toxic and Radioactive Waste Center of Expertise (HTRW-CX) provides technical assistance and information regarding use of innovative technologies for cleanup of contaminated properties. Detailed information about a variety of 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 on the site. Visit the HTRW-CX Web site at ***www.environmental.usace.army.mil/info/technical/it/it.html*** for more information on the center's innovative technology programs.

Interstate Technology and Regulatory Council

ITRC is a state-led coalition working with industry and other stakeholders to achieve regulatory acceptance of environmental technologies. ITRC consists of 43 states, the District of Columbia, multiple federal partners, industry participants, and other stakeholders, cooperating to break down barriers and reduce compliance costs, making it easier to use new technologies, and helping states to maximize resources. ITRC brings together a diverse group of environmental experts and stakeholders from both the public and private sectors to broaden and deepen technical knowledge and to streamline the regulation of new environmental technologies. ITRC has established a team of experts specifically focused on redevelopment issues. ITRC accomplishes its mission in two ways: it develops guidance documents and training courses to meet the needs of both regulators and environmental consultants, and it works with state representatives to ensure that ITRC products and services have maximum impact among state environmental agencies and technology users. ITRC was originated in 1995 based on a previous initiative conducted by the Western Governors' Association (WGA). In January 1999, ITRC became affiliated with the Environmental Research Institute of the States (ERIS). ERIS is a 501(c)3 nonprofit educational subsidiary of the Environmental Council of the States (ECOS). ITRC receives regional support from WGA and the Southern States Energy Board (SSEB) and receives financial support from the U.S. Department of Energy (DOE), the U.S. Department of Defense (DoD), and EPA. Brownfields decision-makers will find success stories, guidance documents, training materials, and other information related to the use of innovative technologies developed by ITRC on its Web site at ***www.ITRCweb.org***.

INFORMATION CENTERS, TRAINING, AND OTHER RESOURCES

RCRA Online

RCRA Online is an online database that provides users access to thousands of letters, memoranda, and questions and answers issued by EPA's Office of Solid Waste (OSW). The documents indexed in the database represent past EPA Headquarters interpretations of the RCRA regulations governing management of solid, hazardous, and medical wastes. Users can retrieve documents through topical, full text, and advanced search functions and can view the actual text of documents identified in a search. Detailed instructions on how to use the database are provided, as are tips for conducting searches. RCRA Online is available online at ***www.epa.gov/rcraonline***. An updated pdf version of the RCRA Online brochure (EPA 530-F-03-011) is provided on the Road Map at ***www.brownfieldstsc.org***.

Superfund and Emergency Planning and Community Right-to-Know Act Call Center

The Superfund and Emergency Planning and Community Right-to-Know Act (EPCRA) Call Center is a publicly accessible service that provides up-to-date information on several EPA programs. The Call Center responds to factual questions about federal regulations related to the following program areas:

– EPCRA
– Risk Management Program regulations under the Clean Air Act (CAA)
– CERCLA or Superfund
– Spill prevention, control, and countermeasure (SPCC) plans and oil pollution prevention regulations under the Clean Water Act (CWA)

The Call Center operates Monday through Friday, 9:00 am to 5:00 pm Eastern Standard Time (EST). The center can be reached by telephone at (800) 424-9346 from all nongovernment locations outside the Washington, DC, metropolitan local calling area or at (703) 412-9810 from all locations in the Washington, DC, metropolitan local calling area.

Tax Credits and Deductions for Expensing Environmental Remediation Costs (Section 198)

Section 198 of the Internal Revenue Code (26 U.S.C. §198 (A)(1)(B)(VI)) describes the expensing of costs related to environmental remediation of qualified contaminated sites. As the code specifies, taxpayers are permitted to treat any qualified environmental remediation expense as an expense that is not chargeable to a capital account; such an expenditure can be treated as a deduction for the taxable year in which it is paid or incurred. In general, a qualified remediation expenditure is an expenditure paid or incurred in connection with abatement or control of hazardous substances at a qualified contaminated site. The specific terms and qualifications are described in Section 198 of the Internal Revenue Code.

TechDirect

TechDirect, which is hosted by EPA's OSRTI, is a free e-mail service that highlights new publications and events of interest for site assessment and remediation professionals. At the beginning of every month, the service e-mails a message describing the availability of publications and announcing events. For publications, the message explains how to obtain a hard copy or how to download an electronic version. Interested persons may subscribe online at ***www.clu-in.org/techdrct***.

Toxic Substances Control Act Assistance Information Service

The information service provides technical assistance and information regarding programs implemented under the Toxic Substances Control Act (TSCA), the Asbestos School Hazard Abatement Act (ASHAA), the Asbestos Hazard Emergency Response Act (AHERA), the Asbestos School Hazard Abatement Reauthorization Act (ASHARA), the Residential Lead-Based Paint Hazard Reduction Act (Title X of TSCA), and EPA's 33/50 program. The information service operates Monday through Friday, 8:30 am to 5:00 pm EST. The information service can be reached by telephone at (202)554-1404, by fax at (202) 554-5603, or by e-mail at tsca-hotline@epa.gov.

INFORMATION CENTERS, TRAINING, AND OTHER RESOURCES

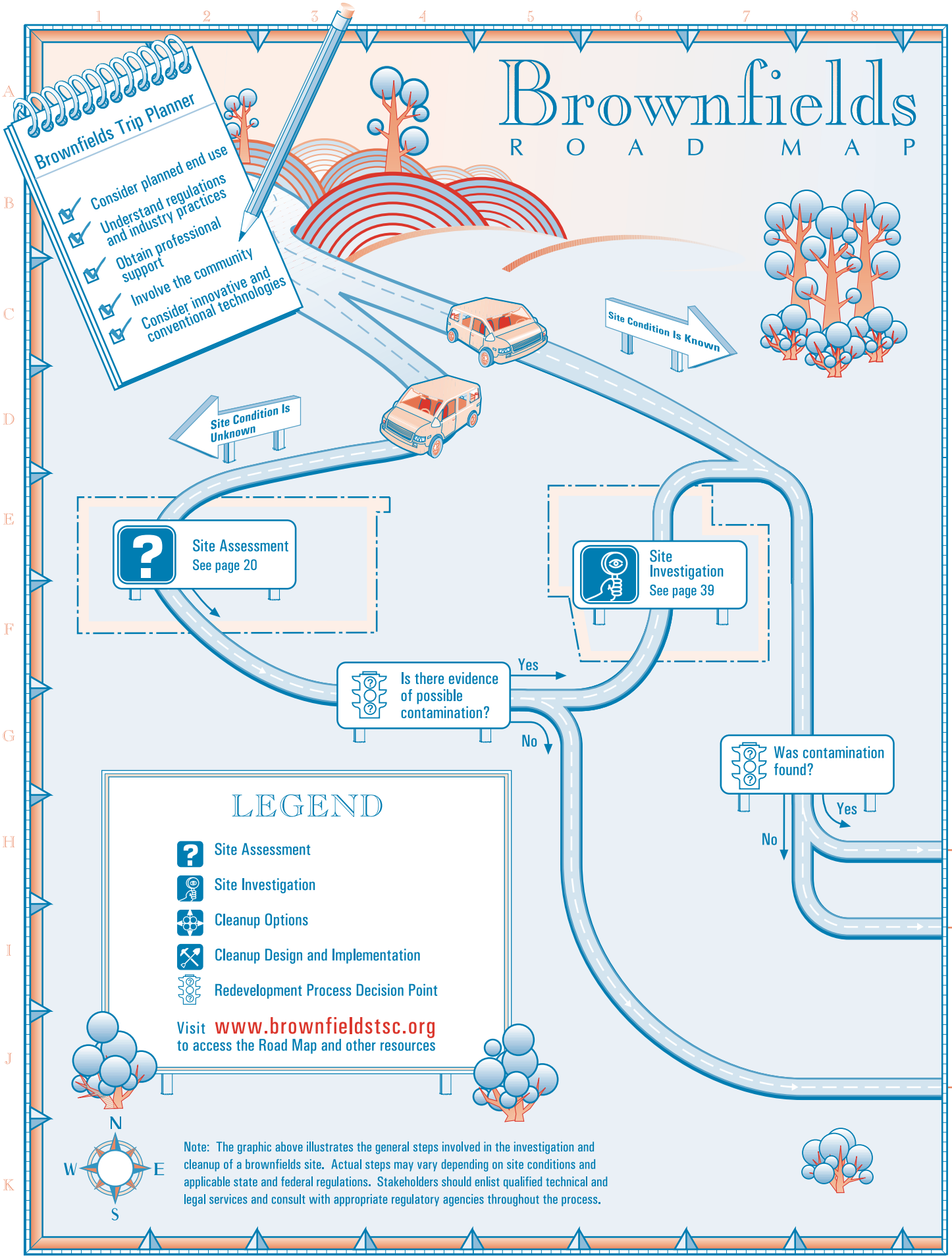
Training Information

Training courses and programs that can be useful for 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 classroom and Internet-based classes as well as schedules for their delivery. Visit the TRAINEX Web site at ***www.trainex.org*** for additional information.
- EPA's "*Streamlined Investigation and Cleanups Using the Triad Approach"* training course is a moderate to advanced-level training program that provides participants an introduction to a wide array of innovative technologies and approaches that can be used to characterize hazardous waste sites. The class stresses the importance of the planning process and the use of field-based measurement technologies and on-site data assessment techniques. Participants will be introduced to the Triad approach and methods for better understanding, planning, and implementing monitoring strategies to improve cleanup at lower costs. In addition, participants will be provided an overview of several of the field analytical and rapid sampling technologies that can support streamlined measurement approaches. For information about the program and the schedule for its delivery, visit the TRAINEX Web site at ***www.trainex.org***; select "CERCLA Education Center (CEC)."
- Information about upcoming courses provided by a variety of federal and nonfederal organizations is provided on OSRTI's CLU-IN Web site at ***www.clu-in.org***; select "Courses and Conferences" under "What's Hot? What's New?"
- The American Society for Testing and Materials (ASTM) also offers many technical and professional training opportunities, such as training on environmental site assessment processes, that may be of interest to brownfields decision-makers. For more information, visit ASTM's Web site at ***www.astm.org/TRAIN***.

Triad Resource Center

The Triad is an innovative approach to decision-making for hazardous waste site characterization and remediation. The Triad approach employs new characterization and treatment tools, using work strategies developed by innovative and successful site professionals. The Triad Resource Center provides the information that hazardous waste site managers and cleanup practitioners need to implement the Triad approach effectively. The Triad Web site provides an overview of Triad; information on its management, regulatory, and technical components; user experiences; and references and resources for additional information. For additional information on Triad, visit the Web site at ***www.triadcentral.org***.


Brownfields
ROAD MAP
Brownfields Trip Planner
Consider planned end use
Understand regulations and industry practices
Obtain professional support
Involve the community
Consider innovative and conventional technologies
Site Condition Is Known
Site Condition Is Unknown
Site Assessment
See page 20
Site Investigation
See page 39
Is there evidence of possible contamination?
Yes
No
Was contamination found?
Yes
No
LEGEND
Site Assessment
Site Investigation
Cleanup Options
Cleanup Design and Implementation
Redevelopment Process Decision Point
Visit www.brownfieldstsc.org
to access the Road Map and other resources
N
W
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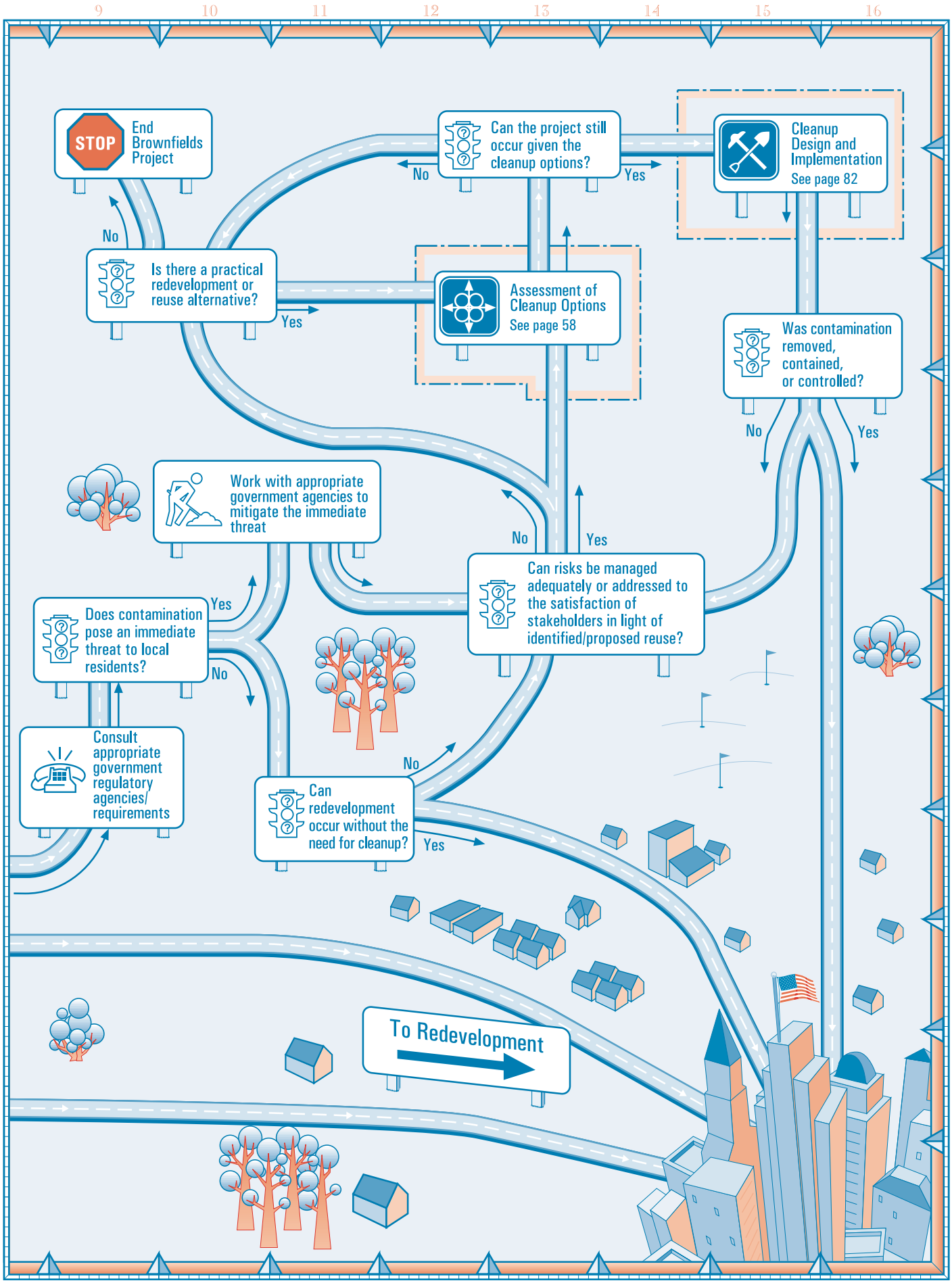
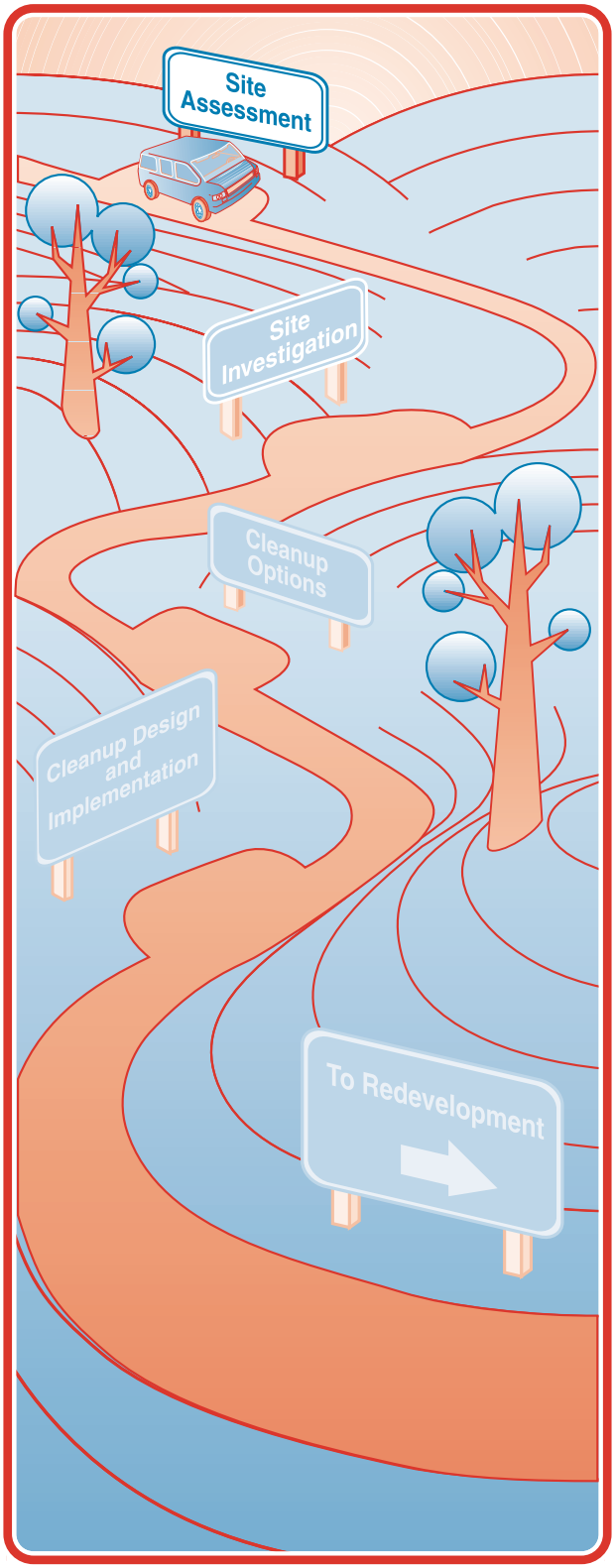
S
Note: The graphic above illustrates the general steps involved in the investigation and cleanup of a brownfields site. Actual steps may vary depending on site conditions and applicable state and federal regulations. Stakeholders should enlist qualified technical and legal services and consult with appropriate regulatory agencies throughout the process.


9
10
11
12
13
14
15
16
STOP
End Brownfields Project
Can the project still occur given the cleanup options?
No
Yes
Cleanup Design and Implementation
See page 82
No
Is there a practical redevelopment or reuse alternative?
Yes
Assessment of Cleanup Options
See page 58
Was contamination removed, contained, or controlled?
No
Yes
Work with appropriate government agencies to mitigate the immediate threat
No
Yes
Can risks be managed adequately or addressed to the satisfaction of stakeholders in light of identified/proposed reuse?
Yes
Does contamination pose an immediate threat to local residents?
No
Consult appropriate government regulatory agencies/ requirements
No
Can redevelopment occur without the need for cleanup?
Yes
To Redevelopment

SITE ASSESSMENT



Collect and Assess Information About the Brownfields Site

The purpose of this step is to evaluate the potential for contamination at a particular site by collecting and reviewing existing information. The site assessment, typically referred to as an ASTM Phase I environmental site 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 site 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 Triad approach is applicable to many elements of monitoring and measurement activities that occur on site - from early investigations aimed at risk estimation, through designing, implementing, and monitoring the implementation of a remedy. The key to the Triad approach, and the benefit to brownfields sites, is that decisions are made with the full consideration of existing information developed during past site use and cleanup activities, and with a thorough understanding of how the site might be reused. Using this approach, activities are performed that target the principal sources of uncertainty that can affect the confidence of site decisions. Use of the Triad approach for site

assessments at brownfields sites allows decision-makers to economically collect the volume and quality of data necessary to reassure regulators and communities that a property is safe for reuse.

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).

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. Examples of sampling and analysis technologies that may be applicable during this phase are presented in Appendix A, Table A-2, Technologies for Analyzing Contaminants at Brownfields Sites. However, the use of technologies may be somewhat limited, since much of the work at this stage involves a search of paper and electronic records.

The following section is intended as a general planning guide and is not a comprehensive listing of assessment activities required under state and federal regulations. For a better understanding of these requirements, users should consult the references identified and work with their appropriate regulatory authority.

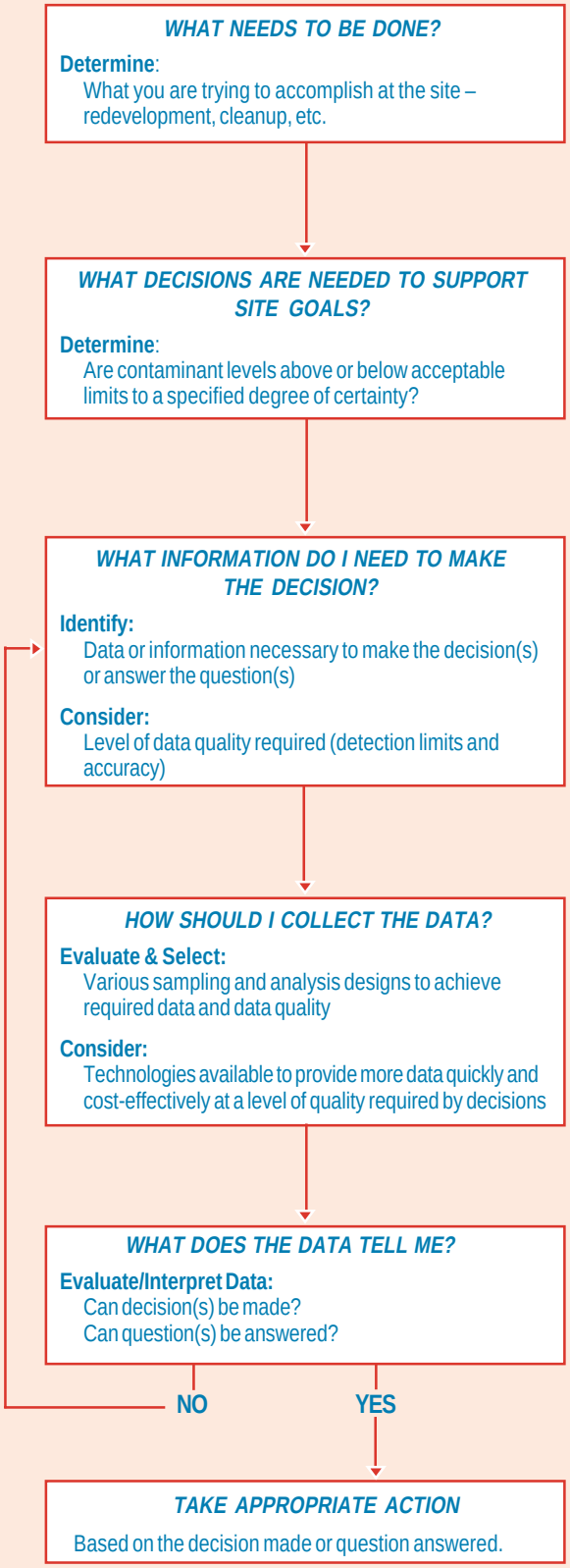
What Do We Need to Know?

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? 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 decisions need to be made, and what data should be collected to support those decisions? What level of quality is necessary and what level of uncertainty is acceptable 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? (See the definition of a VCP in Appendix B, List of Acronyms and Glossary of Key Terms)
6. What are the special needs and concerns of the community? How can community involvement be encouraged and meaningful? 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? Who will be responsible for long-term monitoring and oversight, particularly if residual contamination is left in place?

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.

Linking the Decision, Data, and Technologies



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
- Develop the conceptual site model (CSM). The CSM is the planning tool that organizes existing site information, provides a framework to identify project goals and data gaps, and directs site activities and team communications.
- 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*

The practice of conducting site assessments, or all appropriate inquiries, is intended to satisfy one requirement for obtaining protection from CERCLA liability. To obtain protection from CERCLA liability as a bona fide prospective purchaser, an innocent landowner, or a contiguous property owner; prospective property owners must conduct all appropriate inquiries, or a phase I site assessment, prior to acquiring a property. The Brownfields Law requires EPA to promulgate federal standards and practices governing the conduct of all appropriate inquiries. The Law also established interim standards for conducting "all appropriate inquiry" to determine the environmental condition of a property prior to its acquisition. The interim standard for properties purchased after May 31, 1997, which remains in place until EPA promulgates a final rule establishing federal standards for all appropriate inquiries, is the ASTM E1527-97 or ASTM E1527-00, entitled "Standard Practice for Environmental Site Assessments: Phase I Environmental Site Assessment Process." Spotlight 3 on page 34 provides additional information on the requirements for all appropriate inquiries.

- 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 (see the section, Before You Begin, for an overview of applicable regulations and regulatory guidelines)*
  - *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 (see page 15 in the section, Before You Begin, for a description of community services provided by HSRCs)*
  - *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

Where Do We Find Answers to Our Technology Questions?

Examples of technology resources that are available to assist in assessing a site are listed below. The resources are listed alphabetically under the following categories

A. Resources for Site Assessment

B. Site-Specific Resources for Site Assessment

C. Technology-Specific Resources for Site Assessment

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.

Access the Road Map online at ***www.brownfieldstsc.org*** to view or download the following resources electronically or to obtain a link that provides complete ordering information.

A. Resources for Site Assessment

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.

Archived Internet Seminars
Through the CLU-IN Web site, EPA has presented numerous Internet Seminars covering a wide variety of technical topics related to hazardous waste characterization, monitoring, and remediation. For each seminar topic, EPA has selected the highest-quality offerings and placed them in archives that are accessible on the site. The seminars are Web-based slide presentations with an accompanying audio portion. Examples of archived seminars include the following:

- *Application of Transport Optimization Codes to Groundwater Pump-and-Treat Systems;*
- *Biosensors for Environmental Monitoring - Parts 1 and 2;*
- *Dynamic Data Collection Strategy Using Systematic Planning and Innovative Field-Based Measurement Technologies;*
- *In Situ Treatment of Groundwater Contaminated with Nonaqueous-Phase Liquid (NAPL) Contamination: Fundamentals and Case Studies (In Situ Chemical Oxidation);*
- *In Situ Treatment of Groundwater Contaminated with NAPL Contamination: Fundamentals and Case Studies (NAPL Characterization and Related Cleanup Issues).*

Assessing Contractor Capabilities for Streamlined Site Investigations (EPA 542-R-00-001)
Developed by EPA's BTSC, 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 (E1984-03(2003))
The guide, which was developed by ASTM, discusses redevelopment of a brownfields property and is intended for all stakeholders. It identifies impediments to such redevelopment and suggests solutions that can facilitate completion of a successful project. It describes a 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, which is available at a cost, can be ordered online at ***www.astm.org***.

ASTM Standard Practice for Environmental Site Assessments: Phase I Environmental Site Assessment Process (E1527-00(2003))
The purpose of the practice, which was developed by ASTM, is to define commercial and customary practices in the United States 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, which is available at a cost, can be ordered online at ***www.astm.org***.

Brownfields Technology Primer: Using the Triad Approach to Streamline Brownfields Site Assessment and Cleanup (EPA 542-B-03-002)
This document, which was prepared by EPA's BTSC, provides an educational tool for site owners, project managers, and regulators to help streamline assessment and cleanup activities at brownfields sites. The primer also discusses strategies to reduce costs, decrease time frames, positively affect regulatory and community acceptance, and improve the economics of redevelopment at brownfields sites. The primer is organized in three sections: an introduction; a description of the three elements of the Triad approach, with examples describing the use of each element; and a discussion of the role of the technical team in managing a project, procurement considerations when a project is being planned, and decision-support software and other tools that are available to help brownfields site managers.

Clarifying DQO Terminology Usage to Support Modernization of Site Cleanup Practices (EPA 542-R-01-014)
This report, which was developed by EPA, addresses the need to clarify DQO terminology use in order to support modernization of environmental restoration activities. The document presents a basic conceptual understanding of DQO-related terms in a way that facilitates systematic project planning in the context of site cleanups. A list of descriptions of DQO-related terms and concepts appears first in the report, followed by a more

detailed discussion of the interrelationships among the concepts.

Clean-Up Information Home Page on the World Wide Web (CLU-IN)

The Internet site, which was developed by EPA, 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 remediation and site characterization also is provided: technology verification and evaluation; technology selection tools; contaminant-specific information, guidance and application support; case studies; regulatory development; and publications.

Data Quality Objective Process for Hazardous Waste Site Investigations (EPA 600-R-00-007)

The document focuses on the DQO process as the appropriate systematic planning process to support decision-making. The DQO process is an important tool for project managers and planners to use in defining the types, quality, and quantity of data needed to make defensible decisions. The document is based on the principles and steps developed in Guidance for the Data Quality Objectives Process, but is specific to investigations of hazardous waste sites. The guidance is also consistent with Data Quality Objectives Process for Superfund: Interim Final Guidance (EPA 1993) and Soil Screening Guidance: User's Guide (EPA 1996). Although the document focuses on EPA applications, the guidance also is applicable to programs at the state and local levels.

Data Quality Objectives Web Site

The DQO Web site, which is sponsored by DOE, is a helpful resource for those responsible for preparing a data collection design. The Web site defines the DQO process and explains its role in ensuring that a data collection activity produces results of sufficient quality to support decisions based on those results. The Web site provides step-by-step procedures for the DQO process. It also provides a decision process flow chart, describes purposes and goals related to the use of the DQO process, and reviews relevant DOE and contractor directives. It also provides information on data quality assessment (QA); describes a number of available training courses; lists contacts; and provides glossaries of relevant terms, as well as links to related sites.

Directory of Technical Assistance for Land Revitalization (BTSC) (EPA 542-B-03-001)

EPA's BTSC has prepared the directory to provide information about technical assistance that is available from federal agencies to assist regional, state, and local government personnel in assessment and cleanup decision-making for brownfields reuse and revitalization. This directory includes information about 37 organizations within 10 federal agencies that provide different types of support to help with site assessment and cleanup, including technical support and funding sources. Profiles are included for the agencies and organizations and contain the following types of information: background and location information, relevancy to revitalization, description of the areas of expertise available, discussion of the types of services available, types of funding available and eligibility, contact information and the process for requesting assistance, and examples of specific instances where the organization has previously provided support for site revitalization. Information in the profiles is believed to be current as of March 2003. To help maintain current information, the directory is available as an online searchable database at *www.brownfieldstsc.org/directory*.

Engineering and Design: Requirements for the Preparation of Sampling and Analysis Plans (EM 200-1-3)

Developed by USACE, the manual provides guidance for the preparation of project-specific sampling and analysis plans (SAP) for the collection of environmental data. In addition, the manual presents default sampling and analytical protocols that may be used verbatim or modified based in light of the DQOs for a specific project. The goal of the manual is to promote consistency in the generation and execution of sampling and analysis plans and therefore to help investigators generate chemical data of known quality for the purpose to which those data are to be used.

EPA REmediation And CHaracterization Innovative Technologies (REACH IT) Online Searchable Database

The EPA REmediation And CHaracterization Innovative Technologies (EPA REACH IT) online searchable databases sponsored by EPA's OSRTI is a service provided free of charge to both users and technology vendors. EPA REACH IT is accessible only through the Internet. This database provides users comprehensive, up-to-date information about more than 256 characterization technologies and 481 remediation technologies and their applications. It

combines information submitted by technology service providers about remediation and characterization technologies with information from EPA, DoD, DOE, and state project managers about sites at which innovative technologies are being deployed. 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 updates all of the information available in the system about every six months. Technology vendors may also add or update information in EPA REACH IT at any time through the Data Entry System, or by submitting information by mail. You can search the EPA REACH IT system in several ways. Various search options are available for a user on the home page, including Custom Search; Spotlight; Most Common Searches; Saved Searches; Guided Search; and Vendor, Technology, and Site Index. For questions about whether a technology is eligible for listing in EPA REACH IT, the user may contact the EPA REACH IT help line at (800) 245-4505 or (703) 390-0713 or send an e-mail to epareachit@ttemi.com.

Expedited Site Characterization (ESC) Method (Ames Laboratory Environmental Technologies Development Program)

This Web site, which was developed by DOE, provides information about demonstrations of the ESC method conducted by the Ames Laboratory Environmental Technology Development Program. The ESC demonstrations employ several technologies such as hydrological technologies to better understand the properties and physical characteristics of groundwater movement; geophysical and geotechnical technologies to improve understanding of the subsurface geology and predict "fate and transport" of the target contaminants; analytical technologies designed to detect and quantify the target contaminants; and data fusion technologies to integrate site information into a conceptual site model. The ESC demonstrations include characterization work performed by commercial contractors at existing contaminated sites. Public sessions provide a forum for citizens, media, state and local government officials, EPA and state regulators, technology providers, environmental scientists, engineers and educators to offer input on this new approach and its role within the environmental cleanup process.

Improving Decision Quality: Making the Case for Adopting Next-Generation Site Characterization Practices

This paper, which was published in *Remediation* in spring 2003 as a joint effort of EPA OSRTI and the Northeast Waste Management Officials' Association (NEWMOA), addresses developments in site characterization and the barriers that hinder improved decision-making. The paper discusses the need for the site cleanup industry to continue its technical advancement by using next-generation models based on current scientific understanding. It addresses data quality assessments and the impacts of matrix heterogeneity on analytical results. The paper also discusses the use of the Triad approach – systematic project planning, dynamic work planning strategies, and real-time data generation – as a means of moving beyond existing data paradigms.

Improving Sampling, Analysis, and Data Management for Site Investigation and Cleanup (EPA 542-F-04-001a)

The document, which was published by EPA, describes the three-pronged Triad approach that forms the basis of EPA's national strategy for site characterization and assessment. This streamlined approach to site assessment focuses on systematic planning to ensure the effective use of resources; preparation of a dynamic work plan to support decision-making in the field; and use of on-site analytical tools, rapid sampling platforms, and on-site data interpretation. Following the discussion of the Triad approach to site investigation, the document briefly reviews a number of recent developments that promise marked benefits for cleanup efforts and sets forth the EPA's vision of defensible decisions at an affordable cost that is the goal of the national strategy. The document can be downloaded from CLU-IN under "Publications." See Spotlight 7, "The Triad Approach," for a more detailed description of the approach.

In Search of Representativeness: Evolving the Environmental Data Quality Model

This paper, which was published by EPA OSRTI, discusses the need to update the environmental data quality model to recognize and manage the uncertainties involved in generating representative data from heterogeneous environmental matrices. It discusses issues associated with data quality despite improvements in environmental analytical capabilities. The paper also discusses the

gradually increasing acceptance of new technologies and dynamic work plan strategies by regulators and cleanup practitioners. The complete reference for the paper is as follows: *Quality Assurance*, Volume 9 (2001/2002), Pages 179 through 190.

OnSite OnLine Tools for Site Assessment
Developed by EPA's ORD and EPA Region 9, the Web site offers a set of online tools for site assessment, including calculators for formulas, models, unit conversion factors, and scientific demonstrations for use in assessing the effects of contaminants in groundwater.

Quality Assurance Guidance for Conducting Brownfields Site Assessments (EPA 540-R-98-038)
The document informs brownfields site managers about concepts and issues related to QA 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.

Sensor Technology Information Exchange (SenTIX)
SenTIX serves as a forum to exchange information about sensor technologies and needs. The purpose of the Web site is to serve as a tool to assist those working in the environmental field in cleaning up hazardous waste. The submit and search functions of SenTIX can assist users who are looking for a sensor technology to meet a specific need. The discussion forum also matches developers, vendors, and users. Users can provide sensor-related information online. The site was developed by WPI, a nonprofit organization, under a cooperative agreement with EPA.

Superfund Representative Sampling Guidance
In this December 1995 EPA Superfund guidance, readers learn about the variables that relate to site-specific conditions, sampling design approaches, and techniques for collection and preparation of representative samples. The guidance also discusses the importance of the conceptual site model (CSM). Accuracy of sampling data is critical for project managers and field personnel to accurately characterize actual site conditions when identifying threats, delineating the sources and extent of contamination, and confirming the achievement of cleanup standards. The guidance is available in five volumes covering soil (EPA 540-R-95-141), water (publication number not available), waste (EPA 540-R-95-141), air (EPA 540-R-95-140), and biological materials (EPA 540-R-97-028).

Sustainable Management Approaches and Revitalization Tools - electronic (SMARTe)
The SMARTe web-based decision support tool is a cooperative effort of EPA, ITRC, and the German Federal Ministry for Education and Research. It is designed to aid stakeholders in identifying, applying, and integrating tools and technologies to facilitate the revitalization of potentially contaminated sites in the United States. Currently, SMARTe contains information and databases that allow project stakeholders to assess both market and non-market costs and benefits of redevelopment options, clarify private and public financing options, evaluate and communicate environmental risks and opportunities, and access relevant state-specific information. By October 2007, SMARTe will use expert system technology to integrate environmental, social and economic issues in a multi-criteria decision analysis so that stakeholders can evaluate alternative reuse scenarios.

Technical and Regulatory Guidance for the Triad Approach: A New Paradigm for Environmental Project Management
This document, which was prepared by ITRC's Sampling, Characterization and Monitoring (SCM) Team, introduces the Triad approach as an integrated package of concepts leading to modernized practices for conducting contaminated site work. It explains the relationship of the Triad to existing approaches such as the DQO process, lists the advantages and disadvantages of the Triad, and notes regulatory and organizational barriers that may present obstacles to its use.

B. Site-Specific Resources for Site Assessment

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

EPA Office of Enforcement and Compliance Assurance Industry Sector Notebooks
Developed by EPA's Office of Enforcement and Compliance Assurance (OECA), the sector notebooks provide extensive profiles of selected major industries. Each profile includes information about an industrial process, information about pollution prevention techniques, pollutant release data, pertinent federal statutes and regulations, compliance and enforcement data, information on government and industry partnerships, descriptions

of innovative programs, and bibliographic references. Profiles are available online and on hard copy for the following industry sectors:

- *Aerospace (EPA 310-R-98-001)*
- ***NEW!** Agricultural chemical, pesticide and fertilizer (EPA 310-R-00-003)*
- ***NEW!** Agricultural crop production (EPA 310-R-00-001)*
- ***NEW!** Agricultural livestock production (EPA 310-R-01-002)*
- *Air transportation (EPA 310-R-97-001)*
- *Dry cleaning (EPA 310-R-95-001)*
- *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)*
- *Nonfuel, nonmetal mining (EPA 310-R-95-011)*
- *Oil and gas extractions (EPA 310-R-99-006)*
- ***UPDATED!** Organic chemical (EPA 310-R-95-012)*
- *Petroleum refining (EPA 310-R-95-013)*
- *Pharmaceutical (EPA 310-R-97-005)*
- *Plastic resins and manmade fibers (EPA 310-R-97-006)*
- ***UPDATED!** 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

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 online:

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

Frequently Asked Questions about Dry Cleaning (EPA 744-K-98-002)

The EPA fact sheet addresses a number of issues related to dry cleaning, including EPA's interest in dry cleaning, the process of dry cleaning, the human health and environmental risks associated with chemical solvents used in the dry cleaning process, what dry cleaners and the government are doing to reduce those risks, and other methods of cleaning clothes. The document lists additional sources of information about dry cleaning and EPA's Design for the Environment Program.

Ordnance and Explosives Mandatory Center of Expertise (MCX) and Design Center
The mission of the Ordnance and Explosives MCX and Design Center, which is hosted by the U.S. Army Engineering and Support Center in Huntsville, Alabama, is to safely eliminate or reduce risks posed by ordnance, explosives, and recovered chemical warfare materials at current or formerly used defense sites. The Internet site provides links to information about technical requirements for contracting; fact sheets on ordnance and explosives programs; frequently asked questions related to ordnance response actions; innovative technologies, presentations, and technical papers; and technical guidance and procedures related to ordnance and explosives. Points of contact also are identified.

C. Technology-Specific Resources for Site Assessment

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.

Dry Cleaner Site Assessment & Remediation - A Technology Snapshot
In this report, the State Coalition for Remediation of Drycleaners (SCRD) evaluates trends in the use of technologies to address dry cleaner sites across the country over the last 3 years. The analysis is based on the responses of 28 states to a 2002 SCRD survey and comparison of these responses to those from a similar survey conducted in 1999. SCRD gathered information on technologies that states have used or evaluated for assessment and remediation of solvent-contaminated dry cleaning sites as well as program- and project-specific information concerning contaminant types, general costs, technologies, cleanup standards, guidance documents, and lessons learned.

Study of Assessment and Remediation Technologies for Dry Cleaner Sites
Prepared by SCRD with the support of EPA's OSRTI, the report presents the results of the coalition's evaluation of assessment and remediation technologies commonly used in cleaning up dry cleaner sites. The evaluation was based on the results of responses to questionnaires sent to entities involved in such cleanups in 1999. The report presents those results in detail. An appendix in the report provides descriptions and brief evaluations of assessment technologies frequently used at dry cleaner sites.

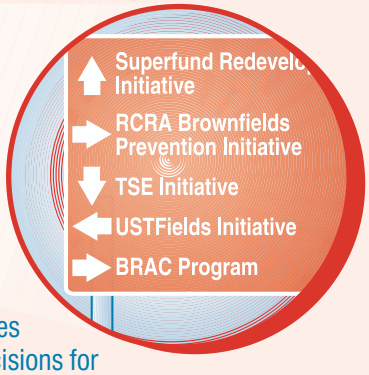
Underground Storage Tanks and Brownfields Sites (EPA 510-F-00-004)
The fact sheet focuses on EPA's "USTfields" Initiative for addressing brownfields properties at which redevelopment is complicated by real or perceived environmental contamination originating from federally regulated USTs. The fact sheet describes the 50 pilot projects implemented or to be implemented under the two phases of the initiative.

Where Do We Go from Here?

Result of Site Assessment	Course of Action
No evidence of 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.*

S1 OTHER REDEVELOPMENT INITIATIVES:

Reducing Barriers to Redevelopment of Brownfields Sites



In partnership with states, tribes, territories, and a broad range of stakeholders, EPA is undertaking the **Land Revitalization Initiative** to restore land to productive economic and green space uses. In April 2003, EPA announced an action agenda to serve as a blueprint for incorporating land reuse into its Superfund, RCRA, brownfields, and UST hazardous waste cleanup programs. Land Reuse Coordinators and Land Reuse Teams have been established in each of EPA's 10 regional offices to ensure coordination among the cleanup programs in implementing the Land Revitalization Agenda. Additional information is available at ***www.epa.gov/oswer/landrevitalization***. EPA has published the *Directory of Technical Assistance for Land Revitalization* (EPA542-B-03-001) to provide information about technical assistance that is available from EPA and other federal agency programs. The document is available at ***www.brownfieldstsc.org***.

At the same time that EPA began its Land Revitalization Initiative, the Agency also announced the **One Cleanup Program**, a long-term initiative designed to support the ongoing planning and quality improvement efforts of EPA's cleanup programs. The goal of the program is to improve the coordination, speed, and effectiveness of cleanups at RCRA and Superfund, brownfields, leaking UST, federal facility, and other contaminated sites. By encouraging improved coordination among EPA programs and with government at all levels, the One Cleanup Program supports the transfer of ideas, experiences, and innovations across all programs as well as effective coordination and communication with the public. More information about EPA's Once Cleanup Program is available at ***www.epa.gov/swerrims/onecleanupprogram***.

A Quick Look

- EPA's Land Revitalization Initiative was established to incorporate land reuse into the Agency's cleanup programs.
- The One Cleanup Program establishes activities to improve the pace, efficiency, and effectiveness of EPA's cleanup programs through improved communication and coordination.
- EPA is addressing redevelopment of Superfund sites through SRI.
- The purpose of the RCRA Brownfields Prevention Initiative is to prevent creation of future brownfields and ensure successful cleanup and long-term, sustainable reuse of RCRA facilities.
- Under the RCRA Brownfields Prevention TSE Initiative, selected sites will receive concentrated, short-term support to prevent them from becoming brownfields sites.
- EPA's OUST supports the cleanup and redevelopment of petroleum-contaminated sites.
- Sharing of lessons learned can benefit the BRAC and Brownfields Programs.

The **Superfund Redevelopment Initiative** (SRI) reflects EPA's commitment to consider reasonably anticipated future land uses when making remedy decisions for Superfund sites so that these sites can be cleaned up to be protective for future users of the land. Because Superfund and brownfields sites are often co-located, there are many opportunities to share information, experiences, and lessons learned at the site level in addition to opportunities for transfer of ideas between programs at other levels. Spotlight 2 provides more detailed information about Superfund Redevelopment.

Under EPA's **RCRA Brownfields Prevention Initiative**, pilot projects are designed to test approaches that better integrate reuse considerations into the corrective action cleanup process. The initiative also addresses concerns that application of RCRA to cleanup activities at brownfields sites may be slowing the progress of cleanup efforts. Although no grant money is associated with the pilot projects, EPA has engaged contractors to help find ways to expedite cleanup at the pilot sites. Additional information about the RCRA Brownfields Prevention Initiative is provided online at ***www.epa.gov/swerosps/bf/rcrabf.htm***.

The **RCRA Brownfields Prevention Targeted Site Efforts (TSE) Initiative** is intended to focus short-term attention and support on sites at which cleanup has been delayed or slowed and to serve as a catalyst to initiate cleanup at such sites in order to prevent them from becoming brownfields sites. Implemented at the regional level, the TSE program will apply to sites that have significant potential for

Continued on next page

S1 Continued ...

OTHER REDEVELOPMENT INITIATIVES:

Reducing Barriers to Redevelopment of Brownfields Sites

redevelopment and reuse and that require a limited amount of EPA support to achieve the next level of cleanup, consensus, or site closure. EPA will offer a small amount of funding to support TSE efforts in each region. For more information about the program, visit ***www.epa.gov/swerosps/rcrabf/tse.htm***.

EPA's Office of Underground Storage Tanks (OUST), focuses on how to improve the cleanup of sites affected by petroleum contamination, thereby fostering the redevelopment of those sites (see Spotlight 4, Underground Storage Tanks at Brownfields Sites, for more information about the USTFields Initiative). Additional details about the initiative also are available online at ***www.epa.gov/oust/rags/ustfield.htm***.

Many aspects of DoD's **Base Realignment and Closure (BRAC) Program** and EPA's Brownfields Program are similar. Significant issues common to both programs include eliminating disincentives and providing assurances to developers and financiers, considering future land use in cleanup decisions, and implementing institutional controls. Because federal facility and brownfields cleanups can have similar effects on communities, EPA and DoD are exploring methods of coordinating BRAC and brownfields activities. Visit the BRAC Internet site at ***www.dtic.mil/envirodod/brac/*** for online access to relevant policies and initiatives, publications, and points of contact.

NEW

S2 SUPERFUND REDEVELOPMENT

EPA's **Superfund Redevelopment Initiative** (SRI) reflects its commitment to consider reasonably anticipated future land uses when making remedy decisions at Superfund hazardous waste sites so that these sites can be cleaned up to be protective of human health and the environment under future uses. Through case studies, fact sheets, an online database of sites, and an Internet site, SRI is providing information about reuse options and the lessons learned through these projects. It is forming partnerships with states, local government agencies, citizen groups, and other federal agencies to restore previously contaminated properties as valuable assets for communities. Some of SRI's most valuable partnerships are with private groups with national memberships. For example, the U.S. Soccer Foundation provides free design and engineering services and sports equipment to communities that want to build soccer fields on Superfund land that has been cleaned up, and where EPA has determined that recreational use is appropriate. The Academy of Model Aeronautics also has an agreement with SRI to provide services, such as mowing and fence maintenance, on cleaned-up land in return for SRI's help in identifying suitable Superfund land that can used by their membership for flying model airplanes. SRI is exploring similar arrangements with partners that want to make agreements with local communities for appropriate use of cleaned-up properties. These partners contribute their services and expertise to communities in exchange for use of the land. SRI contributes information about suitable sites and contacts with Regional staff and local stakeholders. EPA also is committed to the ongoing evaluation of its policies and practices to determine whether changes are needed to further the effort to reuse sites.

Passage of the Brownfields Law in January 2002 clarified CERCLA liability provisions for landowners and potential property owners including the requirement to conduct all appropriate inquiries into the previous ownership, uses, and environmental conditions of a property. Spotlight 3 provides additional information on All Appropriate Inquiry.

On November 10, 2004, EPA announced a new phase of SRI, the **"Return to Use" initiative**. The Initiative focuses on National Priorities List sites that were cleaned up before EPA's current emphasis on considering reuse during response activities. Many of these sites have remained vacant. Returning these sites to beneficial use will provide local communities with valuable green space, recreational amenities, or commercial property. Removing the stigma associated with fenced and vacant Superfund sites may also increase local property values and the tax base. As part of the Initiative, EPA is committed to reviewing remedies in place to determine whether there are relatively modest ways to remove barriers to reuse that are not necessary for the protection of human health and the environment or the remedy. Such actions might include modifying fences that are no longer necessary, issuing Ready for Reuse (RfR) Determinations that identify how a site can be used while maintaining protection of people and the environment, eliminating misleading signs and unnecessary obstacles when conditions at the site no longer merit them, and ensuring that institutional controls are appropriate and effective.

As a starting point for the Initiative, EPA is establishing demonstration projects through partnerships with communities to overcome obstacles to reuse. For its part, EPA will:

- Perform appropriate risk and remedy analyses to support decisions that consider reuse of sites.
- Issue RfR Determinations.

Continued on next page

A Quick Look

- For several years EPA has supported community efforts to return Superfund sites to use through the SRI.
- The "Return to Use" initiative focuses on National Priorities List sites that were cleaned up before EPA's current emphasis on considering reuse during response activities.
- EPA will review remedies in place to identify alterations to the remedy to encourage reuse.
- EPA's new Ready for Reuse Determination is a tool that is used to indicate to the marketplace a property's suitability for reuse.
- EPA will establish demonstration projects through partnerships with communities to overcome obstacles to reuse.

S2 Continued ...

SUPERFUND REDEVELOPMENT

Ready for Reuse Determinations

On February 18, 2004, EPA issued its new Guidance for Preparing Superfund Ready for Reuse Determinations at Superfund sites). A RfR determination is a new type of document developed by the Agency to provide potential users of Superfund sites with an environmental status report that documents a technical determination by EPA, in consultation with states, tribes, and local governments, that all or a portion of a real estate property at a site can support specified types of uses and remain protective of human health and the environment. With this new guidance, EPA provides its staff with the information needed to make and document these determinations, and thus takes a major step forward in its effort to facilitate the reuse of Superfund sites. With the creation of the RfR determination, potential users and the real estate marketplace will have an affirmative statement written in plain English and accompanied by supporting decision documentation, that a site identified as ready for reuse will remain protective as long as all required response conditions and use limitations identified in the site's response decision documents and land title documents continue to be met.

A copy of this guidance is available at ***www.epa.gov/superfund/programs/recycle/rfrguidance.pdf***.

- Direct communities to tools and resources, such as comfort letters and involuntary acquisition fact sheets, which relate to liability issues.
- Connect communities with EPA's national reuse partners, such as the U.S. Soccer Foundation.
- Work with communities that are creating site reuse plans to ensure that the remedies will support the planned activities.

The expectation for local communities is a commitment to the reuse of the Superfund site. Additional contributions will depend on the site's needs and the community's resources.

The Superfund Redevelopment Help Desk at (434) 817-0470 provides Regional Superfund Redevelopment coordinators, RPMs, site attorneys, OSCs, CICs and other staff with information and assistance in carrying out Superfund reuse-related activities. It operates from 8 am to 5 pm, Monday through Friday, with voice mail service after hours.

Key Resources

Visit EPA's SRI Web site at ***www.epa.gov/superfund/programs/recycle*** for additional information on Superfund Redevelopment and the Return to Use Initiative. Related publications available on the site include:

- Land Use in the CERCLA Remedy Selection Process: OSWER 9355.7-04. May 25, 1995.
- Reusing Superfund Sites: OSWER 9230.0-85. March, 2001
- Reusing Cleaned Up Superfund Sites: Recreational Use of Land Above Hazardous Waste Containment Areas: OSWER 9230.0-93: April 12, 2001.
- Reuse Assessments: A Tool To Implement the Superfund Land Use Directive: OSWER 9355.7-06P. June 4, 2001.
- Reusing Superfund Sites: Commercial Use Where Waste is Left on Site: OSWER 9230.0-100, February 26, 2002.
- Reusing Cleaned Up Superfund Sites: Golf Facilities Where Waste is Left on Site: OSWER 9230.0-109. November 20, 2003.
- Guidance for Preparing Superfund Ready for Reuse Determinations: OSWER 9365.0-33. February 12, 2004. (Joint OSRTI/OSRE guidance).
- Guidance for Documenting and Reporting the Superfund Revitalization Performance Measures: OSWER 9202.1-26. November 5, 2004.
- Superfund Redevelopment: Realizing Possibilities: Video
- Frequently Asked Questions: Superfund Redevelopment Program
- Frequently Asked Questions: Return to Use Program

For more information see the resources numbered 75, 77, 93, 121, 123, 124, 125, 127, 128, 129, 130, 131, 141, 147, 152, 153, 154, and 173 in the Index of Resources beginning on page I-1.

NEW

S3

ALL APPROPRIATE INQUIRY:

Standards and Practices to Provide CERCLA Liability Protections

On January 11, 2002, President Bush signed the Small Business Liability Relief and Revitalization Act ("the Brownfields Law"). The Brownfields Law clarifies CERCLA liability provisions for landowners and potential property owners. It provides liability protections for certain property owners, if the property owners comply with specific provisions, including conducting all appropriate inquiry into present and past uses of the property and the potential presence of environmental contamination on the property. The all appropriate inquiry standards and practices are relevant to:

- The innocent landowner defense to CERCLA liability (§101 (35))
- The contiguous property exemption to CERCLA liability (§107 (q))
- The bona fide prospective purchaser exemption to CERCLA liability (§107 (r)(1) and (§101 (40))
- The brownfields site characterization and assessment grant programs (§104 (k)(2))

The Brownfields Law amends Section 101(35)(B) of CERCLA to include an interim standard for conducting all appropriate inquiry and requires EPA to promulgate regulations that establish federal standards and practices for conducting all appropriate inquiries. Congress directed EPA to include, within the standards for all appropriate inquiry, the ten criteria shown below:

- The results of an inquiry by an environmental professional
- Interviews with past and present owners, operators, and occupants of the facility for the purpose of gathering information regarding the potential for contamination at the facility
- Reviews of historical sources, such as chain of title documents, aerial photographs, building department records, and land-use records, to determine previous uses and occupancies of the real property since the property was first developed
- Searches for recorded environmental cleanup liens against the facility that are filed under federal, state, or local law
- Reviews of federal, state, and local government records; waste disposal records; underground storage tank records; and hazardous waste handling, generation, treatment, disposal, and spill records concerning contamination at or near the facility
- Visual inspections of the facility and adjoining properties
- Specialized knowledge or experience on the part of the defendant
- The relationship of the purchase price to the value of the property if the property was not contaminated
- Commonly known or reasonably ascertainable information about the property
- The degree of obviousness of the presence or likely presence of contamination at the property and the ability to detect the contamination by appropriate investigation

A Quick Look

- All appropriate inquiry refers to the requirements for assessing the environmental conditions of a property prior to its acquisition.
- All appropriate inquiry provides CERCLA liability protections for certain landowners and potential property owners.
- The Brownfields Law amends Section 101(35)(B) of CERCLA to include an interim standard for conducting all appropriate inquiry.
- EPA proposed regulations for standards and practices for all appropriate inquiries on August 26, 2004.

EPA's Proposed Rule: Standards and Practices for All Appropriate Inquiries was signed by the EPA Administrator and published in the Federal Register on August 26, 2004 (69 FR 52542). The proposed rule would establish specific regulatory requirements for conducting all appropriate inquiries into the previous ownership, uses, and environmental conditions of a property for the purposes of qualifying for certain landowner liability protections under CERCLA. EPA developed the proposed

Continued on next page

S3 Continued ...

ALL APPROPRIATE INQUIRY:

Standards and Practices to Provide CERCLA Liability Protections

rule using a Negotiated Rulemaking process. The proposed rule retains the regulatory language developed by the Negotiated Rulemaking Committee. The public comment period for the proposed rule closed on November 30, 2004. Currently, EPA is reviewing the comments received in response to the proposed rule and considering the issues raised by commenters. After considering all issues raised within the public comments, EPA will respond to the comments and develop a final rulemaking.

The interim standard for properties purchased after May 31, 1997, which remains in place until EPA promulgates a final rule establishing federal standards for all appropriate inquiries, is the ASTM E1527-97 or ASTM E1527-00, entitled "Standard Practice for Environmental Site Assessments: Phase I Environmental Site Assessment Process.

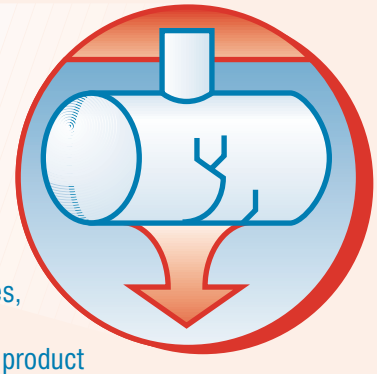
Key Resources

Visit the EPA Web site at ***http://www.epa.gov/brownfields/regneg.htm*** for copies of the proposed rule, a fact sheet, and supplemental information on all appropriate inquiry.

For detailed information on specific aspects of the proposed rule, contact Patricia Overmeyer of EPA's Office of Brownfields Cleanup and Redevelopment at (202) 566-2774 or at *overmeyer.patricia@epa.gov*.

S4 USTs AT BROWNFIELDS SITES:

Technology Options for Tank Remediation



Of the estimated 450,000 brownfields sites in the United States, approximately 100,000 to 200,000 contain abandoned USTs or are affected by leaks of petroleum from such tanks. EPA and many state and local leaders are committed to achieving sustainable development and preserving green space by cleaning up and reusing these petroleum brownfields, which are often located on corner lots and in other prime locations. Reusing abandoned gasoline stations helps to preserve green space, reduce urban sprawl, and reduce the distance that people have to travel, thus decreasing air pollution. Such sites as the West Ogden Pocket Park, a former service station, had been used for illegal dumping and were eyesores to the Chicago community. Cooperation between the Chicago Department of Buildings, Department of the Environment, and Department of Transportation led to tank removal, site remediation, and site restoration. In summer 2001, the West Ogden Pocket Park opened, adding much needed green space to its neighborhood.

With so many UST sites requiring remediation, EPA is promoting faster, more effective, and less costly alternatives to established cleanup methods. EPA and states are continuing their legacy of developing and disseminating innovative tools to address petroleum brownfields. A Ready-for-Reuse Determination is one such tool. It is being used in Sayre, Oklahoma and other places to acknowledge that the site has been cleaned up and is ready and available for a particular type of reuse. Site inventories are helping bring property owners together with end users who may want to use the properties.

Although established technologies such as P&T systems or excavation and disposal in a landfill, have proven effective and are frequently used, innovative technologies may be applicable for cleanup of USTs. EPA's OUST has worked with EPA's ORD to foster development of innovative site assessment and cleanup technologies, such as field measurement techniques, soil vapor surveying, vacuum-enhanced free product recovery, active and passive bioremediation, and MNA. OUST continues to encourage scientifically sound, rapid, and cost-effective corrective action at UST sites. It also encourages the use of expedited site assessments as a means of streamlining the corrective action process, improving data collection, and reducing the overall cost of remediation. The May 2004 publication *Technologies for Treating MtBE and Other Fuel Oxygenates*, (available at ***www.epa.gov/tio/download/remed/542r04009/542r04009.pdf***) is an example of new informational materials that are relevant to UST remediation.

A Quick Look

- USTs are present at many brownfields sites because the owners have closed their businesses and do not have the funds necessary to remove the tanks or properly clean up the tanks.
- Contaminants likely to be found at UST sites include petroleum hydrocarbons, gasoline, diesel fuel, MtBE, BTEX, JP-4 jet fuels, and solvents.
- The USTFields Initiative focuses attention on abandoned or underused industrial and commercial properties at which redevelopment is complicated by environmental contamination originating from USTs.
- The Brownfields Law allocates funding each year to assess and clean up petroleum-contaminated brownfields sites.

Prior to the enactment of the Small Business Liability Relief and Brownfields Revitalization Act or Brownfields Law, petroleum-contaminated sites were not eligible for traditional brownfields funding. Therefore, in 2000, to encourage the reuse of abandoned properties contaminated with petroleum from USTs, OUST created the USTFields Initiative. A total of 50 projects were awarded up to $100,000 each to assess, clean up, and restore high-priority petroleum-impacted sites. Although no additional USTFields pilot projects will be awarded funds, opportunities to address relatively low-risk petroleum sites are now available through the brownfields assessment, cleanup, and revolving loan fund grants. In addition, high-priority and high-risk sites can be addressed by states through the Leaking Underground Storage Tank (LUST) Trust Fund.

The Brownfields Law expanded the original EPA Brownfields Program by making relatively low-risk

Continued on next page

S4 Continued ...

USTs AT BROWNFIELDS SITES:
Technology Options for Tank Remediation

petroleum sites eligible for brownfields assessment and cleanup grant funding and by allotting 25 percent of the funding strictly for petroleum brownfields assessment and cleanup. Previously, petroleum sites were ineligible for brownfields grants funding. In 2004, EPA awarded close to $23 million in brownfields grants to assess and clean up petroleum-contaminated sites. Recipients included abandoned sites such as gasoline stations, industrial properties, and retail properties that contain or are perceived to contain petroleum contamination.

For more information, see the resources numbered 14, 17, 27, 56, 80, 102, 103, 162, 171, and 173 in the Index of Resources beginning on page I-1.

Key Resource

EPA's Office of Underground Storage Tanks Internet Site

View online at ***www.epa.gov/oust***.

Hosted by EPA's OUST, the Internet site provides resources and tools to help owners and operators of UST sites and brownfields stakeholders better assess their options for operation, maintenance, and cleanup of USTs. Information and guidance about technologies suitable for cleaning up releases from UST systems are provided, as are details about current federal UST regulations and UST program priorities, including specific details about the USTFields Initiative. Points of contact in each of the EPA regional offices also are identified. An extensive number of UST publications can be viewed online or downloaded at no charge. In addition, information about state-sponsored UST programs, including links to state Internet sites, is provided on OUST's site at ***www.epa.gov/oust/states/index.htm***.

Some of the more recent publications available at ***www.epa.gov/oust/pubs/index.htm*** include:

- *How to Evaluate Alternative Cleanup Technologies for Underground Storage Tank Sites: A Guide for Corrective Action Plan Reviewers* (EPA 510-R-04-002), May 2004
- *Underground Storage Tanks: Building on the Past to Protect the Future* (EPA 510-R-04-001), March 2004
- *Reuse of Abandoned Gas Station Sites* (EPA-510-F-04-001), February 2004

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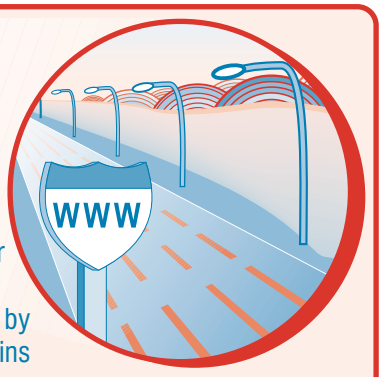
NEW

S5 SUSTAINABLE MANAGEMENT APPROACHES AND REVITALIZATION TOOLS - ELECTRONIC (SMARTe)



Revitalization of contaminated sites is a global concern that requires an integrated approach to mitigate the risks to human health and the environment. Many countries have committed extensive resources to addressing environmental, social, and economic issues related to the cleanup and revitalization of brownfields sites. The challenge is to determine how to capitalize on the available resources, expertise, and knowledge and effectively share and transfer that information to the organizations and individuals responsible for making decisions and implementing revitalization efforts.

EPA and the German Federal Ministry for Education and Research Bundesministerium Für Bildung und Forschung (BMBF) have initiated a cooperative effort to share such information and evaluate new solutions for the revitalization of potentially contaminated sites.

Sustainable Management Approaches and Revitalization Tools - electronic (SMARTe) is a Web-based information source and decision support tool. The purpose of SMARTe is to aid stakeholders in identifying, applying, and integrating tools and technologies to facilitate the revitalization of potentially contaminated sites in the United States. SMARTe is intended to be a living Web-based system that can be updated as new tools, technologies, and approaches become available for revitalization.

SMARTe will provide a decision support tool for developing and evaluating plans for land revitalization. Its decision analysis capabilities are intended to be used by brownfields project stakeholders for:

- Assessing both market and non-market costs and benefits of revitalization options
- Comparing alternative reuse scenarios
- Clarifying both private and public financing options
- Evaluating and communicating environmental risks
- Easing access to pertinent state specific information related to specific projects

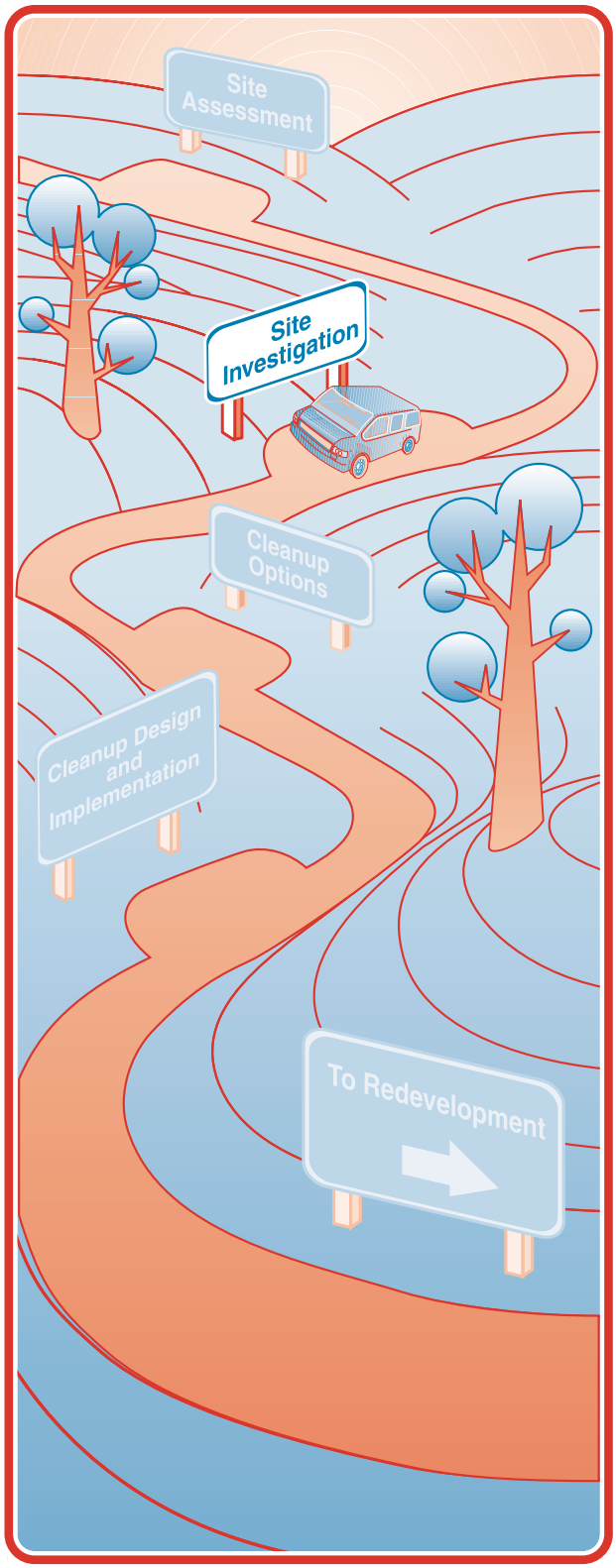
SMARTe is the umbrella providing entry points for tools and information at the level of detail desired by the user. SMARTe contains four components:

- An electronic document that provides information on the revitalization process
- A screening tool that leads the user through the revitalization process
- A tool box to analyze and solve revitalization issues
- A search engine for information tools, and best practices

SMARTe will provide the analytical tools needed to implement and integrate each component of the decision process. In the future, SMARTe will use expert system technology to integrate environmental, social and economic issues in a multi-criteria decision analysis so that stakeholders can evaluate alternative reuse scenarios. The goal of SMARTe is to not only provide the tools and information needed by a user to solve a revitalization issue, but also to integrate these tools and information into an assessment that facilitates sustainable revitalization.

SMARTe is accessible at ***www.smarte.org***.

SITE INVESTIGATION



Identify the Source, Nature, and Extent of Contamination

The site investigation phase focuses on confirming whether any contamination exists at a site, locating any 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 minimize delays or costs in the redevelopment and reuse of property. To ensure that sufficient information is obtained to support future decisions, the proposed cleanup measures and the proposed end use of the site should be considered when identifying data needs during the site investigation.

A site investigation, also referred to as an ASTM Phase II environmental site assessment, 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. Examples of sampling and analysis technologies that may be useful during this phase are presented in Appendix A, Table A-2, Technologies for Analyzing Contaminants at Brownfields Sites.

During site investigation, use of the Triad approach allows decision-makers to implement a strategy that is flexible and meets the needs of the site. Use of systematic planning can result in lower overall project costs. Use of dynamic working strategies can reduce or eliminate the need for multiple mobilizations on a site to reach closeout. For brownfields sites, where decision-making is closely tied to economic constraints and public acceptance, increased information value obtained using real-time measurement technologies collaboratively with definitive fixed laboratory methods for data collection will provide stakeholders with the confidence they need at a reduced cost. Reducing project costs and schedules

to obtain closure means that more dormant or abandoned sites may become economically viable for redevelopment.

What Do We Need to Know?

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 state voluntary cleanup program (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?

The following table describes 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 on site 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 quality assurance (QA) and quality control (QC), the technologies can achieve quantitative results equal to those achieved by off-site analytical laboratories.

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:
  - *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, geophysical, and ecological 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 exposure pathways of direct contact, ingestion, or inhalation of soil and dust, water, and air.
- Depending on state regulatory requirements, 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

Where Do We Find Answers to Our Technology Questions?

Listed below are examples of resources that assist in identifying the environmental condition of a site. The resources are listed alphabetically under the following categories:

A. Resources for Site Investigation

B. Site-Specific Resources for Site Investigation

C. Technology-Specific Resources for Site Investigation

Access the Road Map online at ***www.brownfieldstsc.org*** to view or download the following resources electronically or to obtain a link that provides complete ordering information.

A. Resources for Site Investigation

ASTM Standard Guide for Accelerated Site Characterization for Confirmed or Suspected Petroleum Releases (E1912-98(2004))
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 a cost and can be ordered online at ***www.astm.org***.

ASTM Standard Guide for Environmental Site Assessments: Phase II Environmental Site Assessment Process (E1903-97(2002))
Developed by ASTM, the guide discusses a framework for employing good commercial and customary practices in the United States during 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 guide, which is available at a cost, can ordered online at ***www.astm.org***.

Brownfields and Land Revitalization Technology Support Center
EPA established BTSC to ensure that brownfields decision-makers are aware of the full range of technologies available for conducting site assessments and cleanup and can make informed decisions for their sites. The center helps government decision-makers evaluate strategies to streamline the site assessment and cleanup process, identify and review information about complex technology options, evaluate contractor capabilities and recommendations, explain complex technologies to communities, and plan technology demonstrations. The center is coordinated through EPA's OSRTI and works through EPA's ORD laboratories. BTSC works closely with EPA's Office of Brownfields Cleanup and Redevelopment and in partnership with USACE and ANL. Localities can submit requests for assistance through their EPA Regional Brownfields Coordinator, online at *www.brownfieldstsc.org*, or by calling (877) 838-7220 (toll free). For more information about BTSC, contact Dan Powell of EPA's OSRTI at (703) 603-7196 or powell.dan@epa.gov.

Brownfields Technology Primer: Requesting and Evaluating Proposals that Encourage Innovative Technologies for Investigation and Cleanup (EPA 542-R-01-005)
BTSC prepared this primer to assist site owners, project managers, and others preparing RFPs to solicit support in conducting activities to investigate and clean up contaminated sites. It is specifically intended to assist those individuals in writing specifications that encourage contractors and technology vendors to propose options for using innovative characterization and remediation technologies at brownfields sites. The primer also provides information, from a technology perspective, to guide review teams in their evaluations of proposals and the selection of qualified contractors.

Brownfields Technology Primer: Using the Triad Approach to Streamline Brownfields Site Assessment and Cleanup (EPA 542-B-03-002)
BTSC prepared this document to provide an educational tool for site owners, project managers, and regulators in order to help streamline assessment and cleanup activities at brownfields sites. Strategies that reduce costs, decrease time frames, and positively affect regulatory and community acceptance also can improve the economics of redevelopment at brownfields sites. Increased attention to brownfields sites and the manner in which they are redeveloped places greater importance on the approach to site cleanup. This primer is one in a series that will address specific cleanup issues.

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

Data Quality Objective Process for Hazardous Waste Site Investigations (EPA 600-R-00-007)
The document focuses on the DQO process as the appropriate systematic planning process to support decision-making. The DQO process is an important tool for project managers and planners to use in defining the types, quality, and quantity of data needed to make defensible decisions. The document is based on the principles and steps developed in Guidance for the Data Quality Objectives Process but is specific to investigations of hazardous waste sites. The guidance is also consistent with Data Quality Objectives Process for Superfund: Interim Final Guidance (EPA 1993) and Soil Screening Guidance: User's Guide (EPA 1996). Although the document focuses on EPA applications, the guidance also is applicable to programs at the state and local levels.

Directory of Technical Assistance for Land Revitalization (BTSC) (EPA 542-B-03-001)
BTSC prepared this directory to provide information about technical assistance that is available from federal agencies to assist regional, state, and local government personnel in making assessment and cleanup decisions for brownfields, reuse, and revitalization sites. This directory includes information about 37 organizations within 10 federal agencies that provide different types of support to help with site assessment and cleanup, including technical support and funding sources. Profiles are included for these agencies and organizations and contain the following types of information: background and location information, relevancy to revitalization, description of the areas of expertise available, discussion of the types of services available, types of funding available and eligibility, contact information and the process for requesting assistance, and examples of specific instances in which the organization has previously provided support relevant to site revitalization. Information in the profiles is believed to be current as of March 2003. To help maintain current information, the directory is available as an online database at *www.brownfieldstsc.org/directory/directory.cfm*.

Engineering and Design: Requirements for the Preparation of Sampling and Analysis Plans (EM 200-1-3)
Developed by USACE, this manual provides guidance for the preparation of project-specific SAPs for the collection of environmental data. In addition, the manual presents default sampling and analytical protocols that may be used verbatim or modified based in light of the DQOs for a specific project. The goal of the manual is to promote consistency in the generation and execution of sampling and analysis plans and therefore to help investigators generate chemical data of known quality for the purpose to which those data are to be used.

EPA Office of Solid Waste SW-846 Online: Test Methods for Evaluating Solid Wastes, Physical/Chemical Methods
Developed by EPA's OSW, the Web site provides test procedures and guidance that EPA recommends for use in conducting the evaluations and measurements needed to comply with requirements established under RCRA. The online manual presents state-of-the-art methods of routine analytical testing that have been adapted for use under the RCRA Program. All the documents found in the Third Edition of SW-846, as updated by updates I, II, IIA, IIB, III, and IIIA, are located at the Web site. It presents procedures for field and laboratory QC, sampling, identification of hazardous constituents in wastes, determination of the hazardous characteristics of wastes (toxicity, ignitability, reactivity, or corrosivity), and determination of the physical properties of wastes. It also provides guidance on selecting appropriate methods. The methods can be downloaded from the SW-846 Web site at no cost.

EPA REmediation And CHaracterization Innovative Technologies (REACH IT) Online Searchable Database
The EPA REACH IT online searchable databases sponsored by EPA's OSRTI is a service provided free of charge to both users and technology vendors. This database provides users comprehensive, up-to-date information about more than 256 characterization technologies and 481 remediation technologies and their applications. It combines information submitted by technology service providers about remediation and characterization technologies with information from EPA, DoD, DOE, and state project managers about sites at which innovative technologies are being deployed. 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.

Evaluation of Selected Environmental Decision Support Software (DSS)
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.

Field Analytic Technologies Encyclopedia (FATE)
The online encyclopedia provides information about technologies that investigators can use in the field to characterize contaminated soil and groundwater; monitor the progress of remedial efforts; and, in some cases, perform confirmation sampling and analysis to support closeout of a site. The encyclopedia emphasizes the systematic planning component of the Triad as a necessary step to identify factors and issues that contribute to decision uncertainty. The site also provides a searchable function to enable the user to find an appropriate technology based on the contaminants at a site and the media to be treated, and provides site summaries, links to relevant resources, and training modules. The encyclopedia serves a wide range of users, from engineering students to field technicians and site managers.

Field Sampling and Analysis Technologies Matrix, Version 1.0
The matrix, an online 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: The Keys to Cost-Effective Site Characterization and Cleanup
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.

Improving the Cost-Effectiveness of Hazardous Waste Site Characterization and Monitoring
The report introduces a new standard promoted by EPA's OSWER and OSRTI that encourages more effective and less costly strategies for characterizing and monitoring hazardous waste sites. The new approach uses an integrated triad of systematic planning, dynamic work plans, and on-site analysis for data collection and technical decision-making at hazardous waste sites. Individually, none of the concepts in the Triad approach is new, but it has been demonstrated that the integrated approach completes projects faster, cheaper, and with greater regulatory and client satisfaction than the traditional phased approach. The report includes a list of additional resources regarding innovative technologies and site characterization.

Innovations in Site Characterization Case Study Series
The case studies provide cost and performance information about the 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:

- *Dexsil L2000 PCB/Chloride Analyzer for Drum Surfaces (EPA 542-R-99-003)*
- *Geophysical Investigation at Hazardous Waste Sites (EPA 542-R-00-003)*
- *Hanscom Air Force Base, Operable Unit 1 (EPA 542-R-98-006)*
- *Site Cleanup of the Wenatchee Tree Fruit Test Plot Site Using a Dynamic Work Plan (2000) (EPA 542-R-00-009)*
- ***NEW!** Technology Evaluation: Real-time VOC Analysis Using a Field Portable GC/MS (EPA 542-R-01-011)*

Innovative Remediation and Site Characterization Technologies Resources (EPA 542-C-04-002)
Produced by EPA's OSRTI, this CD-ROM contains resources that provide information to help federal, state, and private sector site managers evaluate site assessment and cleanup alternatives. The ability to gain access to resources that provide

information about innovative site characterization and remediation technologies will increase the understanding of those technologies and of the cost and performance factors related to them. Such understanding is essential to the consideration of those technologies for use in addressing contamination at hazardous waste sites. The information on the CD-ROM is broken down into seven categories: bulletins, fact sheets, journals, and newsletters; community involvement support; electronic resources; organizations, programs and partnerships; publication clearinghouses; publications; and regulatory resources. Several resources included on the CD-ROM also are available at the Road Map online. Copies of the CD-ROM can be ordered through the NSCEP at P.O. Box 42419, Cincinnati, Ohio 45242-2419 or by calling (800) 490-9198 (toll free).

Managing Uncertainty in Environmental Decisions

This paper was published in *Environmental Science and Technology*, a publication of the American Chemical Society, in October 2001. The preparation of this paper was coordinated through EPA OSRTI and included input from USACE. The paper discusses the relationship between data quality concepts and improved decision-making for environmental site investigation and cleanup projects. It addresses the context and use of site investigation-related terminology, conventional data quality approaches, and the use of the Triad approach.

Relationship Between SW-846, PBMS, and Innovative Analytical Technologies (EPA 542-R-01-015)

This paper, which was developed by EPA OSRTI in collaboration with EPA OSW, explains and documents EPA's position regarding testing methods (such as SW-846) used in waste programs and the relationship between regulatory flexibility regarding analytical methods and the use of on-site measurements to improve the cost-effectiveness of contaminated site cleanups. The paper also explains the advantages of a performance-based approach to analytical methods and the use of performance-based measurement systems (PBMS) within EPA programs. The Triad approach to site investigation and characterization, which is based on PBMS principles, also is briefly discussed. This paper will assist brownfields stakeholders by providing information and references that address flexibility and more affordable approaches to performing analyses at contaminated sites.

Resources for Strategic Site Investigation and Monitoring (EPA 542-F-01-030B)

The document is a concise guide to resources, both existing and planned, that support new, streamlined approaches to site investigation and monitoring. It describes training courses available, including some that are downloadable; lists sources of information about available technologies and guidance documents available through EPA programs; and provides sources of information about technology verification and demonstration efforts. The guide also lists a number of Web sites from which related publications and software can be downloaded. The document can be downloaded from CLU-IN under "Publications."

Sensor Technology Information Exchange (SenTIX)

SenTIX serves as a forum to exchange information about sensor technologies and needs. The purpose of the Web site is to serve as a tool to assist those working in the environmental field in cleaning up hazardous waste. The submit and search functions of SenTIX can help match users looking for a sensor technology to meet a specific need. The discussion forum also matches developers, vendors, and users. Users can provide sensor-related information online. The site was developed by (WPI), a nonprofit organization, under a cooperative agreement with EPA.

Site Characterization Library, Version 3.0 (EPA 600/C/05/001)

The Site Characterization Library (Library), which was created by EPA's ORD, National Exposure Research Laboratory (NERL), Environmental Sciences Division (ESD) in Las Vegas, Nevada, provides a centralized, field-portable source for site characterization information. EPA has compiled this compendium in electronic form on both CD-ROM and DVD. The resources contained in the Library were recommended by experts in the field of site characterization and are classified into the following four types: Web sites, audiovisual resources, documents, and software. Version 3.0 of the Library contains over 36,000 pages of guidance in the form of pdf files, software programs, video files, and Web links. It includes 400 documents, 80 Web links, 54 software programs, and 11 audiovisual files. The audio and video files are new to Version 3.0 and contain Internet training seminars relating to site characterization and monitoring technologies and approaches. An alphabetical index of all the resources in this Library is included to enable users to locate resources by title. A section on the Triad approach provides easy access to

information on this innovative site characterization methodology. A limited number of copies of Version 3.0 of the Library are available free of charge by mail from either of the following locations: EPA NSCEP, P.O. Box 42419, Cincinnati, Ohio 45242-2419, telephone: (513) 489-8190 or (800) 490-9198, fax: (513) 489-8695; or EPA NERL, ERD/ORD, P.O. Box 93478, Las Vegas, Nevada 89193-3478, telephone: (702) 798-2365 or (702)798-2207, e-mail: support.cmb@epa.gov.

Superfund Innovative Technology Evaluation (SITE) Program Demonstration Reports

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. The Emerging Technology Program Reports describe emerging innovative technologies and are developed under the terms of a cooperative agreement between the technology developer and EPA.

Sustainable Management Approaches and Revitalization Tools - electronic (SMARTe)

The SMARTe Web-based decision support tool is a cooperative effort of EPA, ITRC, and the German Federal Ministry for Education and Research. It is designed to aid stakeholders in identifying, applying, and integrating tools and technologies to facilitate revitalization of potentially contaminated sites in the United States. Currently, SMARTe contains information and databases that allow project stakeholders to assess both market and nonmarket costs and benefits of redevelopment options, clarify private and public financing options, evaluate and communicate environmental risks and opportunities, and access relevant state-specific information. By October 2007, SMARTe will use expert system technology to integrate environmental, social and economic issues in a multi-criteria decision analysis so that stakeholders can evaluate alternative reuse scenarios.

Triad Resource Center

The Triad Resource Center, a multiagency collaboration of EPA, USACE, ITRC, DOE, the U.S. Navy, the U.S. Air Force, and the State of New Jersey, is maintained by ANL. The center provides information about effective implementation of the Triad approach in decision-making during hazardous waste site characterization and remediation. It also provides an overview of the Triad principles and describes changes in regulatory functions that are required when the Triad approach is used at hazardous waste sites. Also available are descriptions of projects in which Triad principles have been successfully implemented. A reference and resource section includes general reference material, training resources, and information about upcoming conferences and workshops.

Using Dynamic Field Activities for On-Site Decision-Making: A Guide for Project Managers (EPA 540-R-03-002)

This document, which was developed by EPA, provides environmental cleanup professionals with guidance on how to use an on-site decision-making process to streamline field work at contaminated sites. This guidance focuses on how project managers can use dynamic work planning and field-based analytical methods to meet project goals and streamline site activities. Also included are examples of sites where this process has been successfully implemented.

B. Site-Specific Resources for Site Investigation

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

Application of Field-Based Characterization Tools in the Waterfront Voluntary Setting

This report investigates the reasons voluntary action to redevelop potentially contaminated property is subject to market constraints and other pressures that differ vastly from those that affect corrective action programs. It sets forth in detail the current level of application of field-based characterization tools at 115 waterfront brownfields sites and sites being addressed under VCP programs.

Characterization of Mine Leachates and the Development of a Ground-Water Monitoring Strategy for Mine Sites (EPA 600-R-99-007)
The objective of the research project was to develop a better understanding of the composition of mine waste leachates and to identify cost-effective groundwater monitoring parameters that could be incorporated into a monitoring strategy to reliably detect the migration of contaminants from hard-rock mining operations.

Resource for MGP Site Characterization and Remediation: Expedited Site Characterization and Source Remediation at Former Manufactured Gas Plant Sites (EPA 542-R-00-005)
The document provides current information about useful approaches and tools being applied at former manufactured gas plant (MGP) sites to the regulators and utilities that are engaged in characterizing and remediating these sites. The document outlines site management strategies and field tools for expediting site characterization at MGP sites; presents a summary of existing technologies for remediating MGP wastes in soils; provides sufficient information about the benefits, limitations, and costs of each technology, tool, or strategy for comparison and evaluation; and provides, through case studies, examples of the ways in which those tools and strategies can be implemented at MGP sites.

Risk-Management Strategy for PCB-Contaminated Sediments
The report, prepared by the National Research Council's Committee on the Remediation of PCB-Contaminated Sediments under an EPA grant, reviews the nature of the challenge involved in the management of sediments contaminated with PCBs; provides an overview of current knowledge about the inputs, fates, and effects of PCBs; recommends a risk-based framework for use in assessing remediation technologies and risk-management strategies; and elaborates on the framework as it is applicable specifically to sediments contaminated with PCBs.

C. Technology-Specific Resources for Site Investigation

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.

A User's Guide to Environmental Immunochemical Analysis
Developed by EPA's ORD, the document facilitates transfer of immunochemical methods for the analysis of environmental contaminants to the environmental analytical chemistry laboratory. Field personnel who may have a need to employ a measurement technology at a monitoring site also may find this manual helpful. The document instructs the reader in the use and application of immunochemical methods of analysis for environmental contaminants. It includes a general troubleshooting guide, along with specific instructions for certain analytes. The guide is written in a manner that allows the user to apply the information presented to immunoassays that are not discussed in the manual.

Adaptive Sampling and Analysis Program (ASAP), ANL
Developed by the Environmental Assessment Division (EAD) of ANL, an adaptive sampling and analysis program (ASAP) is an expedited approach to collecting data in support of hazardous waste site characterization and remediation. ASAPs rely on "real-time" data collection techniques and in-field decision-making to keep data collection as inexpensive, focused, and efficient as possible. The Web site provides links to related fact sheets and identifies sites where the ASAP approach has been successfully used.

Dense Nonaqueous Phase Liquids (DNAPLs): Review of Emerging Characterization and Remediation Technologies
This document, which was developed by ITRC, is an educational tool for regulators and project managers who work with DNAPL-contaminated sites. The emerging characterization technologies discussed in the document include geophysical and direct-push technologies, and in situ tracers. Emerging remediation technologies described in the document include in situ flushing, dynamic underground stripping, six-phase heating, and in situ chemical oxidation. The document also presents stakeholder concerns about application of these emerging technologies.

Environmental Security Technology Certification Program (ESTCP)

DoD's ESTCP Program promotes innovative, cost-effective environmental characterization and remediation technologies through their demonstration and validation at DoD sites. Successful demonstration leads to acceptance of innovative technologies by DoD end-users and the regulatory community. The Web site provides access to detailed reports about completed demonstration projects that have verified cost and performance of a technology, and fact sheets about ongoing projects where innovative technologies are being tested. Some of the areas under which these demonstrations are being conducted include chlorinated solvents, heavy metals, perchlorate, petroleum hydrocarbons and related compounds and contaminated sediments. Reports about site characterization, monitoring and process optimization are also available. The user can also use the online library to search for reports and fact sheets based on keywords.

Environmental Technology Verification Reports

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 are intended for buyers of technologies, developers of technologies, consulting engineers, and state and federal agencies. The documents verify the environmental performance characteristics of these technologies based on pilot project results. The reports as well as other information about the ETV Program are available on the ETV Web site. Approximately 100 ETV reports and verification statements about the performance of various technologies are available. Examples of these technologies include ambient ammonia sensors, mercury continuous emission monitors, arsenic test kits, rapid polymerase chain reaction (PCR) technologies, laser-induced fluorescence sensors, cone penetrometer-deployed sensors, environmental DSS, explosives detection, field-portable gas chromatograph/mass spectrometer, field-portable X-ray fluorescence analyzer, groundwater sampling, PCB field analysis technologies, portable gas chromatograph/mass spectrometer, soil and soil gas sampling, wellhead monitoring for volatile organic compounds (VOC), and soil sampling technologies.

EPA Dynamic Field Activities Internet Site

Hosted by EPA's OSRTI, the Internet site provides resources to assist decision-makers to streamline activities conducted at hazardous waste sites using real-time data and real-time decisions. Descriptions of the specific elements of dynamic field activities are provided, as well as related guidance documents and publications, including links to relevant Internet sites. Information about on-site analytical tools suitable for use during dynamic field activities also is provided.

EPA Technical Support Project

EPA's OSWER, regional waste management offices, and ORD established the Technical Support Project (TSP) in 1987 to provide technical assistance to regional remedial project managers (RPM), corrective action staff, and on-scene coordinators (OSC). The TSP consists of a network of Regional Forums and specialized Technical Support Centers in ORD, Office of Radiation Programs (ORP) laboratories, and OSWER's Environmental Response Team. The three technical forums within the TSP include the Engineering Forum, the Ground Water Forum, and the Federal Facilities Forum. Members of these forums work to improve communication and assist in technical transfer between the regions and the centers. The Forums also act as technical resources and disseminate TSP information to their regional colleagues. TSP issue papers and fact sheets, which are available online, provide information on remediation technologies or technical issues of concern. Technical assistance requests may be directed to any of the Technical Support Center contacts or to the regional forum representative. Contact information can be found on the TSP Web site at *www.epa.gov/tio/tsp*.

Federal Facilities Forum Issue: Field Sampling and Selecting On-Site Analytical Methods for Explosives in Water (EPA 600-S-99-002)

This paper was prepared by members of the Federal Facilities Forum, a group of EPA scientists and engineers representing EPA regional offices who are committed to identification and resolution of issues affecting federal facility Superfund and RCRA sites. The purpose of the paper is to provide guidance to RPMs about field sampling and on-site analytical methods for detecting and quantifying secondary explosive contaminants in water. The paper is divided into the following sections: (1) purpose and

scope, (2) background information, (3) overview of sampling and analysis of explosives, (4) DQOs, (5) sampling and analysis for explosives in water, (6) a summary of on-site analytical methods and (7) summary of EPA reference analytical methods for explosives in water.

National Environmental Technology Test Sites

The National Environmental Technology Test Sites (NETTS) Program was established by the Strategic Environmental Research and Development Program (SERDP) in 1993 to facilitate the transition of environmental remediation technologies to full-scale use by overcoming the barriers that presently inhibit commercialization of such technologies. SERDP projects focus on five key areas: cleanup, compliance, conservation, pollution prevention, and UXO. The program provides sites for applied research and comparative demonstration and evaluation of innovative and potentially cost-effective cleanup, characterization, and monitoring technologies. These test sites are located at Naval Construction Battalion Center, Port Hueneme, California; Dover Air Force Base, Delaware; and McClellan Air Force Base, Sacramento, California. The NETTS locations offer unique environmental settings, media, and contaminants for field demonstrations at well-characterized test sites as well as the infrastructure and site support required for technology demonstrations. The program provides infrastructure (site preparation, access roads, test pads, offices, laboratories, analytical equipment, drill rigs, field vehicles, utilities, lighting, fencing, and security) and site support (site characterization, demonstration oversight, permitting assistance, and technology transfer assistance). Information about funding opportunities is available at *www.serdp.org/funding/funding.html*.

New England Waste Management Officials (NEWMOA)

NEWMOA is a nonprofit, nonpartisan interstate association that has a membership composed of the hazardous waste, solid waste, waste site cleanup, and pollution prevention program directors for the environmental agencies in Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont. The Web site includes information on pollution prevention, solid and hazardous waste management, waste site cleanup, and brownfields. NEWMOA's waste site cleanup program focuses on issues of interest to state programs that have responsibility for investigation and remediation of contaminated sites. The waste site cleanup program is working on issues surrounding the redevelopment and reuse of contaminated property and the use of innovative site characterization and remediation technologies. The waste site cleanup program area of the Web site contains NEWMOA waste site cleanup technology advisory opinions, conference presentations and surveys, research briefs, workgroup information, and links to other sites. This resource assists states in developing effective strategies for improving the effectiveness of voluntary site cleanups and the redevelopment of brownfields sites and increases understanding of methods to meet the state program requirements of the new brownfields legislation.

Remedial Technology Development Forum (RTDF)

RTDF, which was established in 1992, is a public-private partnership that undertakes research, development, demonstration, and evaluation efforts focused on finding innovative technologies to remediate and to characterize contaminated sites. RTDF includes partners from industry, several federal and state government agencies, and academia who voluntarily share their knowledge, experience, equipment, facilities, and even proprietary technology to achieve common cleanup goals. The RTDF includes eight action teams: Bioremediation of Chlorinated Solvents Consortium, In-Place Inactivation and Natural Ecological Restoration Technologies (IINERT) Soil Metals Action Team, NAPL Cleanup Alliance, Phytoremediation of Organics Action Team, Permeable Reactive Barriers (PRB) Action Team, Sediments Remediation Action Team, Lasagna™ Partnership (inactive), and In Situ Flushing Action Team (inactive). RTDF provides updated information on the technologies addressed by these teams and other innovative approaches to site characterization and treatment.

Site Characterization Technologies for DNAPL Investigations (EPA 542-R-04-017)

Compiled by EPA's OSRTI, this resource provides a summary of information about the current state of technologies available for locating and characterizing DNAPL contaminated sites. This report may be used by remediation site managers to identify suitable characterization technologies for potential or confirmed DNAPL

contamination, screen the technologies for potential application, learn about technology applications at similar sites, and locate additional information on these technologies. The report describes both geophysical and non-geophysical characterization technologies as well as characterization technologies under evaluation.

Tri-Service Site Characterization and Analysis Penetrometer System-SCAPS: Innovative Environmental Technology from Concept to Commercialization

The report, which was published by the U.S. Army Environmental Center, summarizes the development, field demonstration, and regulatory acceptance activities associated with the SCAPS technologies that are used to detect, identify, and quantify subsurface contamination in soil and groundwater.

U.S. Department of Defense: Strategic Environmental Research and Development Program (SERDP)

SERDP is an environmental research and development program planned and executed and in full partnership with DOE and EPA with the participation of numerous other federal and nonfederal organizations. Within its broad areas of interest, the program focuses on cleanup, compliance, conservation, pollution prevention, and UXO technologies. SERDP provides demonstration opportunities through the NETTS Program and encourages technology transfer through an annual technical symposium and workshop. SERDP funds environmental research and development by both government and private sector parties. Additional information about SERDP funding may be obtained at ***www.serdp.org/funding/funding.html***. Users can access detailed performance and cost information for completed demonstrations at the SERDP Web site. Users may also subscribe to a mailing list for quarterly SERDP updates.

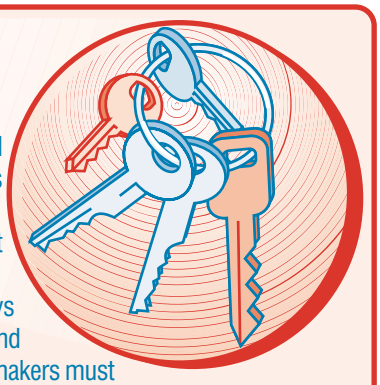
Where Do We Go from Here?

Next Steps

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.*

S6 KEYS TO TECHNOLOGY SELECTION AND ACCEPTANCE



As described throughout the Road Map, innovative technologies and technology approaches offer many advantages in the cleanup of brownfields sites. Stakeholders in such sites, however, first must accept the technology. Brownfields decision-makers should consider the following elements to increase the likelihood that the technology will be accepted, thereby facilitating the cleanup of the site.

1 *Focus on the Decisions that Support Site Goals*

As discussed in Spotlight 7, The Triad approach (see next page), systematic planning is an important element of all cleanup activities. Clear and specific planning to meet explicit decision objectives is essential in managing the process of cleaning up contaminated sites: site assessment, site investigation, site monitoring, and remedy selection. With good planning, brownfields decision-makers can establish the cleanup goals for the site, identify the decisions necessary to achieve those goals, and develop and implement a strategy for addressing the decision needs. Technology decisions are made in the context of the requirements for such decisions. All cleanup activities are driven by the project goals. An explicit statement of the decisions to be made and the way in which the planned approach supports the decisions should be included in the work plan.

2 *Build Consensus*

Investing time, before the site work begins, in developing decisions that are acceptable to all decision-makers will foster more efficient site activities and make successful cleanup more likely. Conversely, allowing work to begin at a site before a common understanding and acceptance of the decisions have been established increases the likelihood that the cleanup process will be inefficient, resulting in delays and inefficient use of time and money. Further, decision-makers must understand that there is uncertainty in all scientific and technical decisions (see below for more information about uncertainty). Clearly defining and accepting uncertainty thresholds before making decisions about the site remedy will build consensus. Decisions also should be made in the context of applicable regulatory requirements, political considerations, budget available for the project, and time constraints.

Managing Uncertainty Managing uncertainty is the unifying theme of the Triad approach, and it is a crucial aspect of the effective use of field analytical methods (see Spotlight 7, The Triad Approach, on the next page). Although not all field analytical technologies employ screening methodologies (for example, field-portable gas chromatography/mass spectrometry [GC/MS] is a definitive analytical methodology), many such technologies (for example, immunoassays) do. In general, data produced by screening analytical methods will present more analytical uncertainty than data produced by definitive methods. However, that fact in itself does not make definitive methods necessarily "better" than screening methods. Definitive methods are not fool-proof – interferences or other problems can cause a marked increase in their analytical uncertainty. On the other hand, a number of strategies can be used to minimize the analytical uncertainty inherent in screening methods. Such strategies include the selection of appropriate QA/QC procedures to ensure that the data are of known and documented quality. Most important, field analytical technologies offer the unique ability to cost-effectively manage the largest single source of decision error—sampling representativeness—an ability that is not available when requirements to use fixed laboratory methods discourage proactive management of sampling uncertainty.

3 *Understand the Technology*

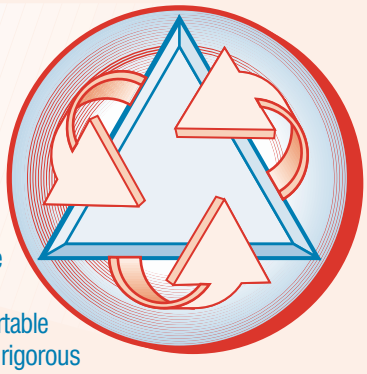
A thorough knowledge of a technology's capabilities and limitations is necessary to secure its acceptance. All technologies are subject to limitations in performance. Planning for the strengths and weaknesses of a technology maximizes understanding of its benefits and its acceptance. "Technology approvers," typically regulators, community groups, and financial service providers are likely to be more receptive of a new approach if the proposer provides a clear explanation of the rationale for its use and demonstrates confidence in its applicability to specific site conditions and needs. This latter point underscores the importance of carefully selecting an experienced, multidimensional team of professionals who have the expertise necessary to plan, present, and implement the chosen approach.

4 *Allow Flexibility*

Streamlining site activities, whether site assessment, site investigation, removal, treatment, or monitoring, requires a flexible approach. Site-specific conditions, including various physical conditions, contamination issues, stakeholder needs, uses of the site, and supporting decisions, require that all decision-makers understand the need for flexibility. Although presumptive remedies, standard methods, applications at other sites, and program guidance can serve as the basis for designing a site-specific cleanup plan and can help decision-makers avoid "starting from scratch" at each site, decision-makers should be wary of depending too heavily on "boilerplate language" and prescriptive methodologies, as well as standard operating procedures and "accepted" methods. While such tools provide excellent starting points, they lack the flexibility to meet site-specific goals. To ensure an efficient and effective cleanup, the actual technology approach, whether established or innovative, must focus on decisions specific to the site.

S7 THE TRIAD APPROACH:

Streamlining Site Investigations and Cleanup Decisions



The modernization of the collection, analysis, interpretation, and management of data to support decisions about hazardous waste sites rests on a three-pronged or "triad" approach. The introduction of new technologies in a dynamic framework allows project managers to meet clearly defined objectives. Such an approach incorporates the elements described below.

Systematic planning is a common-sense approach to assuring that the level of detail in project planning matches the intended use of the data being collected. Once cleanup goals have been defined, systematic planning is undertaken to chart a course for the project that is resource effective, as well as technically sound and defensible to reach these project-critical goals. A team of multidisciplinary, experienced technical staff works to translate the project's goals into realistic technical objectives. The CSM is the planning tool that organizes the information that already is known about the site; the CSM helps the team identify the additional information that must be obtained. The systematic planning process ties project goals to individual activities necessary to reach these goals by identifying data gaps in the CSM. The team then uses the CSM to direct the gathering of needed information, allowing the CSM to evolve and mature as work progresses at the site.

A **dynamic working strategy** approach relies on real-time data to reach decision points. The logic for decision-making is identified and responsibilities, authority, and lines of communication are established. Dynamic work strategy implementation relies on and is driven by critical project decisions needed to reach closure. It uses a decision-tree and real-time uncertainty management practices to reach critical decision points in as few mobilizations as possible. Success of a dynamic approach depends on the presence of experienced staff in the field empowered to make decisions based on the decision logic and their capability to deal with new data and any unexpected issues, as they arise. Field staff maintain close communication with regulators or others overseeing the project during implementation of dynamic work plans.

The use of on-site analytical tools, rapid sampling platforms, and on-site interpretation and management of data makes dynamic work strategies possible. Such **real-time measurement tools** are among the key streamlined site investigation tools because they provide the data that are used for on-site decision-making. The tools are a broad category of analytical methods and equipment that can be applied at the sample collection site. They include methods that can be used outdoors with hand-held, portable equipment, as well as more rigorous methods that require the controlled environments of a mobile laboratory (transportable). During the planning process, the team identifies the type, rigor, and quantity of data needed to answer the questions raised by the CSM. Those decisions then guide the design sampling modifications and the selection of analytical tools.

A Quick Look

- Integrates systematic planning, dynamic work strategies, and real-time measurement technologies to meet project and program goals.
- Takes advantage of real-time results and data assessment to guide additional sampling and to minimize mobilization to reach decision points.
- Focuses site activities on project goals, rather than on analytical methods, thereby saving time and money and fostering better decisions.
- Demonstrated to complete projects faster, cheaper, and with greater regulatory satisfaction than the traditional phased approach to data collection.

The Triad approach enables project managers to minimize uncertainty while expediting site cleanup and reducing project costs. For example, EPA collaborated with the Town of Greenwich, Connecticut to implement the Triad approach to characterize a former power plant site scheduled for redevelopment as a waterfront park. The Triad approach yielded an estimated cost savings of 50 to 60 percent when compared with a traditional approach involving two mobilizations and comprehensive analytical methods at a fixed laboratory. The City of Trenton, New Jersey began implementing the Triad approach in 2001 as part of its program to redevelop a large number of abandoned industrial sites. Overall, the Triad approach eliminated costs associated with follow-on investigation activities while accelerating the redevelopment schedule and reducing decision uncertainty. Additional details about these and other examples are available in the July 2004 edition of EPA's Technology News and Trends newsletter at ***www.epa.gov/tio/download/newsltrs/tnandt0704.pdf***.

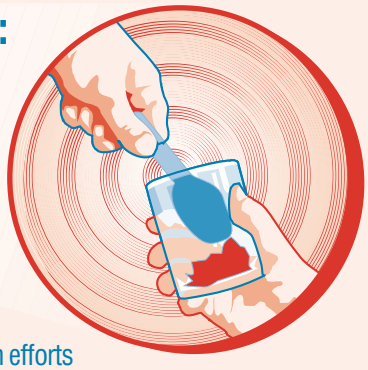
EPA published *Using the Triad Approach to Streamline Brownfields Site Assessment and Cleanup* in June 2003. This document can be obtained from EPA's Brownfields and Land Revitalization Technology Support Center at ***www.brownfieldstsc.org***.

The Triad Resource Center Web site at ***www.triadcentral.org*** provides information on the Triad approach.

For more information, see the resources numbered 9, 24, 48, 63, 79, 140, 159, 167, and 174 in the Index of Resources beginning on page I-1.

S8 DATA QUALITY AND REPRESENTATIVENESS:

Keys to Cost-Effective Site Investigation



The information value of data depends heavily upon the interaction among sampling and analytical designs in relation to the intended use of the data, the site-specific context surrounding that intended use, and the associated quality control. When this concept is understood, on-site analytical tools can play a major role in making environmental decision-making more efficient, defensible, and cost-effective. In today's industrial and regulatory climate, practitioners are often required to make immediate decisions that are based on dependable, representative data. The term "representative data" means that there is some stability in the samples and assurance of data density. On-site analytical techniques offer that type of decision-making assurance to the user of the data.

Brownfields investigations require innovative approaches that are faster, cheaper, and better than common practices. The faster approach reduces sample turnaround times, facilitates in-field decision-making, and minimizes deployment time of crew and equipment. The more cost-effective approach is used to reduce analytical costs, field-labor costs, and completion times. The better approach results in data quality that is as accurate as that attained by fixed off-site laboratories and refined data analysis based on the results of on-site screening. Brownfields sites are essentially industrial sites at which people will want to take measurements, determine the extent of contamination, and institute a plan. The sampling designs for such sites will be dynamic in nature; therefore, the real-time analytical capability offered by field-portable instruments will be essential in successful sampling. Data representativeness will become increasingly important in site characterization and remediation projects in the near future because it supports the dynamic approach by providing real-time feedback. With liability an important consideration at brownfields sites, managing uncertainties and having representative data that reflect the true site conditions is critical to property transactions. Data representativeness can be used successfully to generate scientifically sound data that are able to support defensible project decisions at substantial cost savings over the cost of current practices.

Increased sampling efficiencies, fostered by the use of innovative technologies, allow more targeted sample collection efforts that minimize the handling of samples that provide little value in meeting site-specific data quality objectives. Increased field analytical productivity is obtained when the type of analysis performed is targeted so that more samples can be analyzed each day, thereby bringing about more rapid site characterizations and verification of cleanup. When data needs are articulated clearly, and when a number of modern sampling and analytical options are available, it is possible to optimize data collection so that the information produced is accurate for its intended purpose while still being less costly than previously possible. When applied carefully, on-site analytical methods offer representative and decision-quality data with the added benefits of increased sampling density and real-time availability of results.

Although traditional approaches have tended to focus heavily on the capabilities of definitive analytical methods, the effect of sampling error on the representativeness of monitoring and measurement activities also should be considered. It is important to determine how data obtained from quality assessment samples can be used to identify and control in the measurement process sources of sampling error and uncertainties.

By increasing sampling density, made possible and cost-effective with the use of new sampling and analytical tools, decision-makers can reduce uncertainty and increase understanding of the true conditions of a site. This should increase comfort among site owners, buyers, regulators, and surrounding communities, as well as reduce the likelihood of errors and omissions that could negatively affect the site later.

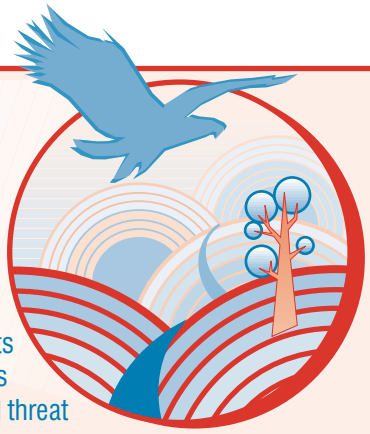
A Quick Look

- Data quality is the function of the data's information content and its ability to represent the true state of a site.
- Data representativeness is the measure of the degree to which samples can be used to estimate the characteristics of the true state of a hazardous waste site.
- Brownfields are considered an "up-and-coming" application in which data quality and representativness will play an important role.

For more information, see the resources numbered 30, 35, 36, 79, 86, and 154 in the Index of Resources beginning on page I-1.

NEW

S9 SUPPORTING TRIBAL REVITALIZATION EFFORTS



State and tribal response programs oversee assessment and cleanup activities at most of the brownfields sites across the country. EPA provides technical assistance and other support to states and tribes in order to help them implement more effective approaches to attaining productive reuse of sites. Two examples of tribal revitalization efforts in partnership with EPA that are based on the use of the Triad approach involve the Tohono O'odham Nation in Arizona and the Crow Creek Sioux Nation in South Dakota.

In October 2002, the Tohono O'odham Nation requested that EPA's BTSC provide support for planning an environmental investigation for the former Minerec Mining Chemical facility. The Minerec facility was constructed in 1990 on native desert in the San Xavier Business Park on land leased from the Tohono O'odham Nation. In 1991, Minerec began limited production of sulfur-containing chemicals that are used in the mining industry to separate ore and a pesticide for agricultural use. Although known locations of chemical releases to facility soil have been investigated, studies have concluded that further investigation is needed. Investigations would be conducted to address uncertainties regarding undocumented, undiscovered releases that may have impacted the facility and to further define areas of known releases to support site cleanup planning.

Systematic planning involved developing a CSM to incorporate existing information and to help design and direct data collection activities supporting reuse plans. The three main tasks identified by BTSC for the investigation included:

- Conducting a soil gas survey using direct-push drilling methodology for sample collection and an on-site laboratory for analysis
- Collecting and analyzing subsurface soil samples to a depth of 20 feet using direct-push drilling methodology and an on-site laboratory
- Further assessing vertical migration of contamination and potential groundwater impacts (if the joint two tasks indicated a potential threat to groundwater).

The soil gas and soil boring investigations were to be conducted in a single mobilization.

The use of a CSM enabled the Tohono O'odham Nation to establish a course for the project that is resource-effective, technically sound, and defensible. The systematic planning process made use of a decision tree and real-time uncertainty management practices to reach critical decision points in a single mobilization.

A Quick Look

- EPA provides technical assistance and other support to states and tribes that are interested in implementing more effective approaches to attaining productive reuse of sites.
- The use of a CSM enabled the Tohono O'odham Nation to establish a course for its project that is resource-effective, technically sound, and defensible.
- Careful planning and the use of creative field-based technologies helped EPA Region 8 and the Crow Creek Sioux Nation to produce a higher density of data and affordably manage uncertainty.

At the Ft. Thompson landfill, the Crow Creek Sioux Nation worked with EPA Region 8 to apply the Triad approach in order to develop a model for landfill closure. Tribal concerns about the landfill site involved impacts on residences and recreational areas, surface water impacts, the ability to reuse land for grazing and other habitat purposes, and official site closure.

The Ft. Thompson landfill, a 12.5-acre community dump used from the 1960s through 2000 for waste burning and disposal, was used primarily by homeowners and small businesses. The potential existed for disposal of pesticides, petroleum products, batteries, and metals. A soil cover had been placed over the dump; some pits and burn areas remained visible.

BTSC assisted EPA Region 8 in formulating an initial CSM that:

- Focused data needs on surface soil and surface water (runoff) pathways instead of the landfill
- Improved data density through use of field-based methods and a dynamic work strategy
- Helped Region 8 develop a model for landfill investigations

Continued on next page

S9 Continued ...

SUPPORTING TRIBAL REVITALIZATION EFFORTS

Based on BTSC recommendations, the project team:

- Eliminated the need to drill into and beneath the landfill (potentially creating new pathways)
- Selected field-based methods to characterize soil and sediment for metals (X-ray fluorescence), total petroleum hydrocarbons (TPH) (colorimetric test kits), and chlordane and other chlorinated pesticides (immunoassay test kits)

Careful planning helped to ensure that the data collected would meet the intended use. Creative field-based technologies were used to affordably manage uncertainty, producing a higher density of data and more defensible decisions. The end result is that decisions made about the site were supported by better information, thus providing a model for future investigations of this type.

The two examples summarized above demonstrate the benefits of improved decision-making through systematic planning. For more information, visit ***www.brownfieldstsc.org***.

NEW

S10 INNOVATIVE APPROACHES TO ASSESSMENT AND CLEANUP OF MINING SITES

Background

The enactment of the Small Business Liability Relief and Brownfields Revitalization Act expanded the definition of brownfields to include mine-scarred lands (MSL), making these properties eligible for the benefits of the Brownfields Program. MSLs are defined as lands, associated waters, and surrounding watersheds where extraction, beneficiation, or processing of ores and minerals (including coal) has occurred. It is estimated that there are more than 500,000 abandoned mining sites composed of hard rock and coal mines located on both public and private land across the United States that involve complex economic, social, and environmental issues. MSLs have become a persistent problem in many communities because of the economic and environmental challenges of cleaning up and reusing the lands.

The inclusion of MSLs in the Brownfields Program strengthens existing mine reclamation programs administered by the U.S. Department of Interior's (DOI) Office of Surface Mining. The Surface Mining Control and Reclamation Act governs surface coal mining activities and established the abandoned mine land reclamation fund. The MSL Working Group, which is composed of six federal agencies, is co-chaired by EPA's Office of Brownfields Cleanup and Redevelopment and DOI's Office of Surface Mining. The MSL Working Group was established to collaboratively address the challenges of MSL cleanup and revitalization.

A Quick Look

- The inclusion of MSLs in the Brownfields Program strengthens existing mine reclamation programs.
- The addition of residuals to soils at abandoned mine sites can help to rebuild the soils in support of further revitalization.
- The Triad approach has proven useful in addressing various types of contamination present on abandoned mine lands.
- Other innovative approaches are being demonstrated to support remediation of abandoned mine lands.

Hard Rock Mining – Remediation Through Addition of Residuals

Several EPA Superfund sites were contaminated by hard rock mining. At some of these sites, contaminated soils are being addressed through use of residuals. Examples of processes that generate potentially useful residuals include dairy, swine, and chicken farming; wastewater treatment; drinking water treatment; phosphorus production; pulp and paper production; sugar beet processing; and energy production from coal or wood. The residuals can readily contribute to rebuilding soil through their ability to re-establish structure and function by adding organic matter and nutrients to the disturbed soils. As a result of recreating a fertile soil horizon, the soil microbial community, invertebrates, and plants will be re-established and it will be possible to attain a self-sustaining system. More importantly, in the proper amendment ratios, residuals can be used to address problems of metal toxicity and acidity. In addition to residual use at upland sites, materials such as wood ash, log yard debris, and biosolids compost have been used to correct toxicity in a tailings pond in order to re-establish wetland functions.

Use of Triad Approach

Various types of contamination associated with coal mining may be addressed using the Triad approach, including contamination related to waste and ash disposal areas, on-site industrial facilities, chemical and solvent storage equipment, buildings and electrical transformers, petroleum storage and usage equipment, and acid mine drainage. Systematic planning, dynamic work strategies, and real-time measurement were applied to several aspects of the investigation.

BTSC provided technical assistance for a pilot project at the Dark Shade Brownfields Site in Somerset County, Pennsylvania. The project focused on applying the Triad approach to investigation activities. The planning was based on a reuse scenario that includes reclamation of the buildings located on site as office space or for other industrial applications. The objectives for the Phase II investigation are as follows:

Continued on next page

S10 Continued ...

INNOVATIVE APPROACHES TO ASSESSMENT AND CLEANUP OF MINING SITES

- Identify whether contaminants are present at concentrations above Act 2 industrial reuse levels in soil and surface water inside and outside the existing structures
- Identify whether disposal or recycling restrictions must be considered prior to removal of existing equipment from the buildings
- Identify whether the configuration of the groundwater flow regime in the area suggests that basement flooding has resulted from groundwater infiltration or an influx of surface water
- Identify options for removal and disposal of the water currently present in the flooded basements of the existing structures
- Identify whether groundwater sampling and analysis activities need to be performed and, if so, for what constituents
- Determine what remediation, if any, should be considered

The following areas were identified for application of the Triad approach:

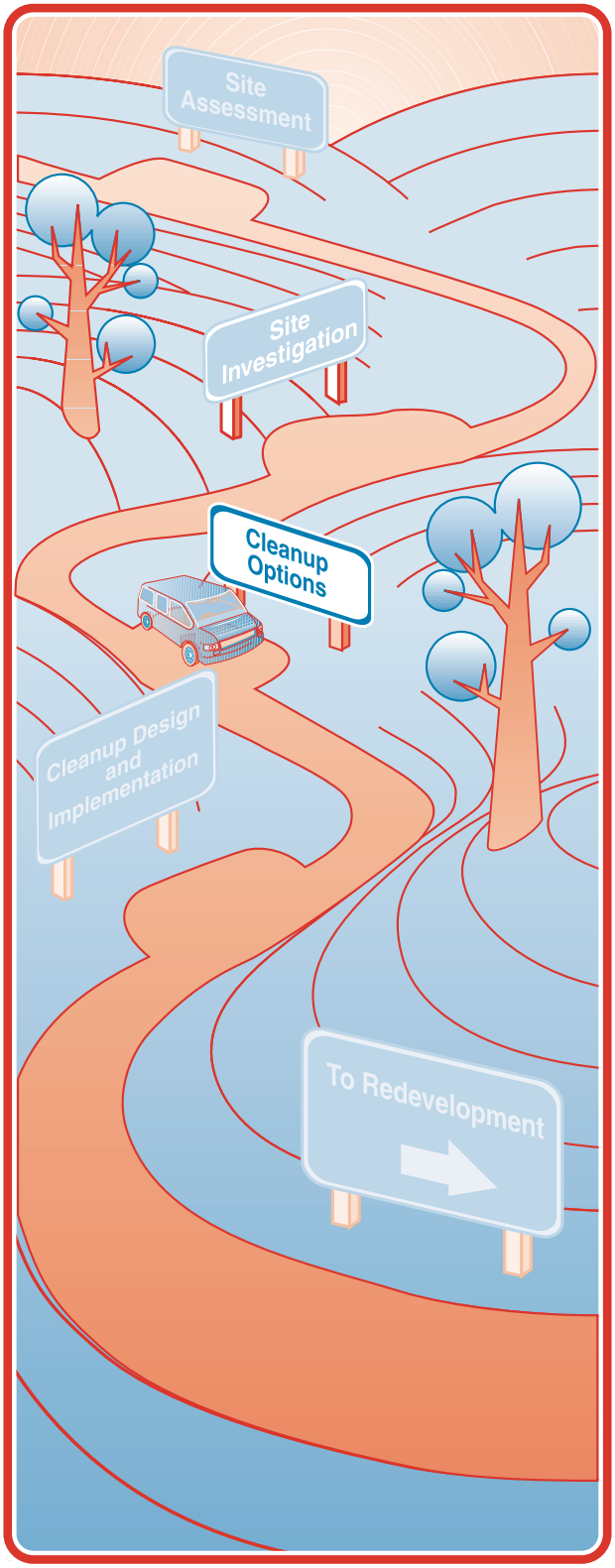
- Collecting wipe, surface water, soil, and groundwater samples to evaluate the potential presence of PCB-containing oil in or on the existing transformers and other machinery
- Evaluating whether the water in flooded basements is contaminated with PCBs, solvents, polynuclear aromatics, or petroleum hydrocarbons (concentrations contaminants of potential concern) at concentrations that would require special handling of water during its disposal or could indicate the presence of a source
- Establishing the lateral and vertical extent of contaminants of potential concern in unsaturated soil
- Estimating the direction of groundwater flow and depth to groundwater beneath the site

Other Innovative Approaches

EPA and other organizations continue to demonstrate and evaluate innovative technologies for the reclamation of mining sites. EPA is developing a primer on mining that will include an overview of innovative approaches that are suitable for consideration for mining sites.

Additional information is available at ***www.epa.gov/superfund/programs/aml***.

ASSESSMENT OF CLEANUP OPTIONS



Evaluate Applicable Cleanup Alternatives for the Site

The review and analysis of cleanup alternatives relies 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 with the 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.

Institutional controls also are an important consideration during this phase. Examples of such legal and administrative requirements include easements, covenants, zoning restrictions, and the posting of advisories to increase community awareness of the environmental conditions and cleanup activities at the site. See Spotlight 16, Understanding the Role of Institutional Controls at Brownfields Sites, for more information about institutional controls.

What Do We Know?

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 B, 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 applicable standards, 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*
  - *See Appendix A, Table A-3, Technologies for Treating Contaminants Found at Brownfields Sites, for examples of technologies that are appropriate for specific types of contaminants*
  - *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 risks, 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 achieves cleanup goals and 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 Answers to Our Technology Questions?

Examples of resources that will assist in reviewing and analyzing cleanup options are listed on the following pages. Resources are listed alphabetically under the following categories:

A. Resources for Cleanup Options

B. Site-Specific Resources for Cleanup Options

C. Technology-Specific Resources for Cleanup Options

Access the Road Map online at ***www.brownfieldstsc.org*** to view or download the following resources electronically or to obtain a link that provides complete ordering information.

A. Resources for Cleanup Options

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.

ASTM Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites (E1739-95e1(2003))
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, which is available at a cost, can be ordered online at ***www.astm.org***.

Breaking Barriers to the Use of Innovative Technologies: State Regulatory Role in Unexploded Ordnance Detection and Characterization Technology Selection
The report, which was published in 2000 by the ITRC, contains an analysis of case studies from states having experience in remediating UXO-contaminated sites. The report supports early and meaningful state regulatory involvement in the selection of innovative UXO characterization and remediation technologies. The report also offers recommendations to ensure the appropriate participation of states in the selection of technologies for characterizing and remediating UXO-contaminated sites.

Brownfields Technology Primer: Requesting and Evaluating Proposals That Encourage Innovative Technologies for Investigation and Cleanup (EPA 542-R-01-005)
BTSC prepared this primer to assist site owners, project managers, and others preparing RFPs to solicit support in conducting activities to investigate and clean up contaminated sites. It is specifically intended to assist those individuals in writing specifications that encourage contractors and technology vendors to propose options for using innovative characterization and remediation technologies at brownfields sites. The primer also provides information, from a technology perspective, to guide review teams in their evaluations of proposals and the selection of qualified contractors.

Citizen's Guides to Understanding Innovative Treatment Technologies
The guides are prepared by EPA to provide site managers with nontechnical outreach materials that they can share with communities in the vicinity of sites. The guides present information on innovative technologies that have been selected or applied at some cleanup sites, provide overviews of the technologies, and present success stories about sites at which innovative technologies have been applied. Both English and Spanish versions of the guides are available. The guides contain information on the following subjects:

- ***NEW!*** *Activated carbon treatment (EPA 542-F-01-020)*
- ***NEW!*** *Air stripping (EPA 542-F-01-016)*
- ***NEW!*** *Bioremediation (EPA 542-F-01-001)*
- *Capping (EPA 542-F-01-022)*
- ***NEW!*** *Chemical dehalogenation (EPA 542-F-01-010)*
- *Chemical oxidation (EPA 542-F-01-013)*
- *Fracturing (EPA 542-F-01-015)*

- *In situ flushing (EPA 542-F-01-011)*
- ***NEW!** In situ thermal treatment methods (EPA 542-F-01-012)*
- *Incineration (EPA 542-F-01-018)*
- *Monitored natural attenuation (EPA 542-F-01-004)*
- ***NEW!** Permeable reactive barriers (EPA 542-F-01-005)*
- ***NEW!** Phytoremediation (EPA 542-F-01-002)*
- *Pump and treat (EPA 542-F-01-025)*
- ***NEW!** Soil excavation (EPA 542-F-01-023)*
- ***NEW!** Soil washing (EPA 542-F-01-008)*
- *Solidification/stabilization (EPA 542-F-01-024)*
- *Solvent extraction (EPA 542-F-01-009)*
- ***NEW!** Soil vapor extraction (SVE) and air sparging (EPA 542-F-01-006)*
- *Thermal desorption (EPA 542-F-01-003)*
- *Vitrification (EPA 542-F-01-017)*

Clean-Up Information Home Page on the World Wide Web (CLU-IN)
The Internet site, which was developed by EPA, 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 remediation and site characterization also is provided: technology verification and evaluation; technology selection tools; contaminant-specific information, guidance and application support; case studies; regulatory development; and publications.

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

Directory of Technical Assistance for Land Revitalization (BTSC) (EPA 542-B-03-001)
BTSC has prepared this directory to provide information about technical assistance that is available from federal agencies to assist regional, state, and local government personnel in making assessment and cleanup decisions for brownfields, reuse, and revitalization sites. This directory includes information about 37 organizations within 10 federal agencies that provide different types of support to help with site assessment and cleanup, including technical support and funding sources. Profiles are included for these agencies and organizations and contain the following types of information: background and location information, relevancy to revitalization, description of the areas of expertise available, discussion of the types of services available, types of funding available and eligibility, contact information and the process for requesting assistance, and examples of specific instances in which the organization has previously provided support relevant to site revitalization. Information in the profiles is believed to be current as of March 2003. To help maintain current information, the directory is available as an online searchable database at ***www.brownfieldstsc.org/directory***.

EPA REmediation And CHaracterization Innovative Technologies (REACH IT) Online Searchable Database

The EPA REACH IT online searchable databases sponsored by EPA's OSRTI, is a service provided free of charge to both users and technology vendors. EPA REACH IT is accessible only through the Internet. This database provides users with comprehensive, up-to-date information about more than 254 characterization technologies and 484 remediation technologies and their applications. It combines information submitted by technology service providers about remediation and characterization technologies with information from EPA, DoD, DOE, and state project managers about sites at which innovative technologies are being deployed. 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 cleanup technology options that can be employed during the investigation and the cleanup phases that follow, as well as data about various types of sites. EPA updates all of the information available in the system about every six months. Technology vendors may also add or update information in EPA REACH IT at any time through the Data Entry System or by submitting information by mail. You can search the EPA REACH IT system in several ways. Various search options are available for a user on the home page, including Custom Search; Spotlight; Most Common Searches; Saved Searches; Guided Search; and Vendor, Technology, and Site Index. For questions about whether a technology is eligible for listing in EPA REACH IT, the user may contact the EPA REACH IT help line at (800) 245-4505 or (703) 390-0713 or send an e-mail to epareachit@ttemi.com.

Evaluation of Selected Environmental Decision Support Software (DSS)

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)

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 Case Studies

The case studies provide the user with information about specific characterization and remediation technology optimization applications. Four focus areas have been established by FRTR for providing performance and cost information on technology applications: remediation case study reports, characterization and monitoring case study reports, technology assessment reports, and long-term monitoring/optimization case study reports. FRTR case studies are developed by DoD, USACE, the U.S. Navy, the U.S. Air Force, DOE, DOI, and EPA. The case studies focus on full-scale and large field demonstration projects and include site background information, technology descriptions, cost and performance information, and lessons learned. The technologies include innovative and conventional treatment technologies for contaminated soil, groundwater, and solid media. Users can 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)

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.

Innovative Remediation and Site Characterization Technologies Resources (EPA 542-C-04-002)

Produced by EPA's OSRTI, this CD-ROM contains resources that provide information to help federal, state, and private sector site managers

evaluate site assessment and cleanup alternatives. The ability to gain access to resources that provide information about innovative site characterization and remediation technologies will increase the understanding of those technologies and of the cost and performance factors related to them. Such understanding is essential to consideration of those technologies for use in addressing contamination at hazardous waste sites. The information on the CD-ROM is broken down into seven categories: bulletins, fact sheets, journals, and newsletters; community involvement support; electronic resources; organizations, programs, and partnerships; publication clearinghouses; publications; and regulatory resources. Several resources included on the CD-ROM also are available at the Road Map online. Copies of the CD-ROM can be ordered through NSCEP at P.O. Box 42419, Cincinnati, Ohio 45242-2419 or by calling (800) 490-9198 toll free.

Innovative Remediation Technologies: Field-Scale Demonstration Projects in North America, 2nd Edition (EPA 542-B-00-004)
EPA's publication, *Completed North American Innovative Technology Demonstration Projects*, is available in an online, searchable database of ongoing and completed field demonstrations of innovative remediation technologies sponsored by government agencies working in partnership with private technology developers to bring new technologies into the hazardous waste remediation marketplace.

Rapid Commercialization Initiative Final Report for an Integrated In Situ Remediation Technology (Lasagna™) (DOE/OR/22459-1)
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 4.0
The document, which was developed by FRTR, is intended to help 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 is divided into five sections: Introduction, Contaminant Perspectives, Treatment Perspectives, Treatment Technology Profiles, and References. 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 information resources also are included.

Reuse Assessments: A Tool to Implement the Superfund Land Use Directive (OSWER Directive 9355.7-06P)
This memorandum, which was signed on June 4, 2001, by EPA's OERR, presents information that supports the development of assumptions related to future land use when making remedy selection decisions for response actions conducted at Superfund sites. The Reuse Assessment guide, which provides information about the collection and evaluation of information for developing assumptions, and the Superfund Land Use Directive, which provides basic information about developing and using future land use assumptions to support Superfund remedial actions, are included as attachments to the directive.

Site Remediation Technology InfoBase: A Guide to Federal Programs, Information Resources, and Publications on Contaminated Site Cleanup Technologies, Second Edition (EPA 542-B-00-005)
Prepared by the member agencies of 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 Program: Technology Profiles, Eleventh Edition
Developed by EPA's SITE Program, these documents (contained in three volumes) provide 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. The following volumes are available: Demonstration Program, Volume 1 (EPA 540-R-03-501); Emerging Technology Program, Volume 2 (EPA 540-R-03-501A); and Monitoring and Measurement Program, Volume 3 (EPA 540-R-03-501B).

TechKnow™ Database
Developed by the Global Network of Environment and Technology (GNET), TechKnow is an online, interactive database that 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 *www.techknow.org*. There is no cost to use TechKnow, but users are required to register on GNET.

Treatment Technologies for Site Cleanup: Annual Status Report (Eleventh Edition) (EPA 542-R-03-009)
This report, which was developed by EPA, documents the status and achievements (as of March 2003) of treatment technology applications for soil, other solid wastes, and groundwater at Superfund sites. The data in this report were gathered from Superfund records of decision (ROD) from fiscal years (FY) 1982 through 2002, close-out reports (COR) from FYs 1983 through 2002, and project managers at Superfund remedial action sites. The report examines in situ and ex situ treatment technologies for soil, sludge, sediment, other solid matrix wastes, and NAPLs; in situ and ex situ P&T groundwater treatment technologies; vertical engineered barriers (VEB); and the selection of MNA remedies for groundwater. This edition of the annual status report summarizes 1,811 technology applications identified for Superfund remedial actions. EPA created a searchable, online system to allow access to the data that form the basis for this report. This searchable system is available at *http://cfpub.epa.gov/asr/*.

B. Site-Specific Resources for Cleanup Options

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

Air Sparging: Technology Transfer and Multi-Site Evaluation (CU-9808)
Developed by ESTCP, this document presents an evaluation of the Air Sparging Design Paradigm implemented at 10 field sites. The goal of the study was to determine the effectiveness of the paradigm and to modify it as necessary based on the results of the evaluation. The document explains the technology and demonstration design and provides an assessment of the performance and cost of the technology in field applications.

Arsenic Treatment Technologies for Soil, Waste, and Water (EPA 542-R-02-042)
This report, which was prepared by EPA, contains current information on treatment technologies for wastes and environmental media containing arsenic. The intended audience for the report includes hazardous waste site managers, generators and treaters of arsenic-contaminated waste and wastewater, owners and operators of drinking water treatment plants, regulators, and the interested public. The report summarizes information on 13 technologies used to treat arsenic, identifies sites and facilities where arsenic treatment has been used, and provides references to more detailed arsenic treatment information.

Assessment of Phytoremediation as an In-Situ Technique for Cleaning Oil-Contaminated Sites
The document, which is based on a review of the relevant literature, provides examples of the phytoremediation of petroleum hydrocarbons and discusses the key mechanisms of that process, as well as the special considerations involved in phytoremediation of petrochemicals. The document also discusses the benefits, limitations, and costs of phytoremediation, compared with alternative approaches, including natural attenuation, engineering, and bioremediation.

Catalog of EPA Materials on USTs (EPA 510-B-00-001)
The booklet provides an annotated list of UST materials and includes ordering information. Many of the informational leaflets, booklets, videos, and software items listed are designed to provide UST owners and operators with information to help them comply with the federal UST requirements.

DNAPL Remediation: Selected Projects Approaching Regulatory Closure - Status Update (EPA 542-R-04-016)
This paper, which was prepared by EPA's OSRTI, is a status update on the use of DNAPL source reduction remedial technologies. The document provides information about recent projects in which regulatory closure has been reached and projects that are approaching regulatory closure

following source reduction. Information is presented about the challenges associated with DNAPL remediation and the types of in situ technologies used, and data and findings are included concerning the relative effectiveness of field applications of these technologies. Project profiles for eight field applications are provided that illustrate some of the findings presented in the paper.

EPA ORD Brownfields Guides - Technical Approaches to Characterizing and Cleaning Up Iron and Steel Mill Sites Under the Brownfields Initiative (EPA 625-R-98-007)

The Brownfields Guides, which were developed by EPA ORD, are designed to help communities, states, municipalities, and the private sector address brownfields sites more effectively. EPA has developed this "Iron and Steel" guide to provide decision-makers such as city planners, private sector developers, and others involved in redeveloping brownfields with a better understanding of the technical issues involved in assessing and cleaning up iron and steel mill sites so they can make the most informed decisions possible. This guide provides the user with an understanding of common industrial processes at iron and steel mills and the relationship between these processes and potential releases of contaminants to the environment. The guide also includes a discussion of site assessment, screening and cleanup levels, and technologies that can be used to assess and clean up the types of contaminants likely to be present at iron and steel mill sites. A list of relevant acronyms, a glossary of key terms, and an extensive bibliography are also provided.

EPA ORD Brownfields Guides - Technical Approaches to Characterizing and Cleaning Up Metal Finishing Sites Under the Brownfields Initiative (EPA 625-R-98-006)

The Brownfields Guides, which were developed by EPA ORD, are designed to help communities, states, municipalities, and the private sector address brownfields sites more effectively. EPA has developed this "Metal Finishing" guide to provide those involved in redeveloping brownfields with a better understanding of the technical issues involved in assessing and cleaning up metal finishing sites so they can make the most informed decisions possible. This guide provides the user with an understanding of common industrial processes at metal finishing facilities and the relationship between these processes and potential releases of contaminants to the environment. It also provides information on the types of contaminants likely to be present at these sites. The guide includes a discussion of a conceptual framework for pathways by which contaminants may migrate off site and environmental and human health concerns to be considered when cleanup options for these sites are evaluated. In addition, a list of relevant acronyms, a glossary of key terms, and an extensive bibliography are provided.

Groundwater Cleanup: Overview of Operating Experience at 28 Sites (EPA 542-R-99-006)

The report summarizes information about the groundwater remediation systems at 28 sites throughout the United States at which completed or ongoing groundwater cleanup programs are in place. It includes details about design, operation, and performance of the systems; capital, operating, and unit costs of the systems; and factors that potentially affect the cost and performance of the systems. The report compares and contrasts data from the case studies to assist those involved in evaluating and selecting remedies for groundwater contamination at hazardous waste sites. Of the 28 projects presented in the case studies, 24 are Superfund remedial actions, one is a Superfund removal action, one is a cleanup conducted by state authorities, and two are corrective actions taken under RCRA. The sites represent a range of site types and hydrogeological conditions.

How to Evaluate Alternative Cleanup Technologies for Underground Storage Tank Sites: A Guide for Corrective Action Plan Reviewers (EPA 510-R-04-002)

The guide was developed by EPA to assist state regulators in efficiently and confidently evaluating corrective action plans (CAP) that incorporate alternative technologies. The guide, which was written in nontechnical language, takes the reader through the steps involved in reviewing a CAP. Earlier versions of the guide (1994 and 1995) covered technologies such as SVE, air sparging, biosparging, landfarming, biopiles, bioventing, low-temperature thermal desorption, natural attenuation, dual-phase extraction, and in situ groundwater bioremediation. The revised version (2004) has two new chapters on enhanced aerobic bioremediation and chemical oxidation and two revised chapters: the introduction and a chapter on MNA. Each technology chapter presents a comprehensive description of a 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; a discussion and instructions to help the regulator evaluate whether a CAP is technically sound; a checklist to assist the regulator in determining whether a CAP includes all the steps necessary; and a list of references.

Impact of Landfill Closure Designs on Long-Term Natural Attenuation of Chlorinated Hydrocarbons
Developed by ESTCP, this landfill closure evaluation document is intended to help users develop alternative landfill closure designs and management strategies that can enhance the long-term natural attenuation of chlorinated solvents in landfills and landfill leachate-contaminated groundwater. The design approach proposed in this document maximizes the use of natural remediation and management techniques for landfill closures.

Innovations in Site Characterization Case Study Series
The case studies, which were developed by EPA, provide cost and performance information about the 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:

- *Dexsil L2000 PCB/Chloride Analyzer for Drum Surfaces (EPA 542-R-99-003)*
- *Geophysical Investigation at Hazardous Waste Sites (EPA 542-R-00-003)*
- *Hanscom Air Force Base, Operable Unit 1 (EPA 542-R-98-006)*
- *Site Cleanup of the Wenatchee Tree Fruit Test Plot Site Using a Dynamic Work Plan (2000) (EPA 542-R-00-009)*
- ***NEW!** Technology Evaluation: Real-time VOC Analysis Using a Field Portable GC/MS (EPA 542-R-01-011)*

InterAgency DNAPL Consortium Home Page
The Web site is sponsored by the Interagency DNAPL Consortium (IDC). IDC is an alliance of five federal agencies, including the National Aeronautics and Space Administration (NASA), EPA, DOE, the U.S. Navy, and the U.S. Air Force. It reports on the IDC's effort to evaluate and compare the cost and performance of three innovative remediation technologies for the treatment of DNAPLS. The three technologies are being applied for the treatment of trichloroethene (TCE) at Launch Complex 34 at Cape Canaveral Air Force Station, Florida. The three technologies being demonstrated in side-by-side plots at the launch area are chemical oxidation with the use of potassium permanganate, six-phase heating, and dynamic underground stripping.

MtBE Fact Sheet #2: Remediation of MtBE-Contaminated Soil and Groundwater (EPA 510-F-98-002)
Developed by EPA's OUST, the fact sheet describes the physical and chemical characteristics of methyl tertiary butyl ether (MtBE) and identifies alternative technologies for remediating it.

North Atlantic Treaty Organization/ Committee on the Challenges of Modern Society (NATO/CCMS) Pilot Study Evaluation of Demonstrated and Emerging Technologies for the Treatment of Contaminated Land and Groundwater (Phase III) 2002 Annual Report (EPA 542-R-02-010)
This document reports on the fourth meeting for the Phase III Pilot Study on the Evaluation of Demonstrated and Emerging Technologies for the Treatment and Clean Up of Contaminated Land and Groundwater. The Phase III study, which concluded in 2002, focused on technologies for treating contaminated land and groundwater. The study addressed issues of sustainability, environmental merit, and cost-effectiveness with continued emphasis on emerging remediation technologies. The objectives of the study were to critically evaluate technologies, promote appropriate use of technologies, use information technology systems to disseminate study products, and foster innovative thinking about contaminated land.

Resource for MGP Site Characterization and Remediation: Expedited Site Characterization and Source Remediation at Former Manufactured Gas Plant Sites (EPA 542-R-00-005)
The document provides current information about useful approaches and tools being applied at former MGP sites to the regulators and utilities that are engaged in characterizing and remediating these sites. The document outlines site management strategies and field tools for expediting site characterization at MGP sites; presents a summary of existing technologies for remediating MGP wastes in soils; provides sufficient information about the benefits, limitations, and costs of each technology, tool, or strategy for comparison and evaluation; and provides, through case studies, examples of the ways in which those tools and strategies can be implemented at MGP sites.

State Coalition for Remediation of Drycleaners (SCRD) Internet Site
The SCRD Internet site, which is supported by EPA's OSRTI, provides extensive information about state remediation programs and resources related to the remediation of dry cleaner sites. Descriptions of state programs and points of contact in each of the member states are provided. Publications, regulations, and other documents are identified as well. Brownfields stakeholders involved in the assessment and cleanup of dry cleaner sites in Alabama, Connecticut, Florida, Illinois, Kansas, Minnesota, Missouri, North Carolina, Oregon, South Carolina, Tennessee, Texas, and Wisconsin may be particularly interested in the detailed information provided about programs in those states. Profiles of the remediation of specific sites throughout the United States are intended to assist users, particularly state officials, in making more informed decisions related to the remediation of sites in their states, and, when possible, to provide additional resources. Publications developed by the SCRD, as well as state and federal resources pertinent to issues associated with dry cleaner sites, can be viewed online or downloaded at no charge.

The Bioremediation and Phytoremediation of Pesticide-Contaminated Sites
The technology assessment report discusses the use of bioremediation and phytoremediation for the cleanup of sites contaminated with pesticides. It provides information about the current status of the two technologies to federal and state agencies, consulting engineering firms, private industries, and technology developers.

Treatment Experiences at RCRA Corrective Actions (EPA 542-F-00-020)
The fact sheet summarizes information about the use of treatment technologies at 30 RCRA corrective action sites. It focuses on ongoing or completed cleanups of contaminated soil or groundwater at RCRA sites for which key information, such as the type of technology used and the point of contact, was available. The sites illustrate the types of cleanups conducted at RCRA corrective action sites; they are not intended to be representative of all cleanups conducted under RCRA.

Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites
The policy directive, which was issued on 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 for Cleanup Options

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.

Air Sparging Design Paradigm
This design guidance resulted from research and development efforts sponsored by the U.S. Air Force Armstrong Laboratory and the U.S. Naval Facilities Engineering Research Center and from field research and data analysis conducted by Battelle Memorial Institute, Arizona State University, Oregon Graduate Institute, Parsons Engineering-Science, and Colorado State University. The guidance provides details on air sparging principles; site characterization; pilot testing; system design, installation, and operation; and system monitoring. Use of the design paradigm is illustrated in descriptions of field studies and by using the results of controlled physical model studies. The guidance is organized in sections that provide an overview of air sparging in general and the specific design paradigm

followed by a discussion of site characterization, air sparging application, pilot testing, and system design and monitoring.

Analysis of Selected Enhancements for Soil Vapor Extraction (EPA 542-R-97-007)
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 them with an up-to-date report on the status of enhancement technologies in 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.

Application Guide for Bioslurping - Volume I
This application guide, which was developed by Battelle for NFESC, is presented in two volumes. Volume I provides principles and practices of bioslurping to assist project managers in preliminary decision-making. Based on Volume I, a site manager may determine whether this technology is feasible for a site contaminated with light nonaqueous phase liquid (LNAPL).

Application Guide for Bioslurping - Volume 2
This application guide, which was developed by Battelle for the Naval Facilities Engineering Service Center (NFESC), is presented in two volumes. Volume I provides principles and practices of bioslurping to assist project managers in preliminary decision-making, and Volume II contains a detailed description of the bioslurper system; testing procedures; system design, installation, operation, and monitoring; and an approach for site closure.

Bioremediation of Chlorinated Solvent Contaminated Groundwater
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.

Brownfields Technology Primer: Requesting and Evaluating Proposals That Encourage Innovative Technologies for Investigation and Cleanup (EPA 542-R-01-005)
BTSC prepared this primer to assist site owners, project managers, and others preparing RFPs to solicit support in conducting activities to investigate and clean up contaminated sites. It is specifically intended to assist those individuals in writing specifications that encourage contractors and technology vendors to propose options for using innovative characterization and remediation technologies at brownfields sites. The primer also provides information, from a technology perspective, to guide review teams in their evaluations of proposals and the selection of qualified contractors.

Brownfields Technology Primer: Selecting and Using Phytoremediation for Site Cleanup (EPA 542-R-01-006)
BTSC developed this document to provide an educational tool for site owners, project managers, and regulators to help evaluate the applicability of the phytoremediation process at brownfields sites. The primer explains the types of biological processes involved in phytoremediation; provides examples of the sites and contaminants where phytoremediation has been applied; and discusses technical considerations in selecting and designing phytoremediation systems, activities necessary to operate and maintain phytoremediation systems, and examples of estimated potential cost savings from using phytoremediation versus more conventional treatment processes. The primer also provides a comprehensive list of other resources that are available to assist decision-makers in evaluating phytoremediation as an option for cleaning up contaminated sites.

Capstone Report on the Application, Monitoring, and Performance of Permeable Reactive Barriers for Ground-Water Remediation: Volume 1 (EPA 600-R-03-045a)

This report, which was developed by EPA, discusses geochemical and microbiological processes within zero-valent iron PRBs that may contribute to changes in iron reactivity over time and decreases in reaction zone permeability. Two full-scale PRBs are evaluated in this report. Detailed water sampling and analysis, core sampling, and solid-phase characterization studies were carried out to: (1) evaluate spatial and temporal trends in contaminant concentrations and key geochemical parameters, (2) characterize the type and nature of surface precipitates forming over time in the reactive barriers, and (3) identify the type and extent of microbiological activity within and around the reactive barriers.

Capstone Report on the Application, Monitoring, and Performance of Permeable Reactive Barriers for Ground-Water Remediation: Volume 2 (EPA 600-R-03-045b)

This report, which was developed by EPA, discusses soil and groundwater sampling methods and procedures used to evaluate the long-term performance of PRBs at two sites: one in Elizabeth City, North Carolina, and the other one in Denver Federal Center near Lakewood, Colorado. Both PRBs were installed in 1996 and have been monitored and studied since their installation to determine their continued effectiveness in removing contaminants from groundwater. The report points out that an effective monitoring program requires appropriate soil and groundwater sampling techniques.

CLU-IN Technology Focus

The Technology Focus, a section of EPA OSRTI's CLU-IN site, provides a compilation of the most relevant information sources for a range of remediation technologies. Grouped by specific technologies, the resources provide technology descriptions, information about applications and use of technologies, relevant engineering and regulatory guidance, and links to training sources and additional references. Information about the following technologies is available: air sparging, bioreactor landfills, bioremediation of chlorinated solvents, bioventing and biosparging, electrokinetics, fracturing, groundwater circulating wells, in situ flushing, in situ oxidation, multiphase extraction, natural attenuation, PRBs, phytoremediation, solvent extraction, SVE, soil washing, thermal desorption, and thermal enhancements.

Cost Analyses for Selected Groundwater Cleanup Projects: Pump-and-Treat Systems and Permeable Reactive Barriers (EPA 542-R-00-013)

Developed on the basis of case studies prepared by EPA, other members of FRTR, and the Remediation Technologies Development Forum, the report presents the results of an analysis of groundwater cleanup costs for P&T systems and PRBs at 48 sites. Targeted for site managers, technology developers, and users, as well as others involved in groundwater remediation efforts, the report provides detailed information about the costs of groundwater cleanup technologies and factors that affect those costs. Of the 48 sites, 32 had P&T systems and 16 had PRBs.

Engineered Approaches to In Situ Bioremediation of Chlorinated Solvents: Fundamentals and Field Applications (EPA 542-R-00-008)

The report provides an overview of in situ bioremediation for the remediation of chlorinated solvents in contaminated soil and groundwater. It describes mechanisms for the degradation of chlorinated solvents, enhancements of such mechanisms by the addition of various materials and chemicals, design approaches, and factors to consider when selecting and using the technology. The report also presents a list of vendors of the technology and nine case studies of field applications.

Engineering and Design: Adsorption Design Guide (DG 1110-1-2)

The guide, published by USACE, provides practical guidance for the design of liquid- and vapor-phase devices for the adsorption of organic chemicals. The adsorptive media addressed include granular activated carbon (GAC) and other alternative adsorption media, such as powdered activated carbon (PAC) and non-carbon adsorbents. It addresses various types of adsorption media, applicability, use of various adsorption process technologies, design of equipment and ancillary components, availability, advantages, disadvantages, regeneration methods, costs, and safety considerations.

Engineering and Design: Soil Vapor Extraction and Bioventing (EM 1110-1-4001)
This guide, which was published by USACE to provide practical guidance for design and operation of SVE and bioventing (BV) systems. It discusses all aspects of the engineering of SVE and BV systems, including site characterization, technology selection; bench- and pilot-scale testing, design, installation, operation, and closure.

EPA's Office of Underground Storage Tanks Internet Site
Hosted by EPA's OUST, the Internet site provides resources and tools to assist owners and operators of USTs and brownfields stakeholders to better assess their options for the operation, maintenance, and cleanup of USTs. Information and guidance about technologies suitable for cleaning up releases from UST systems are provided, as well as details about current federal UST regulations and UST program priorities, including specific details about the USTFields Initiative. Points of contact in each of the EPA regional offices also are identified. An extensive number of UST publications can be viewed online or downloaded at no charge. In addition, information about state-sponsored UST programs, including links to state Internet sites, is provided on OUST's site at *www.epa.gov/swerust1/states/index.htm*.

Evaluation of Performance and Longevity at Permeable Reactive Barrier Sites (CU-9907)
Developed by ESTCP, this report presents an evaluation of short- and long-term performance issues associated with PRBs installed at several DoD sites. The report assesses the longevity of PRBs made from iron and the hydraulic performance of various PRBs in terms of their ability to meet groundwater capture zone and residence time requirements. The report describes PRB technology and provides an assessment of the performance and cost of the technology when implemented in the field. It also addresses implementation issues such as scale-up, regulatory constraints, and monitoring.

Evaluation of Permeable Reactive Barrier Performance - Revised Report
This document, which was prepared for FRTR by DoD, DOE, and EPA, summarizes field performance evaluations of several PRBs installed at sites under the purview of DoD, DOE, and EPA. The evaluations focus on the longevity and hydraulic performance of the PRBs in various geologic settings. The results of these studies are being provided to RPMs at government-owned sites to aid in decision-making. The document also discusses compliance and monitoring issues related to PRBs.

Evaluation of Phytoremediation for Management of Chlorinated Solvents in Soil and Groundwater (EPA 542-R-05-001)
This document, prepared by the RTDF, is designed to briefly introduce various phytotechnologies; identify potential applications of phytoremediation to control, transform, or manage chlorinated solvents in soil and groundwater; show how to conduct a preliminary assessment to determine if a particular site is a good candidate for phytoremediation; and describe monitoring options and show how to assess the effectiveness of phytoremediation at full-scale field implementation. It is intended to aid regulators, site owners, consultants, and other stakeholders in understanding the proper application of phytotechnology to remediate groundwater contaminated with halogenated solvents.

Evapotranspiration Landfill Cover Systems Fact Sheet (EPA 542-F-03-015)
This fact sheet, which was prepared by EPA, provides a summary of an innovative landfill final cover design called evapotranspiration (ET) covers. The information in this fact sheet was obtained from currently available technical literature and from discussions with site managers. The general ET cover concept involves use of one or more vegetated soil layers to retain water until it is either transpired through vegetation or evaporated from the soil surface. The fact sheet discusses general considerations of ET cover design, performance, monitoring, cost, status, and limitations and provides project-specific examples. Final cover systems are used as part of the remediation and final closure for landfills, contaminated areas at or near the ground surface, and other waste disposal sites. As of September 2003, ET covers have been proposed, tested, or installed at 64 sites throughout the United States, generally from Georgia to Oregon.

Field Applications of In Situ Remediation Technologies: Chemical Oxidation (EPA 542-R-98-008)
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)
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)
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 PRBs. 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.

Geophysical Techniques to Locate DNAPLs: Profiles of Federally Funded Projects (EPA 542-R-98-020)
The document provides to researchers and practitioners a status report on federal projects that are using noninvasive geophysical techniques to locate DNAPLs in the subsurface.

Groundwater Pump and Treat Systems: Summary of Selected Cost and Performance Information at Superfund-Financed Sites (EPA 542-R-01-021a and EPA 542-R-01-021b)
This report, which was published by EPA, summarizes Phase 1 (the data collection phase) of the Nationwide Fund-lead Pump and Treat Optimization Project. The first phase of this project identified a total of 88 Fund-lead (EPA-lead and state-lead with Fund money) P&T systems within the Superfund Program. System identification was accomplished through use of online databases and discussions with project liaisons in each region. The number of Fund-lead P&T systems in EPA regions ranged from zero in Region 8 to 22 in Region 2. The report identifies the 88 Fund-lead P&T systems, summarizes the information submitted by RPMs, and presents the screening and selection of those systems to receive remediation system evaluations (RSE). The EPA 542-R-01-021a report does not contain data appendices. The "b" version of the report includes all appendices.

Ground-Water Remediation Technologies Analysis Center Technology Reports
Developed by the Ground-Water Remediation Technologies Analysis Center (GWRTAC), various 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 general overviews of and introductions to selected groundwater technologies. More detailed information and technical analyses are provided in the Technical Evaluation Reports. Each of these reports provides a comprehensive description of a specific technology, performance information, information about its applicability and cost, a discussion of regulatory and policy requirements and issues, and a summary of lessons learned. The Technology Status Reports are summary documents that provide information about the status of and current development efforts for specific emerging groundwater technologies or address related topics. Examples of some of the topics covered include air sparging, chlorinated solvents, DNAPL remediation, electrokinetics, hydraulic and pneumatic fracturing, in situ bioremediation, in situ chemical treatment, in situ soil flushing, permeable reactive wells, phytoremediation, groundwater circulation wells, in situ S/S, in situ vitrification, LNAPL remediation, perchlorate remediation, remediation of metals, SVE and dual -phase extraction, thermal enhancements, and treatment trains.

Groundwater Remedies Selected at Superfund Sites (EPA 542-R-01-022)
EPA prepared this report to document the selection of groundwater treatment and MNA remedies for Superfund remedial action sites. The report presents data on groundwater treatment and MNA remedy decisions and analyzes trends in these decisions over time. The focus of this report is on groundwater treatment and MNA remedies that result in reduction of contaminant concentrations or mobility. Groundwater containment and other remedies are not addressed in this report.

Hydraulic Optimization Demonstration for Groundwater Pump-and-Treat Systems
The report, contained in two separate volumes, presents a screening analysis that users can use to determine whether they can achieve significant cost savings by altering key aspects of an existing or planned P&T system. The first volume, intended for a broad audience, describes the screening analysis, which uses spreadsheets to allow quick and inexpensive cost comparison of alternatives under consideration for use at a site, in terms of net present value (NPV). The second volume, intended for a more technical audience, provides case study examples of the application of hydraulic optimization at three sites. Site-specific factors, as well as the steps involved to conduct the analysis, are described in detail. The following volumes are available:

- *Volume I: Pre-Optimization Screening Method and Demonstration (EPA 542-R-99-011A)*
- *Volume II: Application of Hydraulic Optimization (EPA 542-R-99-011B)*

In Situ Electrokinetic Remediation of Metal Contaminated Soils Technology Status Report (SFIM-AEC-ET-CR-99022)
The report, which was published by the U.S. Army Environmental Center for ESTCP, provides an overview of the current developmental status of electrokinetic remediation for metals-contaminated soils. The report identifies concerns about the in situ application of the technology and issues that require further investigation. It also presents the results of a field demonstration conducted at Naval Air Weapons Station at Point Mugu to illustrate concerns about the in situ application of the technology at its current stage of development.

In Situ Treatment of Chlorinated Solvents: Fundamentals and Field Applications (EPA 542-R-04-010)
This report, which was prepared by EPA, contains information about the use of in situ thermal treatment technologies to treat chlorinated solvents in source zones containing free-phase contamination or high concentrations of contaminants that are either sorbed to soil or dissolved in groundwater in the saturated or unsaturated zone. The information in this report may be helpful to site managers, site owners, treatment technology vendors, regulators, consulting firms, and others involved in the cleanup of sites contaminated with chlorinated solvents. The report describes three in situ thermal technologies: steam-enhanced extraction, electrical resistive heating, and electrical conductive heating. The report also discusses overall applicability issues and engineering considerations for the use of these technologies in the field.

In Situ Treatment of Contaminated Sediments
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.

Introduction to Phytoremediation (EPA 600-R-99-107)
The document provides a tool for regulators, owners, neighbors, and managers to use in evaluating the applicability of phytoremediation to a site. The document defines terms and provides a framework for use in developing an understanding of phytoremediation applications. It is a compilation of information obtained through research and remediation work that has been done to date.

ITRC Phytoremediation Decision Tree
The document, which was produced by the ITRC workgroup, provides a tool that can be used to determine whether phytoremediation can be effective at a given site. It is designed to complement existing phytoremediation documents. It allows the user to use basic information about a specific site, through a flow chart layout, to decide whether phytoremediation is feasible at that site.

Leak Detection for Landfill Liners: Overview of Tools for Vadose Zone Monitoring (EPA 542-R-98-019)
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.

Long-Term Performance of Permeable Reactive Barriers Using Zero-Valent Iron: An Evaluation at Two Sites (Environmental Research Brief) (EPA 600-S-02-001)
This environmental research brief, which was developed by EPA ORD, presents findings over the past 4 years at two sites where detailed EPA investigations have focused on the long-term performance of PRBs. The document also examines the field performance of multiple PRBs across the United States.

Monitored Natural Attenuation of Chlorinated Solvents (EPA 600-F-98-022)
The fact sheet, which was 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" 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)
The fact sheet, which was 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 petroleum hydrocarbons and explains how decision-makers evaluate the role of MNA at a contaminated site.

MtBE Treatment Profiles
This Web site is sponsored jointly by EPA's OSRTI and OUST. The searchable Web site contains data on almost 400 completed and ongoing applications of MtBE treatment for drinking water and contaminated media. The treatment profiles describe sites at which technologies (both in situ and ex situ/aboveground) have been used to treat MtBE in groundwater, soil, and drinking water. The technologies include air stripping and sparging, carbon adsorption, bioremediation (in situ and ex situ), in situ chemical oxidation, SVE and dual-phase extraction, and P&T. The profiles include active links to 18 case studies that present more in-depth information about the treatment sites. EPA encourages project managers, site owners, and technology vendors to add new MtBE treatment profiles to the Web site. Once information is provided, it may be updated to add more recent data, add data for more fields, or correct errors in existing data.

Multi-Phase Extraction: State of the Practice (EPA 542-R-99-004)
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.

Natural Attenuation of Chlorinated Solvents in Groundwater: Principles and Practices
The industrial members of the Bioremediation of Chlorinated Solvents Consortium (bioconsortium) of the RTDF prepared the document to disseminate up-to-date scientific information about natural attenuation of chlorinated solvents. The mission of the RTDF bioconsortium is to accelerate the development of cost-effective bioremediation processes for degrading chlorinated solvents and to achieve public and regulatory acceptance of those processes as safe and effective. The document provides a framework to be used in evaluating natural attenuation of chlorinated VOCs.

Natural Attenuation of MtBE in the Subsurface under Methanogenic Conditions (EPA 600-R-00-006)
The document presents a case study conducted at the former Fuel Farm Site at the U.S. Coast Guard Support Center at Elizabeth City, North Carolina. The case study is intended to answer several questions: Can MtBE be biodegraded under methanogenic conditions in groundwater that was contaminated by a fuel spill? Will biodegradation produce lower concentrations of MtBE than those required under regulatory standards? Is the rate of degradation in the laboratory adequate to explain the distribution of MtBE in the groundwater at the field site? What is the relationship between the degradation of MtBE and the degradation of benzene, toluene, ethylbenzene, and xylene (BTEX) compounds? What is the rate of natural attenuation at the source area?

Overview of the Phytoremediation of Lead and Mercury
The report assesses the current state of phytoremediation as an innovative technology and discusses its usefulness and potential in the remediation of lead- and mercury-contaminated soils found at hazardous waste sites. The advantages and disadvantages, limitations, current status, projected market, and environmental concerns associated with this new and innovative technology are discussed. Case studies involving the phytoremediation of lead and mercury detailing bench and full-scale projects are also provided.

Permeable Reactive Barrier Technologies for Contaminant Remediation (EPA 600-R-98-125)
The document provides information about PRBs in terms of treatable contaminants, designs, feasibility studies, and construction options. Summaries of several current installations also are provided.

Permeable Reactive Barriers for Inorganics
The report provides a summary of information about PRBs for inorganics and a discussion of the current status of such barriers. It contains information gathered from a range of currently available sources, including project documents, reports, periodicals, the Internet, and personal communication with parties involved in projects that use the barriers.

Phytoremediation of Contaminated Soil and Ground Water at Hazardous Waste Sites (EPA 540-S-01-005)
The issue paper was developed for the EPA Regional Ground Water Forum. The paper provides a concise discussion of the processes associated with the use of phytoremediation as a cleanup or containment technique for remediation of hazardous waste sites, sediment, groundwater, surface water, and wastewater.

Phytoremediation Resource Guide (EPA 542-B-99-003)
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.

Phytotechnology Technical and Regulatory Guidance (Phyto-2)
The document, which was published by ITRC, provides technical and regulatory guidance to help regulators understand, evaluate, and make informed decisions about phytotechnology proposals. The document includes a description of phytotechnologies and discussions of regulatory and policy issues, technical requirements for phytotechnologies, and concerns on the part of stakeholders. It also provides case studies and technical references.

Proven Alternatives for Aboveground Treatment of Arsenic in Groundwater (EPA 542-S-02-002)
This issue paper, which was developed for EPA's Engineering Forum, identifies and summarizes experiences with proven aboveground treatment alternatives for arsenic in groundwater and provides information on their relative effectiveness and cost. The four technologies included in the report are precipitation/coprecipitation, adsorption, ion exchange, and membrane filtration. The report describes the theory and operation of each technology, provides available project-specific performance and cost data, and discusses limitations. The report also discusses special considerations for retrofitting systems to meet the lower arsenic maximum contaminant level (MCL) of 10 micrograms per liter (µg/L).

Remediation Technology Cost Compendium - Year 2000 (EPA 542-R-01-009)
This cost compendium, which was prepared by EPA's OSRTI, captures current information about the costs of the following six remediation technologies: (1) bioremediation, (2) thermal desorption, (3) SVE, (4) on-site incineration, (5) groundwater P&T systems, and (6) PRBs. Cost data were obtained from federal agency sources, including case studies and reports prepared by the FRTR; DOE's Los Alamos National Laboratory; the USACE Hazardous, Toxic, and Radioactive Waste Center for Expertise; and the U.S. Air Force Center for Environmental Excellence (AFCEE). The report includes six sections, each of which describes the cost analysis for one of the six technologies. Each of the sections includes a brief description of the technology, a discussion of the methodology used in the cost analysis, and the results of the cost analysis.

Solidification/Stabilization Use at Superfund Sites (EPA 542-R-00-010)
The report provides to interested stakeholders, such as project managers, technology service providers, consulting engineers, site owners, and the general public, the most recent information about S/S applications at Superfund sites as well as information about trends in the use of the technology, specific types of applications, and costs.

Study of Assessment and Remediation Technologies for Dry Cleaner Sites
Prepared by SCRD, with the support of EPA's OSRTI, the report presents the results of the Coalition's evaluation of assessment and remediation technologies commonly used in cleaning up dry cleaner sites. The evaluation was based on the results of responses to questionnaires sent to entities involved in such cleanups in 1999. The report presents those results in detail. An appendix in the report provides descriptions and brief evaluations of assessment technologies frequently used at dry cleaner sites.

Subsurface Containment and Monitoring Systems: Barriers and Beyond (Overview Report)
The document provides a summary of information about subsurface barriers – vertical and horizontal – with an emphasis on emerging and innovative vertical barrier technologies. It also presents a discussion of the current status of such barriers. The report is not intended to be inclusive; it merely provides an overview of the current work in the field on subsurface barrier technologies drawn from information gathered from a range of sources, including project documents, reports, periodicals, the Internet, and personal communication with parties involved in projects that use such barriers.

Subsurface Remediation: Improving Long-Term Monitoring and Remedial Systems Performance Conference Proceedings, June 1999 (EPA 540-B-00-002)
The document, which was compiled by EPA's OSRTI, summarizes the presentations made and workshops conducted during a conference on improving long-term monitoring (LTM) and the performance of remedial systems. The conference, sponsored and developed by FRTR, took place in St. Louis, Missouri, from June 8 through 11, 1999. The conference provided up-to-date information about LTM and system optimization through presentations and topical workshops.

Surfactant-Enhanced Aquifer Remediation (SEAR) Implementation Manual (TR-2219-ENV)
This implementation manual, which was prepared by Intera Inc. and NFESC, is designed to familiarize RPMs, engineers, and scientists working on environmental remediation projects with the major tasks and planning parameters involved in implementing an in situ surfactant flood or SEAR project to remove DNAPLs. The manual is intended to help users understand basic design and implementation issues, attain remedial objectives, and follow risk management methodologies and approaches in order to avoid misapplication of surfactant flooding for DNAPL removal.

A Systematic Approach to In Situ Bioremediation in Groundwater, Including Decision Trees for In Situ Bioremediation of Nitrates, Carbon Tetrachloride, and Perchlorate
This document, which was prepared by ITRC, provides guidance for the systematic characterization, evaluation, design, and testing efforts associated with implementing in situ bioremediation (ISB) for a biotreatable contaminant. It serves as guidance for regulators, consultants, responsible parties, and stakeholders when an ISB technology is being considered. This document presents decision trees for reviewing, planning, evaluating, and approving ISB systems for the saturated subsurface and defines site parameters and appropriate ranges of criteria for characterization, testing, design, and monitoring efforts. The information provided in this document will support ISB evaluation.

Technical and Regulatory Guidance for Surfactant/Cosolvent Flushing of DNAPL Source Zones

This guidance, which was prepared by ITRC, provides technical and regulatory information for those involved in selecting and implementing surfactant and cosolvent flushing as a remedial action for DNAPLs. The guidance describes the technology and discusses the major factors that need to be considered in evaluating design and implementation work plans for surfactant and cosolvent flushing of DNAPLs.

Technical and Regulatory Requirements for Enhanced In Situ Bioremediation of Chlorinated Solvents in Groundwater

The report, which was published by ITRC, 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.

Technologies for Treating MtBE and Other Fuel Oxygenates (EPA 542-R-04-009)

This report, which was developed by EPA's OSRTI, provides an overview of the treatment technologies used to remediate groundwater, soil, and drinking water contaminated with MtBE and other fuel oxygenates. The treatment methods discussed include air sparging, SVE, MPE, in situ and ex situ bioremediation, in situ chemical oxidation, P&T, and drinking water treatment. Information in the report can be used to help evaluate these technologies based on their effectiveness at specific sites. The report summarizes available performance and cost information for these technologies, provides examples of where each has been used, and identifies additional sources of information.

Technology Status Review: In Situ Oxidation

This report, which was published by ESTCP, provides a survey of sites where in situ oxidation (ISO) has been used. The overall objective of the project summarized in the report was to assess the current status of ISO and determine what additional information is needed to understand the site conditions for which ISO is appropriate.

Underground Injection Control (UIC) Program

The federal UIC Program works with state and local governments to prevent contamination of drinking water resources caused by the underground injection of waste. Among the wastes the UIC program regulates are more than nine billion gallons of hazardous waste every year; more than two billion gallons of brine from oil and gas operations every day; and automotive, industrial, sanitary and other wastes that are injected into shallow aquifers.

Use of Field-Scale Phytotechnology for Chlorinated Solvents, Metals, Explosives/ Propellants and Pesticides - Status Update (EPA 542-R-05- 002)

This status report, which was published by EPA OSRTI, provides information about 79 phytotechnology projects conducted at sites in the United States and Canada, including Superfund sites and federal and military sites that are being addressed under state, local, or voluntary cleanup programs. These projects involved treatment of soil or groundwater contaminated with chlorinated solvents, metals, explosives and propellants, and pesticides. The document is meant to be a networking tool for federal, state, and industrial employees to share lessons learned from and practical experiences with field-scale applications of phytotechnology.

Where Do We Go from Here?

Next Steps

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.*

S11 STATE DRYCLEANER REMEDIATION PROGRAMS:

An Innovative Approach to Cleanup

State-mandated programs have had a major impact in turning former dry cleaner sites into marketable properties. Soil and groundwater contaminated by dry cleaning solvent are associated with many of these sites. Resource and budget constraints pose challenges to states as they undertake assessment and pursue remediation of these properties. With support from EPA's OSRTI, the State Coalition for Remediation of Drycleaners (SCRD) was established in 1998 to (1) provide a forum for exchange of information and discussion of implementation issues related to established state dry cleaner programs, (2) share information and lessons learned, and (3) encourage the use of innovative technologies in the remediation of dry cleaner sites. The coalition is made up of representatives of states that have established dry cleaner remediation programs, including Alabama, Connecticut, Florida, Illinois, Kansas, Minnesota, Missouri, North Carolina, Oregon, South Carolina, Tennessee, Texas, and Wisconsin. A subgroup of the coalition has focused its efforts on conducting research about state programs and use of innovative technologies to assess and remediate sites contaminated with dry cleaning solvents. In its 2004 report, *Drycleaner Site Assessment and Remediation – A Technology Snapshot (2003)* the coalition reports the results of a 2002 survey performed to evaluate changes in use of innovative technologies. Surveys such as these provide information in the search for cost-efficient and technically effective assessment and remediation technologies. Such studies as the one performed at the Armen Cleaners site in Ann Arbor, Michigan, will continue to generate new information about innovative analytical approaches. That study was successful in building a collaborative data set to confirm the completeness of vapor intrusion and ambient air pathways. The study also better defined the extent of indoor air contamination and identified potential residential receptors of concern. Overall, although EPA's investigation built upon previous data to delineate significant sources of PCE at the site, it also found that vapor and ambient air concentrations of tetrachloroethene (PCE) were fairly localized, dropping quickly with distance from the site. The project was unique in its application of a number of innovative, real-time analytical approaches as well as its use of the Triad approach to stress systematic planning and dynamic work strategies in order to expedite and improve site characterization and cleanup.

A Quick Look

- Dry cleaners use chlorinated solvents, particularly PCE, in their operations and have contributed to contamination of soil and groundwater at many brownfields sites.
- SCRD provides a forum for exchange of information and lessons learned regarding the use of innovative technologies in the assessment and remediation of dry cleaner sites.
- Innovative technologies are of particular benefit at small dry cleaner sites because limited funding for cleanup of such sites is often an issue.

For more information, see the resources numbered 41, 72, 148, and 149 in the Index of Resources beginning on page I-1.

KEY RESOURCE

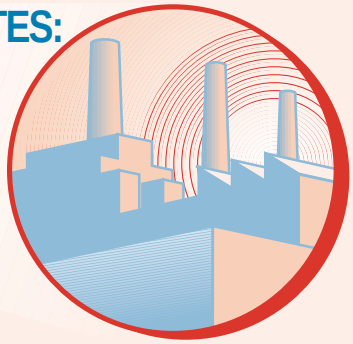
State Coalition for Remediation of Drycleaners (SCRD) Internet Site

View on line at *www.drycleancoalition.org*

The SCRD Internet site, which is supported by EPA's OSRTI, provides extensive information about state remediation programs and resources related to remediation of dry cleaner sites. Descriptions of state programs and points of contact in member states are provided. Relevant publications, regulations, and other documents are identified as well. Brownfields stakeholders involved in the assessment and cleanup of dry cleaner sites in Alabama, Connecticut, Florida, Illinois, Kansas, Minnesota, Missouri, North Carolina, Oregon, South Carolina, Tennessee, Texas, and Wisconsin may be particularly interested in the detailed information provided about programs in those states. Profiles of the remediation of specific sites throughout the United States are intended to assist users, particularly state officials, in making more informed decisions regarding remediation of sites in their states. Publications developed by SCRD, as well as state and federal resources that are pertinent to issues associated with dry cleaner sites can be viewed online or downloaded at no charge.

S12 REMEDIATING MANUFACTURED GAS PLANT SITES:

Emerging Remediation Technologies



From the early 1800s through the mid-1900s, manufactured gas plant (MGP) sites were operated nationwide to produce gas from coal or oil for lighting, heating, and cooking. The gas manufacturing and purification processes conducted at the plants yielded gas plant residues that included tars, sludges, lampblack, light oils, spent oxide wastes, and other hydrocarbon products. Although many of the by-products were recycled, excess residues remained at MGP sites. The residues contain polycyclic aromatic hydrocarbons (PAH), petroleum hydrocarbons, benzene, cyanide, metals, and phenols. The base contaminant, coal tar, is composed of a complex mixture of PAHs that generally exhibit low volatility, low solubility, and low biodegradability. Consequently, those components are difficult to treat.

There are an estimated 3,000 to 5,000 former MGP sites across the country; some of those sites still are owned by the successors to the utilities that founded them. MGPs typically were built on the outskirts of cities that since have grown. Today, therefore, the under-used sites often are located in inner city areas, many of which are being considered for redevelopment under the Brownfields Program. The redevelopment of MGP sites for reuse can help the utility industry turn potential liabilities into assets. For example, in the city of Fort Myers, Florida, a former MGP site was redeveloped into a private, nonprofit museum and aquarium called the Imaginarium.

As the business environment has spurred companies to reassess land holdings and better manage environmental concerns, the MGP sites have become a central focus. Many companies are investigating and remediating such sites. The similarities in the configuration of the sites and in the contaminants found at them provide opportunities to apply innovative approaches that benefit from economies of scale. Former MGP sites offer an ideal opportunity to apply tools and technologies that expedite site characterization and source remediation.

A Quick Look

- Although MGPs have closed and most have been demolished, such facilities have left a legacy of environmental contamination.
- Releases of coal tars, oils, and condensates produced in MGP plants contributed to a wide range of contamination with PAHs, phenols, benzene, and cyanide.
- As utilities discover more MGP sites, they are faced with the need to identify cost-effective, environmentally safe, and innovative approaches for the characterization and remediation of those sites.

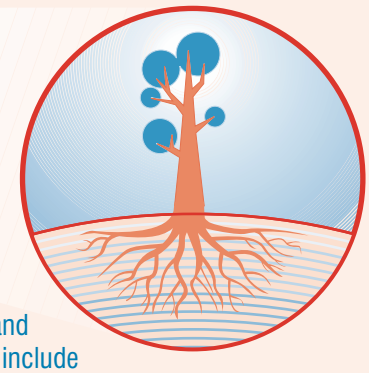
Thermal desorption has been used successfully to remediate soils that contain MGP wastes (for example, lampblack and coal tar), achieving reductions of more than 98 percent in concentrations of PAHs; total petroleum hydrocarbons (TPH); benzene, toluene, ethylbenzene, and xylene (BTEX) compounds; and cyanide. Performance data have demonstrated that less than 10 parts per billion (ppb) of residual PAHs and cyanides can be achieved through the application of thermal desorption. Other technologies that have proven successful in remediating MGP wastes include co-burning in utility boilers, recycling in road beds, in situ bioremediation, landfarming, and soil washing.

Because former MGP sites are prevalent and represent a large area of unused land with complex remedy needs, new technologies are being encouraged and field-tested to demonstrate their technical feasibility. Opportunities exist to demonstrate and refine new assessment and remediation technologies that can assist in expediting cleanup processes that can place these contaminated sites back into productive use.

For more information, see the resource numbered 139 in the Index of Resources beginning on page I-1.

S13 PHYTOREMEDIATION TECHNOLOGY:

A Growing Field



Phytoremediation includes the use of plants and natural processes to remediate or stabilize hazardous wastes in soil, sediments, surface water, or groundwater. By acting as filters or traps, plants can degrade organic pollutants, extract metal contaminants, or contain and stabilize the movement of contaminants. Phytoremediation first was tested actively at waste sites in the early 1990s, and use of the approach has been increasing. Phytoremediation has been implemented on a full or demonstration scale at more than 200 sites nationwide. As the number of projects grows, new information about the cost and performance of phytoremediation will become available.

Phytoremediation provides many advantages because it has the potential to work at a broad variety of sites and on myriad contaminants involving potentially less costs than other options. Types of sites at which phytoremediation has been applied with some degree of success in cleaning up the sites include pipelines, industrial and municipal landfills, agricultural fields, wood treatment sites, military installations, fuel storage tank farms, army ammunition plants, sewage treatment plants, and mining sites.

A Quick Look

- An aesthetically pleasing, passive cleanup technology powered by solar energy.
- A technology that is most useful at sites at which shallow, low levels of contamination are present.
- A cost-effective technology that has the potential to clean up a wide variety of brownfields sites.
- Can also be used for other functions related to site cleanup, such as erosion control and runoff control.

Phytoremediation is being tested and evaluated for its effectiveness in treating a wide array of contaminants found at brownfields sites. Current results indicate that plants have the potential to enhance remediation of petroleum hydrocarbons, BTEX, polycyclic aromatic hydrocarbons (PAH), PCBs, chlorinated solvents, heavy metals, and pesticide waste. In addition to providing a long-term solution, phytoremediation is an excellent option for providing an interim solution for containing the spread of contaminants and beginning the treatment process. Phytoremediation does not require the excavation of soil, and its application may require only minimal material handling. Further, phytoremediation can have a positive effect on the aesthetic character of a site, may be an attractive alternative for use at large sites at which other methods of remediation are not cost-effective or practical, and can be used in conjunction with other technologies when the redevelopment and land use plans for the site include the use of vegetation.

Decision-makers at brownfields sites at which there are relatively low concentrations of contaminants (that is, organics, nutrients, or metals) over a large cleanup area and in shallow soils, streams, and groundwater should consider the use of phytoremediation. Phytoremediation also may be considered for use in conjunction with other technologies when redevelopment and land use plans for a site include the use of vegetation. Among the types of plants used for phytoremediation are hybrid poplar, willow, and cottonwood trees; rye, Bermuda, sorghum, and fescue grasses; legumes (clover, alfalfa, and cowpeas); aquatic and wetland plants (water hyacinth and bullrush); and hyperaccumulators for metals (such as alpine pennycress for zinc or alyssum for nickel). If levels of contamination are so high that the concentrations of contaminants are toxic to plants (phytotoxic), phytoremediation may not be an effective treatment option.

Because phytoremediation has been used more frequently on a demonstration-scale basis, site owners may find it necessary to show its potential applicability and efficacy on a site-specific basis. Doing so may require an up-front commitment of time and resources to demonstrate that the performance of phytoremediation is comparable to the performance of traditionally accepted technology options. However, such an investment ultimately could save site owners significant amounts of money when they clean up their properties for redevelopment. In recent years, EPA has compiled new information to assist site decision-makers who may be reluctant to use phytotechnology

Continued on next page

S13 Continued ...

PHYTOREMEDIATION TECHNOLOGY: A Growing Field

because of the limited amount of information about its use at actual field-scale projects. In a recent paper, *Use of Field-Scale Phytotechnology for Chlorinated Solvents, Metals, Explosives and Propellants, and Pesticides STATUS UPDATE* (April 2005), EPA provides information on phytotechnology applications and identifies such examples as the Edward Sears property that was used from the mid-1960s to the early 1990s for the repackaging and sale of paints, adhesives, paint thinners, and various military surplus materials. Groundwater at the site was contaminated with a variety of solvents, including methylene chloride, trimethylbenzene, TCE, and xylenes. A field demonstration of phytotechnology using hybrid poplars to clean up shallow groundwater at the site was performed beginning in 1996. Substantial reductions in contaminant concentrations have been reported. For example, data covering the period from 1995 to 2004 shows that concentrations of methylene chloride was reduced from as high as 6,700 ìg/L to below detection; trimethylbenze from as high as 1,890 to 730 ìg/L; and TCE from as high as 510 to 46 ìg/L. Groundwater monitoring is ongoing at the site.

In addition to the document discussed above, other resources are available at ***www.epa.gov/tio/pubitech.htm*** including:

Brownfields Technology Primer: Selecting and Using Phytoremediation for Site Cleanup (EPA 542-R-01-006), July 2001

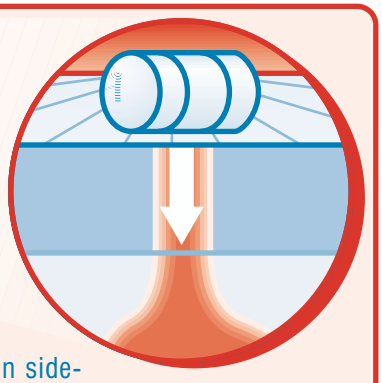
Phytoremediation Resource Guide (EPA 542-B-99-003), June 1999

For more information, see the resources numbered 13, 23, 29, 32, 59, 95, 96, 115, 118, 119, 120, and 164 in the Index of Resources beginning on page I-1.

S14

CLEANUP OF DNAPLS:

A Widespread Challenge



It is estimated that billions of dollars will be spent by the private and public sector to clean up sites contaminated with DNAPL. Denser than water, DNAPLs tend to sink through the water table and form a product pool on top of such impermeable soil layers as clay. DNAPLs also can sink and migrate laterally through fractures in bedrock. Numerous variables influence fate and transport of DNAPLs in the subsurface, and it can be difficult to predict the path DNAPLs will take.

Because of these properties, DNAPLs act as a continuing source of contamination. DNAPLs may cause serious, long-term contamination of groundwater and pose a significant challenge to cleanup of the site, especially for established technologies such as pump-and-treat. At sites with significant DNAPL contamination, pump-and-treat systems may require several hundreds of years to clean up the groundwater.

Sites likely contaminated with DNAPLs include dry cleaning facilities, wood preservation sites, MGP sites, and solvent sites (industrial operations using large quantities of solvents as well as solvent disposal and recovery sites).

To accelerate the development and implementation of innovative technologies for remediating DNAPLs in groundwater, the Interagency DNAPL consortium (IDC) was formed. The consortium has developed a national action plan that proposes collaborative efforts among federal agencies, private sector entities, and responsible parties in research and development, technology demonstrations, and full-scale technology deployment to reduce the perceived risk associated with innovative technologies. The interagency agreement supports the testing of new and existing technologies in side-by-side demonstrations to compare cost and performance data that will be used to expedite regulatory acceptance and use of innovative remedial technologies at other sites.

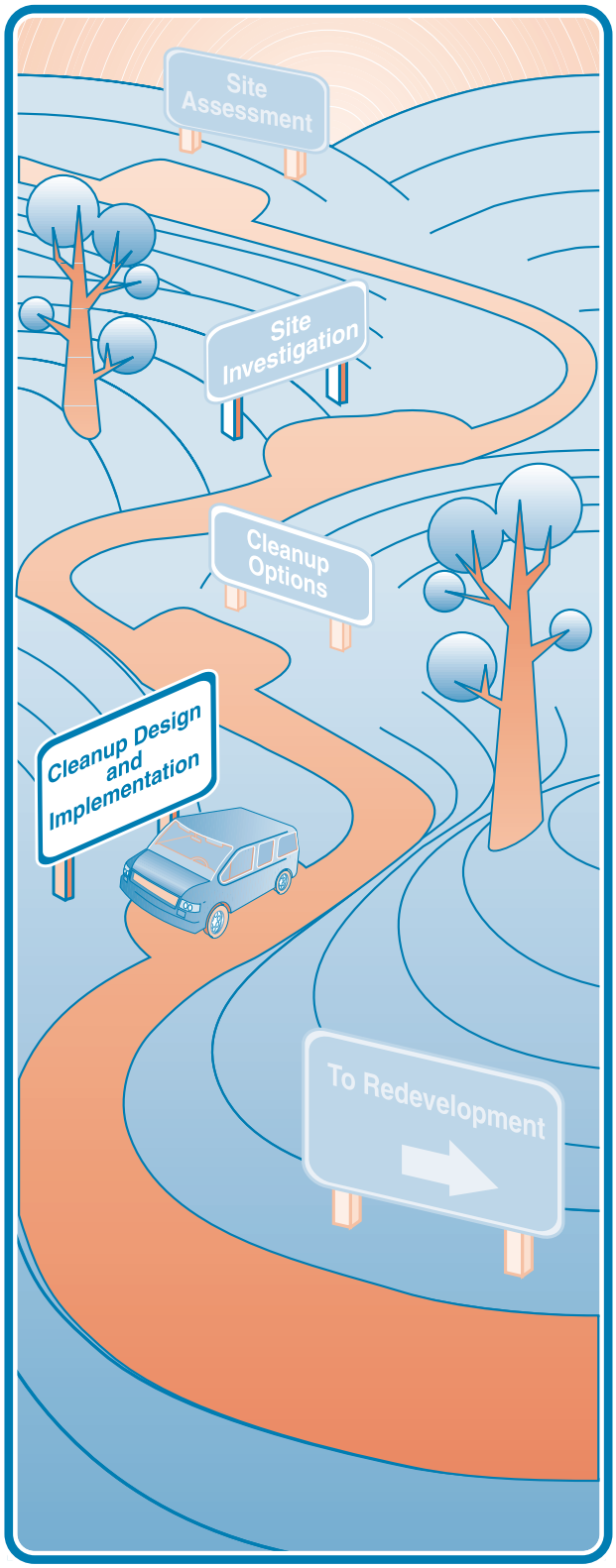
A Quick Look

- Most commonly occurring DNAPLs typically are industrial chlorinated solvents such as TCE, PCE, and carbon tetrachloride (CCl_4). Other prevalent DNAPLs include creosote, pentachlorophenol (PCP), and PAH coal tars.
- DNAPLs are present at 60 to 70 percent of the Superfund NPL sites.
- Among the number of innovative technologies that are demonstrating success and providing promising results in reducing DNAPL contamination are in situ thermal treatment, in situ chemical oxidation, and ISB.

EPA continues to support the evaluation and application of technologies for the assessment and remediation of sites contaminated with DNAPLs. In *DNAPL Remediation: Selected Projects Approaching Regulatory Closure STATUS UPDATE* (EPA 542-R-04-016) (November 2004), EPA provides information on the challenges of DNAPL characterization and remediation, and overview of DNAPL remediation technologies, a description of DNAPL remediation projects, and a summary of findings.

For more information, see the resources numbered 30, 40, 73, 90 (specifically the case study titled "Geophysical Investigation at Hazardous Waste Sites"), 94, and 158 in the Index of Resources beginning on page I-1.

CLEANUP DESIGN AND IMPLEMENTATION



Develop and Carry Out Detailed Cleanup Plans for the Site

The cleanup design and implementation phase focuses on developing and carrying out 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?

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, if applicable, and/or county or local officials to facilitate the placement and implementation of institutional controls

Where Do We Find Answers to Our Technology Questions?

Listed below are examples of technology resources that provide information about cleanup designs and implementations including regulatory guidelines and community outreach materials. In addition, technologies identified during the site investigation phase may be appropriate to monitor cleanup performance and close-out. The Resources are listed alphabetically for the following categories:

A. Resources for Cleanup Design and Implementation

B. Site-Specific Resources for Cleanup Design and Implementation

C. Technology-Specific Resources for Cleanup Design and Implementation

Access the Road Map online at ***www.brownfieldstsc.org*** to view or download the following resources electronically or to obtain a link that provides complete ordering information.

A. Resources for Cleanup Design and Implementation

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

Characterization of Mine Leachates and the Development of a Ground-Water Monitoring Strategy for Mine Sites (EPA 600-R-99-007)
The objective of the research project was to develop a better understanding of the composition of mine waste leachates and to identify cost-effective groundwater monitoring parameters that could be incorporated into a monitoring strategy to reliably detect the migration of contaminants from hard rock mining operations.

Citizen's Guides to Understanding Innovative Treatment Technologies
The guides are prepared by EPA to provide site managers with nontechnical outreach materials that they can share with communities in the vicinity of sites. The guides present information on innovative technologies that have been selected or applied at some cleanup sites,

provide overviews of the technologies, and present success stories about sites at which innovative technologies have been applied. Both English and Spanish versions of the guides are available. The guides contain information on the following subjects:

- ***NEW!*** *Activated carbon treatment (EPA 542-F-01-020)*
- ***NEW!*** *Air stripping (EPA 542-F-01-016)*
- *Bioremediation (EPA 542-F-01-001)*
- ***NEW!*** *Capping (EPA 542-F-01-022)*
- ***NEW!*** *Chemical dehalogenation (EPA 542-F-01-010)*
- *Chemical oxidation (EPA 542-F-01-013)*
- *Fracturing (EPA 542-F-01-015)*
- *In situ flushing (EPA 542-F-01-011)*
- *In situ thermal treatment methods (EPA 542-F-01-012)*
- ***NEW!*** *Incineration (EPA 542-F-01-018)*
- *Monitored natural attenuation (EPA 542-F-01-004)*
- *Permeable reactive barriers (EPA 542-F-01-005)*
- *Phytoremediation (EPA 542-F-01-002)*
- ***NEW!*** *Pump and treat (EPA 542-F-01-025)*
- ***NEW!*** *Soil excavation (EPA 542-F-01-023)*
- *Soil washing (EPA 542-F-01-008)*
- ***NEW!*** *Solidification/Stabilization (EPA 542-F-01-024)*
- ***NEW!*** *Solvent extraction (EPA 542-F-01-009)*
- *Soil vapor extraction and air sparging (EPA 542-F-01-006)*
- *Thermal desorption (EPA 542-F-01-003)*
- ***NEW!*** *Vitrification (EPA 542-F-01-017)*

Design Solutions for Vapor Intrusion and Indoor Air Quality (EPA 500-F-04-004)
This fact sheet, compiled by EPA OSWER, provides an overview of technical and health issues regarding vapor intrusion into indoor air and its effect on land redevelopment. The fact sheet discusses how to anticipate the potential for vapor intrusion; evaluate the extent of the problem; and prevent or correct the problem.

Directory of Technical Assistance for Land Revitalization (BTSC) (EPA 542-B-03-001)
BTSC has prepared this directory to provide information about technical assistance that is available from federal agencies to assist regional, state, and local government personnel in making assessment and cleanup decisions for brownfields, reuse, and revitalization sites. This directory includes information about 37 organizations within 10 federal agencies that provide different types of support to help with site assessment and cleanup, including technical support and funding sources. Profiles are included for these agencies and organizations and contain the following types of information: background and location information, relevancy to revitalization, description of the areas of expertise available, discussion of the types of services available, types of funding available and eligibility, contact information and the process for requesting assistance, and examples of specific instances in which the organization has previously provided support relevant to site revitalization. Information in the profiles is believed to be current as of March 2003. To help maintain current information, the directory is available as an online searchable database at ***www.brownfieldstsc.org/directory***.

EPA REmediation And CHaracterization Innovative Technologies (REACH IT) Online Searchable Database
The EPA REACH IT online searchable databases sponsored by EPA's OSRTI is a service provided free of charge to both users and technology vendors. EPA REACH IT is accessible only through the Internet. This database provides users with comprehensive, up-to-date information about more than 254 characterization technologies and 484 remediation technologies and their applications. It combines information submitted by technology service providers about remediation and characterization technologies with information from EPA, DoD, DOE, and state project managers about sites at which innovative technologies are being deployed. 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 updates all of the information

available in the system about every six months. Technology vendors may also add or update information in EPA REACH IT at any time through the Data Entry System or by submitting information by mail. You can search the EPA REACH IT system in several ways. Various search options are available for a user on the home page, including Custom Search; Spotlight; Most Common Searches; Saved Searches; Guided Search; and Vendor, Technology, and Site Index. For questions about whether a technology is eligible for listing in EPA REACH IT, the user may contact the EPA REACH IT help line at (800) 245-4505 or (703) 390-0713 or send an e-mail to epareachit@ttemi.com.

Federal Remediation Technologies Roundtable Case Studies

The case studies provide the user with information about specific characterization and remediation, technology optimization applications. Four focus areas have been established by FRTR for providing performance and cost information on technology applications: remediation case study reports, characterization and monitoring case study reports, technology assessment reports, and LTM/optimization case study reports. FRTR case studies are developed by DoD, USACE, the U.S. Navy, the U.S. Air Force, DOE, DOI, and EPA. The case studies focus on full-scale and large field demonstration projects and include site background information, technology description, cost and performance information, and lessons learned. The technologies include innovative and conventional treatment technologies for contaminated soil, groundwater, and solid media. Users can search the case studies by groups of contaminants, media, waste management practices that contribute to contamination, and treatment systems.

Federal Remediation Technologies Roundtable Remediation Optimization Web Site

Remediation process optimization (RPO) involves systematic monitoring and evaluation to detect and respond to changes in remedial system performance. System optimization offers benefits that include enhanced protectiveness, reduced cost, shortened cleanup times, and the increased likelihood of site close-out. The Web site includes a searchable database of optimization case studies, meeting and conference materials from events related to remediation system optimization, general optimization tools and processes, descriptions of broad-based optimization projects, definitions of optimization acronyms, and a list of RPO points of contact. Monitoring optimization includes approaches for increasing efficiency, reducing cost, identifying uncertainty, and increasing reliability of long-term monitoring. Simulation optimization involves the use of mathematical optimization techniques coupled with groundwater simulation models to determine optimal pumping locations and rates for plume containment and/or cleanup. Treatment technology optimization includes information on specific in situ and ex situ remedial technologies.

Improving the Cost-Effectiveness of Hazardous Waste Site Characterization and Monitoring

The report introduces a new standard promoted by EPA's OSWER and OSRTI that encourages more effective and less costly strategies for characterizing and monitoring hazardous waste sites. The new approach uses an integrated triad of systematic planning, dynamic work plans, and on-site analysis for data collection and technical decision-making at hazardous waste sites. Individually, none of the concepts in the Triad approach is new, but it has been demonstrated that the integrated approach completes projects faster, cheaper, and with greater regulatory and client satisfaction than the traditional phased approach. The report includes a list of additional resources regarding innovative technologies and site characterization.

Institutional Controls: A Site Manager's Guide to Identifying, Evaluating, and Selecting Institutional Controls at Superfund and RCRA Corrective Action Cleanups (EPA 540-F-00-005)

The fact sheet provides site managers and decision-makers at Superfund and RCRA corrective action sites with an overview of the types of institutional controls that commonly are used or implemented and outlines the factors that generally should be considered when evaluating and selecting institutional controls as part of the remedy. The fact sheet also provides guidance to the public and the regulated community in the matter of how EPA intends to evaluate and implement institutional controls as part of cleanup decisions. Detailed descriptions of the different types of institutional controls are provided, as are a glossary and a checklist for implementing institutional controls.

OSWER Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (Subsurface Vapor Intrusion Guidance)
This draft guidance, issued by EPA OSWER, provides current technical and policy recommendations on determining if the vapor intrusion pathway poses an unacceptable risk to human health at cleanup sites. At the time of issuing this draft guidance, OSWER has recommended its use at RCRA Corrective Action sites, Superfund sites and brownfields sites, but not for UST sites. The draft document is intended to serve as an aid in evaluating the potential for human exposure from the vapor intrusion pathway given the state-of-the-science at this time. EPA believes that the document provides relevant information and guidance currently available on the issue of vapor intrusion.

Vapor Intrusion Issues at Brownfields Sites
This background document, prepared by the ITRC, is designed to help stakeholders involved with redevelopment projects to develop a consistent approach to vapor intrusion evaluation, regulatory approval, and deployment of specific technologies at specific sites. The document provides an overview of vapor intrusion, the type of contaminants that may have vapor intrusion potential, the possibility of brownfields sites to have indoor air exposure from vapor intrusion, and the steps that can be taken to limit such exposure. The document provides an international perspective on the problem by including information about vapor intrusion problems and case studies of affected sites in Germany.

B. Site-Specific Resources for Cleanup Design and Implementation

Listed below are case studies and other resources that provide information and lessons learned from the application of innovative technologies to specific contaminants and site types.

Naval Air Station Pensacola, Optimization of RAO to Treat Chlorinated Hydrocarbons in Groundwater
This summary report, which was prepared by NFESC, describes LTM cost reductions associated with reducing sampling frequency and the number of constituents being analyzed for. The U.S. Navy, in conjunction with regulators, optimized remedial action operation (RAO) at a former sludge drying bed and surge pond site at Naval Air Station (NAS) Pensacola in Florida. The RAO resulted in improvements in the monitoring program, a modification to the remedial strategy, accelerated site cleanup, and significant cost savings.

Naval Submarine Base, Kings Bay (In Situ Chemical Oxidation)
During the early 1990s, a plume of chlorinated solvents was discovered in groundwater moving toward a residential area located near Site 11, Old Camden County Landfill, Naval Submarine Base (NSB), Kings Bay, Georgia. To prevent further off-site contamination, a P&T system was designed and installed to hydraulically contain the plume at the perimeter of the landfill and adjacent to the residential area. An RAO modification reduced long-term P&T for hydraulic containment to a period of less than 2 months after chemical oxidation treatments. Additionally, this modification resulted in savings of more than several million dollars over the life of the remedy. NFESC compiled the summary report to describe system optimization, such as implementing in situ chemical oxidation in addition to P&T in order to reduce contaminant concentrations in source areas. MNA was implemented to address residual concentrations.

Pilot Project to Optimize Superfund-Financed Pump and Treat Systems: Summary Report and Lessons Learned (EPA 542-R-02-008 a-u)
This report, which was compiled by EPA, summarizes Phase II (site optimization) of the Nationwide Fund-lead Pump and Treat Optimization Project. This phase included conducting RSEs at the 20 sites selected in Phase I with the purpose of providing recommendations to improve remedy effectiveness, reduce remedy costs, improve technical operations, and gain site close-out. RSEs at 4 of the 20 P&T systems (two in Region 4 and two in Region 5) were previously conducted as part of a demonstration project completed in 2000. The RSE process was developed by USACE.

Pump and Treat and Air Sparging of Contaminated Groundwater at the Gold Coast Superfund Site, Miami, Florida, September 1998

Gold Coast Oil Corporation operated as a spent oil and solvent recovery facility from 1970 to 1982 near Miami, Florida, and discharged chlorinated solvents directly onto the soil. DNAPL was also observed in groundwater at this site. The case study report prepared by EPA describes modifications to the P&T extraction system, including enlarging two extraction wells, shutting down the system for 4 months, conducting air sparging in source areas, and adding peroxide to wells for a certain period of time. The report describes the results and cost of implementing these modifications at the site. Cleanup standards were met at this site within approximately 4 years after the system modifications.

Pump and Treat and In Situ Bioremediation of Contaminated Groundwater at French Limited Superfund Site, Crosby, Texas, September 1998

The French Limited site was used as a disposal site for industrial waste material that included chlorinated solvents and organic contaminants such as benzene and chloroform. Active remediation was conducted at the site from January 1992 through December 1995 using groundwater extraction and above-ground treatment; enhanced aquifer flushing through pressure injection of clean water; and accelerated ISB through the addition of oxygen, phosphorus, and nitrate. Source control was achieved through installation of sheet-pile walls around lagoon and DNAPL source areas. The case study report prepared by EPA describes modifications to the treatment system, including adding a second sheet-pile wall around DNAPL. The report also describes the results and cost of implementing these modifications at the site.

Pump and Treat and In Situ Bioremediation of Contaminated Groundwater at the Libby Groundwater Superfund Site, Libby, Montana, September 1998

The Libby site is a former wood-treating facility where widespread creosote and PCP contamination was observed. The remedial strategy at this site was to address the source area by removing the NAPL and to stimulate bioremediation in the downgradient upper-aquifer plume. The three components of the aquifer remedial system included a source area extraction system, an intermediate injection system, and a boundary injection system. The case study report prepared by EPA describes modifications to the extraction and treatment system, including converting to low-shear pumps, abandoning four extraction wells and constructing a new one, and replacing a peroxide aeration system for ISB of source water with a bubbleless system. The report also describes the results and cost of implementing these modifications at the site.

Pump and Treat and Permeable Reactive Barrier to Treat Contaminated Groundwater at the Former Intersil, Inc. Site, Sunnyvale, California, September 1998

The Former Intersil, Inc., site housed a semiconductor manufacturer that caused groundwater in the area to be contaminated with chlorinated solvents. A P&T system was operated at this site from 1987 until 1995. After the mass removal by the P&T system had asymptotically declined, a PRB was selected as an alternative technology. The case study report prepared by EPA describes modifications to the P&T system, including upgrading the system and switching to a PRB in 1995. The report also describes the results and cost of implementing these two technologies at the site.

Pump and Treat of Contaminated Groundwater at the Mid-South Wood Products Superfund Site, Mena, Arkansas, September 1998

The Mid-South Wood Products site was contaminated with PCP, PAHs, and heavy metals. DNAPL and LNAPL were observed in groundwater at the site. The case study report developed by EPA describes modifications to the site extraction and treatment system, including removing five extraction wells, continuously adjusting the pumping schedule for the extraction wells, and adding a carbon treatment system for 1 year. The system optimization was performed after 8 years of systems operation, and groundwater contamination was reduced to one localized area of concern. The report also describes the results and cost of implementing P&T at the site.

Pump and Treat of Contaminated Groundwater at the SCRDI Dixiana Superfund Site, Cayce, South Carolina, September 1998

The SCRDI Dixiana site, a former industrial waste storage facility contaminated with chlorinated solvents, provided a cleanup challenge because of its complex hydrogeology. The case study report compiled by EPA describes modifications to the site extraction and treatment system, including adding a collection trench, reducing the number of extraction wells by five, and replacing the tower air-stripper with a shallow air stripper. The report also describes the results and cost of implementing P&T at the site.

Pump and Treat of Contaminated Groundwater at the Solid State Circuits Superfund Site, Republic, Missouri, September 1998

The Solid State Circuits site is a former manufacturing facility contaminated with chlorinated solvents. The groundwater, which was characterized as a leaky artesian system occurring in karst formations with shallow and deep bedrock zones, posed a cleanup challenge. A P&T system was operated at the site for several years, but cleanup goals were not achieved. Hence, the system had to be modified in order to enhance its performance. The case study report prepared by EPA describes modifications to the extraction and treatment system, including adding three extraction wells off site to contain the plume and electronically linking the air stripper blower to transfer pumps so that the blower would shut off when the pumps were not operating. The report also describes the results and cost of implementing P&T at the site.

Pump and Treat of Contaminated Groundwater at the United Chrome Superfund Site, Corvallis, Oregon, September 1998

The United Chrome Superfund site is a former industrial hard chrome plating facility where chromium contamination was widespread. The case study report prepared by EPA describes modifications to the site extraction and treatment system, including turning off some extraction wells, flushing some areas, sending untreated water to a Publicly Owned Treatment Works (POTW), and injecting deep aquifer water into the upper aquifer. The report also describes the results and cost of implementing P&T at the site.

Pump and Treat of Contaminated Groundwater at the Western Processing Superfund Site, Kent, Washington, September 1998

The Western Processing site was operated as a waste processing facility from 1961 to 1983. Over 400 businesses transported industrial wastes to the site to be stored, reclaimed, or buried. The original approach to groundwater treatment at this site was an aggressive effort to fully restore the site to its original condition within 7 years. Restoration was a priority, and high costs were incurred to achieve this goal, including high P&T system operating costs. After 8 years of P&T, the goal of restoration was changed to containment based on the technical impracticability of achieving full restoration. This case study report prepared by EPA describes modifications to extraction and treatment system, including discontinuing operation of 210 shallow well points, installing deep wells, and adding metal precipitation to the treatment system. The report also describes the results and cost of implementing P&T at the site.

Remedial Action Operation Optimization Case Study: Eastern Groundwater Plume, New Brunswick, Maine

This case study report, which was prepared by NFESC, includes an effectiveness evaluation for the Eastern Groundwater Plume P&T system at NAS Brunswick in Maine. The primary purpose of the evaluation is to assess the ongoing RAO program for this system and to provide recommendations for attainment of site remedial action objectives and site closure.

Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water (EPA 600-R-98-128)

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 U.S. Air Force, 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.*

NEW

S15 VAPOR INTRUSION

Subsurface Vapor Intrusion Guidance

Vapor intrusion is the migration of volatile chemicals from the subsurface into overlying buildings. Vapor intrusion is typically associated with releases of volatile organic compounds (VOCs) such as petroleum products and chlorinated solvents to soil and groundwater from former gas stations, dry cleaners, automobile repair shops, and industrial facilities. VOCs in buried wastes and contaminated groundwater can emit vapors that may migrate through the subsurface into air spaces of overlying buildings through foundation cracks, holes in concrete floors, and small gaps around pipes and utility lines. Certain site characteristics such as the presence of a high water table or fractured bedrock can increase the likelihood of vapor intrusion.

Vapor intrusion is an emerging concern at brownfields sites. The underground contaminant vapors can act as hidden sources of contamination that may not be detected during the due diligence process for property transfers. Redevelopment of older buildings with damaged foundations can increase the potential for vapor intrusion. In extreme cases, the vapors may accumulate in dwellings or occupied buildings to levels that may pose near-term safety hazards, acute health effects or aesthetic problems. In most cases, however, the chemical concentrations are low, or depending on site-specific conditions, vapors may not be present at detectable concentrations.

A Quick Look

- Vapor intrusion is the migration of volatile chemicals from the subsurface into overlying buildings.
- Vapor intrusion is an emerging concern at brownfields sites.
- Several strategies have been developed to reduce or eliminate indoor air contaminant concentrations using source control of the contaminant of concern, improving ventilation in buildings, air treatment methods, and land use controls.
- Savings can be realized when controls are addressed prior to redevelopment.

Some states along with EPA have developed methods to screen for sites with potential vapor intrusion concerns. Several strategies have been developed to reduce or eliminate indoor air contaminant concentrations including source remediation, as well as building-specific engineering (e.g., improved ventilation) and land use controls. While all exposure controls may need ongoing operation, maintenance and monitoring, considerable savings can be realized when controls such as vapor barriers, or active and passive venting systems, are included prior to redevelopment.

For additional information, visit: *www.epa.gov/epaoswer/hazwaste/ca/eis/vapor.htm*, *www.itrcweb.org/Documents/BRNFLD-1.pdf*, and *http://iavi.rti.org*.

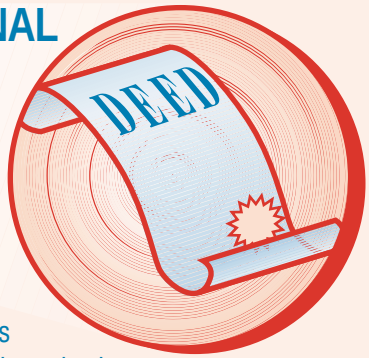
EPA Subsurface Vapor Intrusion Guidance

On November 29, 2002 (67 FR 71169), EPA published the *Draft Guidance For Evaluating The Vapor Intrusion to Indoor Air Pathway From Groundwater And Soils* (Subsurface Vapor Intrusion Guidance). The draft guidance is intended to provide a tool to conduct a screening evaluation as to whether or not the vapor intrusion exposure pathway is complete and to determine whether it poses an unacceptable risk to human health. It is not intended to provide recommendations for delineating extent of risk or eliminating risk. The draft guidance provides a three-tiered approach to evaluating the vapor intrusion pathway: Primary Screening, Secondary Screening, and Site-Specific Pathway Assessment. Each tier contains a set of questions that aid in the determination of whether a vapor intrusion pathway is complete. A complete pathway means that humans are exposed to vapors originating from site contamination. For those sites determined to have a complete pathway, the draft guidance provides ways to evaluate whether the pathway poses a potential significant risk to human health. If a site is determined to have an incomplete vapor intrusion pathway, further consideration of the current site situation generally should not be needed. In addition to brownfields sites, this draft guidance is suitable for use at RCRA Corrective Action and Superfund sites.

A copy of the draft guidance, a fact sheet, and other background information is available at: ***www.epa.gov/epaoswer/hazwaste/ca/eis/vapor.htm***.

S16 UNDERSTANDING THE ROLE OF INSTITUTIONAL CONTROLS AT BROWNFIELDS SITES:

Major Concepts and Issues



Institutional controls (ICs) are administrative and legal restrictions or limitations placed on the use of a site to minimize potential exposure to chemicals of concern or to prevent activities that might interfere with the effectiveness of a response action. Institutional controls are vital elements of response alternatives because they influence and supplement the physical component of the remedy to be implemented. On one hand, the right combination of ICs is necessary to ensure the protectiveness of the remedy and may be critical for obtaining the liability protections under the Brownfields Law; on the other hand, the wrong combination of institutional controls can be a real or perceived impediment to reuse of a site. ICs provide an added measure of protectiveness at contaminated sites and are not a substitute for thorough investigation and cleanup. The use of ICs must be carefully considered when weighing remedial options as their use may entail a long-term financial and administrative burden to ensure effectiveness and may be a disincentive to prospective purchasers and developers.

A Quick Look

- Institutional controls are administrative and legal mechanisms that are intended to reduce exposure to residual contamination and protect the integrity of a remedy at a former industrial facility or waste disposal sites.
- The role of institutional controls is an important consideration during the cleanup of a brownfields site.
- Examples of institutional controls include covenants, recorded deed notices, restrictions, and advisories.

The Small Business Liability Relief and Brownfields Revitalization Act addresses ICs at brownfields sites in two sections. First, in Section 104, Subtitle A, local governments are permitted to use up to 10 percent of a grant to enforce institutional controls or monitor population health effects. Thus, local governments can now use EPA funds to enforce ICs. The Act also makes compliance with ICs and land use restrictions a prerequisite for landowner liability protection. Subtitle B of the Act establishes three landowner liability defenses: the bona fide prospective purchaser defense, the contiguous landowner liability defense, and the innocent landowner defense. To qualify for any of these defenses, the landowner must demonstrate its compliance with land use restrictions that were part of or connected with a response action. A landowner must also show that it has not impeded the effectiveness or integrity of ICs established in connection with a response action to qualify for liability protection.

The term "institutional control" can be applied to a wide spectrum of legal and administrative measures. In general, mechanisms for creating ICs can be divided into four categories:

- Proprietary controls
- Governmental controls
- Enforcement and permit mechanisms with IC components
- Informational tools

Proprietary controls are unique because they are based on real property law. Examples of proprietary controls include covenants, which are written contracts that can prohibit specific types of development or construction on the land, and easements, which can grant property access or restrict the owner to land uses that are compatible with the intended use.

Governmental controls involve restrictions that generally fall within the traditional police powers of state and local governments. Examples of governmental controls include zoning, by which restrictions can be imposed through the local zoning or land use planning authority that limit property access and prohibit disturbance of the response action; well drilling prohibitions; and ordinances for building permit processes and master planning activities.

Another common type of IC is **enforcement mechanisms**. Such ICs include administrative orders, consent decrees, and RCRA permits that require a landowner, usually a potentially responsible party (PRP), to limit certain activities at a site. These ICs are used most frequently for CERCLA and RCRA cleanups.

The final category of ICs is **informational tools**. Informational tools provide information about residual or capped contamination or provide notification that such contamination may remain on site or that a remedy has been undertaken. Typical examples of these tools include state registries of contaminated properties, deed notices, and advisories. Informational tools are used most frequently as a secondary measure to help ensure the overall reliability of other institutional controls.

Continued on next page

S16 Continued ...

UNDERSTANDING THE ROLE OF INSTITUTIONAL CONTROLS AT BROWNFIELDS SITES:

Major Concepts and Issues

ICs are designed to ensure that the postremediation use of a property is compatible with the level of cleanup. ICs, however, have several limitations. For example, deed notices are informational, not enforceable. An easement cannot be established unless a party is willing to hold the easement. Some state governments cannot hold easements, and other parties may be unwilling to do so. Zoning laws may not be fully effective unless they are monitored and enforced over the long term, and local governments may not have the resources for such oversight. Furthermore, zoning ordinances are not necessarily permanent; they can be repealed, or local governments can grant exceptions after public hearings.

Concern has been expressed about the long-term viability of ICs as a remediation tool. For example, they may be forgotten, enforcement agencies may not effectively review properties or land users' actions, or land users simply may ignore the controls and take their chances. To ensure successful implementation, monitoring, and enforcement of ICs, EPA is developing and issuing policies and guidance. In February 2003, EPA issued the draft guidance *Institutional Controls: A Guide to Implementing, Monitoring, and Enforcing Institutional Controls at Superfund, Brownfields, Federal Facility, UST and RCRA Corrective Action Cleanups.* The purpose of this guidance is to (1) provide Superfund, brownfields, federal facility, UST, and RCRA corrective action site managers and site attorneys with an overview of their responsibilities for implementation, monitoring, and enforcement of institutional controls at their sites and (2) discuss some of the common issues that site managers and site attorneys may encounter when carrying out these responsibilities. This guidance is the second in a series of guidance documents on the use of ICs. The first guidance, *Institutional Controls: A Site Manager's Guide to Identifying, Evaluating and Selecting Institutional Controls at Superfund and RCRA Corrective Action Cleanups* (OSWER 9355.0-74FS-P, EPA 540-F-00-005) (September 2000), provides direction for identifying, evaluating, and selecting ICs. This guidance is available on the Internet at ***www.epa.gov/superfund/action/ic/index.htm***.

In September 2004, EPA issued OSWER Directive 9355.0-106 to set forth its *Strategy to Ensure Institutional Control Implementation at Superfund Sites*. The strategy will assist EPA regional and Headquarters personnel in preparing region-specific action plans and in conducting the work necessary to ensure the proper implementation of ICs at Superfund sites. This work includes gathering information and entering it in the Institutional Controls Tracking System (ICTS), evaluating the data generated by the ICTS, prioritizing and conducting site-specific follow-up activities, building the capacity to better manage and review institutional control information, and coordinating with other interested parties.

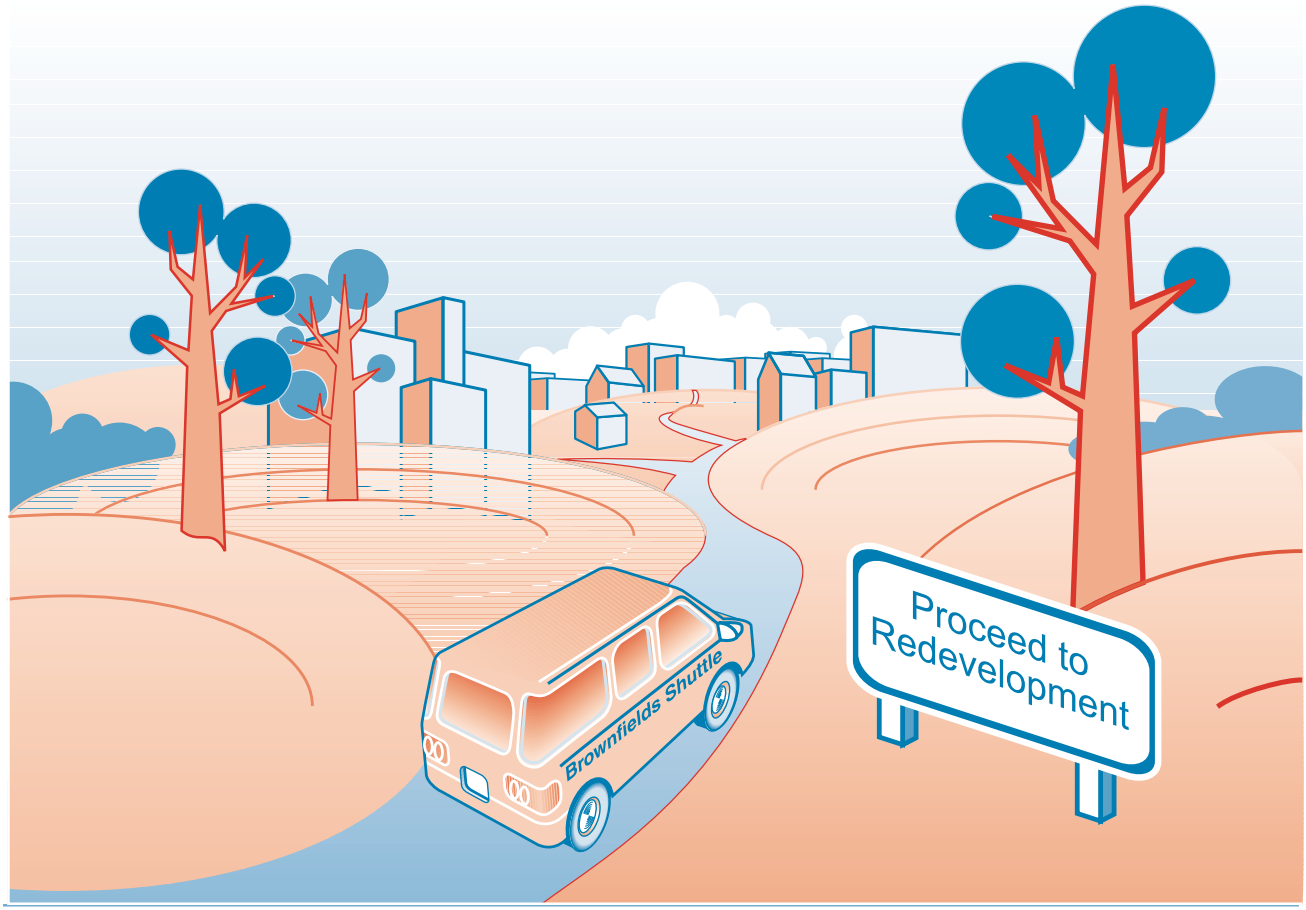
Because land use remains the principal domain of local governments, those governments play a significant role in the management and oversight of ICs. However, it is not always clear what that role will be. Many local governments do not yet have the capacity and resources necessary to meet the challenges of long-term stewardship. With an improved understanding of the terms and issues related to ICs, local governments and brownfields stakeholders will be in a better position to respond effectively to the long-term challenges of using ICs to promote site reuse while ensuring that public health and the environment are protected.

An indication of the significance of IC issues to local governments is the establishment of LUCs.org (***www.lucs.org***) through cooperative agreements between the International City/County Management Association (ICMA) and EPA. LUCs.org is part of ICMA's continuing effort to enhance the effectiveness of local government through professional management practices. ICMA and its partner agencies and organizations have come to understand the importance of providing a clearinghouse of information on the subject for the use of all stakeholder groups.

In addition to their designated implementing role in regulatory programs, states may also have broader authorities affecting their ability to implement ICs. A number of states are establishing specific requirements as part of VCPs that address the use of ICs.

ICs are a mechanism for providing a certain degree of safety in the absence of technology that could clean up contaminated sites thoroughly. Decision-makers should weigh the full costs of such options, including capital costs, costs of long-term sampling and analysis, and costs of replacing equipment, as well as concerns about potential long-term risks associated with contaminants left in place against the costs of options that would remove the contaminants permanently.

For more information, see the resource numbered 93 in the Index of Resources beginning on page I-1.


Brownfields Shuttle
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APPENDICES

APPENDIX A

Appendix A

GUIDE TO CONTAMINANTS AND TECHNOLOGIES

The tables provided in this appendix are intended to help brownfields stakeholders better understand the types of contaminants typically found at brownfields sites and the range of technologies that may be appropriate for assessing and remediating those contaminants during the various phases of a site cleanup.

What Are the Causes of Contamination at Brownfields Sites?

Section 101 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) defines brownfields sites as "real property, the expansion, redevelopment, or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant, or contaminant." Almost any former property, industrial or nonindustrial, where chemicals were used, produced, or reclaimed is a potential brownfields site. Over the operational history of the site or through its current use, contamination may have resulted from use, storage, or disposal of various products or chemicals. Some of the products commonly used or generated at the sites that may have resulted in contamination of structures, soils, or groundwater include the following:

- Acids and bases
- Batteries
- Cleaning products
- Coal tar
- Degreasing agents
- Diesel fuel
- Dyes, pigments, and inks
- Electrical equipment
- Explosives and ordnance
- Fertilizers
- Gasoline
- Hydraulic fluids and lubricants
- Insulation
- Motor oil
- Oil sludge and waste oil
- Paints
- Pesticides, herbicides, and insecticides
- Plastics
- Polymers and epoxy compounds
- Refrigerants and coolants
- Soaps
- Solvents
- Surfactants
- Waxes

A wide variety of chemical contaminants may be present at brownfields sites. The following tables present information on the sites, typical contaminants, and investigative and remedial technologies:

- Table A-1 lists common site types, activities that may have lead to contamination, and contaminant groups typically associated with the site types
- Table A-2 lists technologies used to analyze contaminants commonly found at brownfields sites
- Table A-3 lists technologies used to treat contaminants commonly found at brownfields sites

Seven general contaminant groups are included in Tables A-1, A-2, and A-3. Descriptions of the seven contaminant groups have been included at the end of this appendix to provide supplemental information about them. In addition, supplemental information about treatment technologies described in Table A-3 also has been included at the end of this appendix.

The information in this appendix was obtained from various U.S. Environmental Protection Agency (EPA) sources. The appendix is intended to provide general information on brownfields sites, contaminants, and technologies and is not intended to be all-inclusive. Contaminants and activities associated with common brownfields site types may not be relevant to every site. Additionally, investigation and remediation technologies may not be appropriate for the listed contaminants in all situations. Stakeholders should consult EPA or state officials, qualified professionals, and other sources of information when proceeding with redevelopment activities.

What Types of Contaminants Are Found at Brownfields Sites?

Various contaminants potentially may be present at brownfields sites. Table A-1 lists common brownfields site types, activities that may have lead to contamination over the operational history of these sites, and the contaminant groups typically associated with these activities. In this appendix, contaminant groups are presented rather than the specific contaminants. Information about the contaminant groups is included beginning on page A-11. Please note that if a contaminant group is listed, it does not imply that all the contaminants within a particular group are associated with each site type.

Table A-1. Typical Contaminants Found at Brownfields Sites

Site Type	Site Activities	Halogenated VOCs	Nonhalogenated VOCs	Halogenated SVOCs	Nonhalogenated SVOCs	Fuels	Metals and Metalloids	Explosives
Agricultural	Feed supply and other agricultural chemical distribution points may be contaminated with fertilizers, pesticides, and herbicides. Groundwater, drainage area sediments, soils, and nearby surface waters may be contaminated with pesticides and herbicides and could exhibit elevated levels of nitrate from fertilizer runoff. Contamination at agricultural sites may also arise from chemicals used to operate, clean, and maintain farm equipment such as fuel, oil, grease, and solvents.	X	X	X	X		X	
Battery recycling and disposal	Battery recycling and disposal facilities regenerate, reclaim, and dispose of used batteries. Many batteries contain toxic constituents such as lead, mercury, and cadmium. The metal in used batteries is separated from other battery constituents and processed for reuse. Lead-acid automobile batteries must be "broken" to reclaim the lead within. In battery breaking, the top of the battery casing is removed, the sulfuric acid solution inside is drained, and the lead components are separated from the casing. The remaining battery casing may be rinsed prior to disposal in order to remove residual lead oxide. Discarded acid and rinse water may be stored in lagoons or tanks. Chemicals may be released to soil and groundwater by leaking tanks or through spillage during the breaking process. Discarded casings may be buried. Any metal remaining on buried, discarded casings may leach into soil and groundwater. The extracted metal must be smelted prior to reuse. Particulate matter emitted by the smelter may contaminate nearby surface soil.						X	
Chemical and dye manufacturing	A wide range of chemicals are used and generated in facilities that manufacture, reformulate, and package various chemicals and dyes for commercial and industrial use. The types of contaminants released depend on the raw materials, processes, equipment and maintenance practices used. Environmental contamination resulting from chemical and dye manufacturing may persist in nearby or downstream surface waters or sediments long after operations have ceased. Moreover, chemical operations can change over time or involve multiple processes; therefore, the sites may be overlaid with several generations of wastes from a variety of products or processes. Many chemical facilities also have quality assurance and research laboratories that use small quantities of toxic chemicals that could contaminate isolated locations.	X	X	X	X			

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Site Type	Site Activities	Halogenated VOCs	Nonhalogenated VOCs	Halogenated SVOCs	Nonhalogenated SVOCs	Fuels	Metals and Metalloids	Explosives
Chlor-alkali manufacturing	Chlor-alkali plants produce a variety of chemicals, including chlorine, caustic soda, hydrochloric acid, sodium hypochlorite, sodium hydrosulfite, salt, hydrogen, sulfur dioxide, and spent sulfuric acid. Three basic processes are used for the manufacture of chlorine and caustic soda from brine: the mercury cell, diaphragm cell, and membrane cell processes. The mercury cell process uses elemental mercury as the cathode and produces mercury-contaminated wastewater, solid waste, and gaseous emissions. The process and waste streams must be carefully controlled to prevent the release of mercury to the environment. The diaphragm cell process may use lead or graphite anodes and asbestos diaphragms and may generate chlorinated hydrocarbons as a by-product. The membrane cell process is the most modern and has economic and environmental advantages. The primary by-product of the membrane cell process is dilute hydrochloric acid, which must be neutralized before it is discharged into the environment.	X		X			X	
Cosmetics manufacturing	Cosmetics are mixtures of surfactants, oils, and other ingredients. Cosmetics may contain mineral or metallic and nonmetallic additives. In sunscreen, for example, titanium and zinc are used as sun blockers. The color of makeup is determined by the concentrations and ratio of black or red iron oxide, titanium dioxide, and/or zinc oxide. Metal dyes are used in fingernail polish. The uses and concentrations of heavy metals play an important role in cosmetics production and a primary environmental concern at these site types.	X	X				X	
Drum recycling	Drum recycling facilities clean used drums for reuse. Soil and groundwater contamination at these facilities may result from leaking and spilling of residual chemicals and oils. The variety of chemicals stored in drums makes characterizing potential contaminants difficult. Contaminants could include acids, bases, corrosives, reactive chemicals, flammable materials, and oils. Spillage of paint, paint thinners, and solvents can also contaminate drum recycling facilities.	X	X	X	X	X	X	
Dry cleaning	The dry cleaning industry provides garment cleaning and related services such as clothes pressing and finishing. The dry cleaning process is physically very similar to the home laundry process except that clothes are washed in dry cleaning solvent instead of water. Dry cleaning sites may become contaminated because of leaks, spills, and improper disposal of solvents.	X	X					
Gasoline stations	Gasoline stations consist of pump islands, underground storage tanks (UST) for fuel, small storage areas, and service areas (which typically contain either hydraulic lifts or pits) for changing automobile engine oil and other maintenance activities. Gasoline and diesel fuel are transferred from bulk tank trucks to large USTs. Spills at the transfer areas and pumps along with overfilling of and leakage from the USTs are likely sources of contamination at gasoline stations. The primary contaminants of concern at gasoline stations include petroleum hydrocarbons; Benzene, Toluene, Ethylbenzene, and Xylenes (BTEX); and fuel oxygenates such as methyl tertiary butyl ether. Service areas typically have small containers of ethylene glycol (coolant), hydraulic oils, lubricants, automotive batteries (lead and acid), and compressed gas especially acetylene and oxygen cylinders for welding operations. Surface soils may be contaminated because of historical spills or dumping of used lubricants, coolants, and cleaning solvents generated during service activities. Subsurface soils and groundwater, especially in the vicinity of USTs, may also be contaminated because of spills, overfilling, and leaks.		X		X	X	X	

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Site Type	Site Activities	Halogenated VOCs	Nonhalogenated VOCs	Halogenated SVOCs	Nonhalogenated SVOCs	Fuels	Metals and Metalloids	Explosives
Glass manufacturing	The glass industry consists of firms engaged in primary glass manufacturing and of others that create products using purchased glass. The primary contaminants associated with glass manufacturing are metals such as lead, arsenic, chromium, and others. Other chemicals used in the glass manufacturing process include hydrofluoric acid, sulfuric acid, and various organic and inorganic solvents. Contaminants may be released to the environment through spills and leaks of raw materials and plant maintenance waste as well as insufficiently treated air emissions.						X	
Hospitals	Hospitals use a variety of toxic chemicals for diagnostic and therapeutic procedures as well as for cleaning and sterilization. Hazardous materials used include chemotherapy and antineoplastic chemicals, formaldehyde, photographic chemicals, radionuclides, solvents, mercury, anesthetic gases, and other toxic or corrosive chemicals. These substances may be released to the environment through leaks and spills, improper disposal of wastes, and insufficient treatment of wasterwater. In addition, medical waste incinerators may release mercury into the air.	X	X				X	
Incinerators	An incinerator is an enclosed device that uses controlled flame combustion to thermally break down waste to an ash residue that contains little or no combustible material. Incinerators may accept specific wastes such as municipal solid waste, sewage sludge, or medical waste. Contamination from incinerators may be associated with storage and handling of waste materials prior to incineration as well as disposal of ash and other by-products of the combustion process.			X			X	X
Landfills, municipal and industrial	Landfills are now restricted to household garbage, yard wastes, construction debris, and office wastes. Prior to 1970, however, landfills could accept industrial wastes. Therefore, older landfills are more likely to be contaminated with hazardous chemicals. Even modern landfills can contain a host of chemicals from household wastes such as oils, paints, solvents, corrosive cleaners, batteries, and gardening products. Illegal dumping at landfills can also cause serious contamination. Improperly designed landfills have a higher likelihood of surface soil and groundwater contamination and may trap explosive levels of methane gas and hydrogen sulfide in the soil.	X	X	X	X	X	X	
Leather manufacturing	Leather tanning is the process of converting raw hides or skins into leather. Hides and skins absorb tannic acid and other chemical substances that prevent them from decaying, make them resistant to wetting, and keep them supple and durable. Tanning is essentially the reaction of collagen fibers in the hide with tannins, chromium, alum, or other chemical agents. The most common tanning agents used in the United States are trivalent chromium and vegetable tannins extracted from certain tree barks. Alum, syntans (manmade chemicals), formaldehyde, glutaraldehyde, and heavy oils are also used as tanning agents.					X	X	

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Site Type	Site Activities	Halogenated VOCs	Nonhalogenated VOCs	Halogenated SVOCs	Nonhalogenated SVOCs	Fuels	Metals and Metalloids	Explosives
Machine shops and metal fabrication	The fabricated metal product industry has facilities that generally perform two functions: forming metal shapes and performing metal finishing operations, including surface preparation. Metal fabricators produce ferrous and nonferrous metal products. Machining and other metal working may generate waste metals, lubricants, cleaners, and other materials. These substances may impact soil, groundwater, and surface water if they are spilled, leaked, or improperly disposed.	X	X	X			X	
Manufactured gas plants and coal gasification	Manufactured gas has been produced as a fuel source from coal and oil since the early 1800s. Typically, coal or oil is heated and the resulting volatilized gases are distilled to produce natural gas. Depending on the process design, various by-products can be recovered, including anthracene, benzene, cresol, naphthalene, paraffin, phenol, toluene, and xylenes. Waste products from manufactured gas operations include coal fines, coal tar, cyanide salts, hydrogen sulfide gas, ammonia, and wastewater. Leakage and spillage from storage drums or tanks may contaminate surface and subsurface soils, sediments, surface water, and groundwater.		X		X	X	X	
Marine maintenance	Marine maintenance industry establishments engage in general painting and repair of ship or boat structures and engines or power plants. Activities may include painting, servicing engines, structural repairs, engine or power plant maintenance, electroplating, air conditioning and refrigeration service, electrical repair, and other cleaning and repair services. A number of chemicals may be used at marine maintenance facilities, including chemical paint strippers, blast media, antifouling paints, solvents, carburetor cleaner, cutting fluids, acids and alkalis, cyanide, heavy metal baths, fiberglass and reinforcement, resins, and mold release agents.	X	X				X	
Metal plating and finishing	Metal plating operations improve a product's performance (for example its durability or corrosion resistance) or appearance. Metal components are first cleaned (using solvents and/or water-based detergents) to remove dirt and oils from manufacturing operations. The metal components are subsequently etched, plated, and finished in a series of vats or baths. Common plating metals include cadmium, chromium, copper, gold, nickel, silver, and their alloys. Spillage during plating and cleaning operations and leakage or overflows from storage tanks and process vats may contaminate concrete floors and underlying soils. Groundwater may also be contaminated by heavy metals, cyanide, and solvents.	X	X	X	X		X	
Metal recycling and automobile salvage	Automobile salvage yards recover usable parts, scrap metal, and other recyclable materials from old or wrecked automobiles. Nonrecyclable materials are stored on site or sent to a municipal landfill. Metal recyclers purchase metal from a variety of sources and sort and process the scrap metal for resale. Metals commonly salvaged by these facilities include iron, steel, copper, brass, and aluminum. Sites may contain non-recyclable wastes and contaminated materials. Contaminated "auto fluff", a fibrous residue containing plastics, fabrics, and other materials, may be present at sites that perform shredding. Depending on the type of recycling operation conducted at a site, the surrounding soils may be contaminated with heavy metals, asbestos, polychlorinated biphenyls (PCB) oils, hydraulic fluids, lubricating oils, fuels, and solvents.			X		X	X	

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Site Type	Site Activities	Halogenated VOCs	Nonhalogenated VOCs	Halogenated SVOCs	Nonhalogenated SVOCs	Fuels	Metals and Metalloids	Explosives
Munitions manufacturing and ordnance sites	Ordnance sites typically include facilities that manufacture, assemble, store, or dispose of a variety of military munitions such as bombs, shells, grenades, mines, small arms ammunition, and specialty explosives. Potential contaminants in structures and surrounding property include di- and tri-nitro substituted phenols and benzenes, nitroglycerin, metals, ethers, formaldehyde, and ammoniated compounds. Unexploded ordnance (UXO) may be buried along with other waste materials. Groundwater may be contaminated with solvents such as formaldehyde and toluene. Furthermore, because of the age of some facilities, asbestos-containing materials may be found in abandoned buildings and demolition debris.						X	X
Mining	There are three general steps in the mining process: extraction, beneficiation, and processing. Extraction of the mineral value from the rock or matrix is the initial step in the operation. Beneficiation is the processing of extracted materials to clean or concentrate the product either for use as a final product or in preparation for further processing. Beneficiation may involve physical (such as milling) or chemical (such as leaching) separation processes or both. Processing is conducted following beneficiation to further extract or refine the material and prepare it for specific uses. Processing may include a variety of operations such as smelting, refining, roasting and digesting. Chemical contamination at mining sites may result from acidic, metal-laden mine drainage. Spilled, leaked, or improperly disposed of petroleum, lubricants, and other industrial chemicals may also result in site contamination.	X				X	X	
Painting and automobile body repair	Paint shops and automobile body repair shops paint various plastic and metal products and fix truck and automobile body parts. Damaged automobile body parts are replaced or repaired with fillers and are then sanded, primed, and painted. The shops may use cutting torches, welding equipment, solvents and cleaners, fiberglass, various polymers and epoxy compounds, and sand or grit blasting. Gasoline and diesel from vehicle fuel tanks, solvents, cleaners, acids, and paints may be leaked or spilled, contaminating soils and groundwater. Typical contaminants include toluene, acetone, perchloroethylene, xylene, gasoline and diesel fuel, carbon tetrachloride, and hydrochloric and phosphoric acids.	X	X			X	X	
Pesticide manufacturing and use	A pesticide is any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any pest. The term pesticide also applies to herbicides, fungicides, and various other substances used to control pests. Spillage, leakage, and improper storage or disposal of pesticides may result in their release to the environment. Sites may also be contaminated with properly applied but persistent pesticides. Because of the wide variety of pesticides and applications, facilities manufacturing or using pesticides may be contaminated with a broad range of chemicals.	X	X	X	X	X	X	
Petroleum refining and reuse	Oil production facilities consist of oil drilling, refining, storage, transfer, transport, and recycling facilities. Typical materials present at these facilities include crude, fuel, and motor oils as well as waste oils. Production processes at these facilities may contaminate soils with sludges, acids, and waste oil additives as well as co-contaminants such as PCBs when spills, leaks or improper disposal practices occur. In some cases,disposal pits may contain thick tarry sludges with very high pH values. Groundwater and deeper soil may be contaminated with metals and lighter oil fractions such as BTEX.					X	X	

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Site Type	Site Activities	Halogenated VOCs	Nonhalogenated VOCs	Halogenated SVOCs	Nonhalogenated SVOCs	Fuels	Metals and Metalloids	Explosives
Pharmaceutical manufacturing	The pharmaceutical industry manufactures bulk pharmaceutical intermediates and active ingredients, that are further processed into finished products. Chemicals used in the manufacturing process vary according to the desired product and the process type. Equipment must be thoroughly cleaned between processing operations for different products. VOCs are used as solvents at various stages of the manufacturing process. Because of the purity required for products, spent solvent is not usually reused in pharmaceutical manufacturing. It may be sold for nonpharmaceutical use or destroyed via incineration. The ten contaminants most commonly discharged in pharmaceutical wastewater are methanol; ethanol; acetone; isopropanol; acetic acid; methylene chloride; formic acid; ammonium hydroxide; N,N-dimethylacetamide and toluene.	X	X				X	
Photographic film manufacturing and development	Photographic film is coated with an emulsion containing light-sensitive silver halide crystals. Once film has been exposed, it must go through a series of chemical processes to bring out the images. Various chemicals are used as developers and fixing solutions, including hydroquinone, catechols, aminophenols, acetic acid, muriatic (hydrochloric) acid, and sodium or ammonium thiosulfate. Silver solutions are often generated during the photographic development processes.	X	X		X		X	
Plastic manufacturing	Almost all plastics are made from petroleum. Plastics are polymers, which are very long chains of molecules that consist of subunits (monomers) linked together by chemical bonds. Monomers of petrochemical plastics are not typically biodegradable. Wastes generated by the industry include polymers, phthalates, cadmium, solvents, resins, chemical additives, and VOCs.	X	X		X		X	
Printing and ink manufacturing	The printing industry consists of firms engaged in printing using one or more common processes such as lithography, letterpress, flexography, gravure, and screen printing. Contamination may result from spills, leaks, and improper disposal of excess chemicals and wastes, including ink constituents such as metals, cleaners, and solvents used during printing and production processes.	X	X			X	X	
Railroad yards	Railroad yards may consist of any combination of track and switching areas, engine maintenance buildings, engine fueling areas, bulk and container storage and transfer stations, and storage areas for materials used in track and engine maintenance. Materials used at railroad yards include diesel fuel, paint, solvents and degreasing agents, PCB oils, and creosote. Spills, leaks, or dumping of these compounds may contaminate soil and groundwater. Chemical spills and leaks during loading and unloading of tanker and freight cars can also contaminate a railroads yard. Because of the variety of chemicals used at and transported through railroad yards, virtually any type of chemical contamination could be present.	X	X	X	X	X	X	

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Continued

Site Type	Site Activities	Halogenated VOCs	Nonhalogenated VOCs	Halogenated SVOCs	Nonhalogenated SVOCs	Fuels	Metals and Metalloids	Explosives
Research and educational institutions	Academic institutions are often similar to small cities, as they may have research laboratories, automobile repair facilities, power plants, wastewater treatment plants, hazardous waste management and trash disposal activities, asbestos management activities, drinking water supply facilities, grounds maintenance activities and incineration facilities. Educational institutions typically generate small quantities of a variety of wastes, including inorganic acids, organic solvents, metals and metal dust, photographic waste, waste oil, paint, heavy metals, and pesticides.	X	X	X			X	
Semiconductor manufacturing	The semiconductor manufacturing industry is a subset of the electronics manufacturing industry and produces integrated circuits or "chips." Contamination on semiconductor chips is one of the primary reasons that they fail; therefore, chips are cleaned before and after many of the manufacturing steps. Chemicals used in the manufacturing process include various acids, ethylene glycol, hydroxide solutions, halogen gases, fluorocarbons, chlorine, and various organic solvents.	X	X				X	
Smelter operations	The primary use of smelting is to produce iron and steel from iron ore. Smelting is also used to extract copper and other base metals from raw ores. Contamination from smelting operations often takes the form of deposition of airborne metals, asbestos, and sulfur compounds in areas surrounding smelters. Contamination may also result from improper storage and disposal of raw ores or by-product slag.						X	
Underground storage tanks	A UST is a tank and any underground piping connected to a tank where at least 10 percent of the combined volume is under the ground. USTs often contain petroleum products, gasoline, or other chemicals. Faulty installation or inadequate operating and maintenance procedures can cause USTs to release their contents into the environment. The greatest potential hazard from leaking USTs is that petroleum fuels, fuel additives, or other hazardous substances can seep into soil and contaminate groundwater.	X	X			X	X	
Vehicle maintenance	Vehicle maintenance involves handling and managing a wide variety of materials and wastes, including oils, batteries, refrigerants, antifreeze, solvents, asbestos, and fuels. Improper management and disposal of wastes as well as leaks from fuel and waste storage containers may result in contamination of vehicle maintenance facilities.	X	X			X	X	
Wood preservation	Wood preservation sites typically consist of wood preparation facilities, chemical storage tanks, chemical treatment areas (including high-pressure vessels in many cases), drip or drying areas, and wood storage areas. Wood is treated with preservative chemicals either by dipping the wood into a chemical bath or by injecting chemicals into the wood under pressure. Storage tanks at wood preservation sites could contain creosote, pentachlorophenol, or chrome-copper-arsenate (CCA) solutions for wood treatment. These chemicals could enter the environment if the tanks were overfilled or leaked. Contaminated water squeezed from wood during processing and retort sludge may have spilled on the ground, causing soil and ground water contamination. As treated wood is transferred from the treatment area to the drying area, chemicals may drip onto soil and contaminate the soil and groundwater. Likewise, drippage in drying areas, especially in older operations where pressure treatment may not have been used, could result in soil contamination. Runoff from site could also contaminate nearby surface waters.		X	X	X	X	X	

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Site Type	Site Activities	Halogenated VOCs	Nonhalogenated VOCs	Halogenated SVOCs	Nonhalogenated SVOCs	Fuels	Metals and Metalloids	Explosives
Wood pulp and paper manufacturing	The pulp and paper industry produces commodity grades of wood pulp, printing and writing paper, sanitary tissue, industrial-type paper, containerboard, and boxboard using cellulose fiber from timber or purchased or recycled fibers. The two steps involved are pulping and paper or paperboard manufacturing. Pulping is the process of dissolving wood chips into individual fibers using chemical, semichemical, or mechanical methods. Pulping is the major source of environmental impacts in the industry. Chlorinated organic compounds in pulp plant wastewater sludge are of particular concern because of their tendency to partition from effluent to solids. Improper treatment or disposal of wastes may result in contamination being released to the environment. Spills and leaks of process and waste chemicals are other common sources of contamination at pulp mills. Air emissions are also problematic at pulp mills, which are typically noted for their unpleasant odors.	X		X				

Notes:
SVOC = Semivolatile organic compound
VOC = Volatile organic compound

What Technologies May Be Used to Investigate Contamination at Brownfields Sites?

Various analytical technologies may be used to investigate contamination at brownfields sites. Table A-2 contains information on analytical technologies that are available for investigating the contaminant groups presented in Table A-1.

Table A-2. Technologies for Analyzing Contaminants at Brownfields Sites

	Halogenated VOCs	Nonhalogenated VOCs	Halogenated SVOCs	Nonhalogenated SVOCs	Fuels	Metals and Metalloids	Explosives
Amperometric and Galvanic Cell Sensor	X	X				X	
Anodic Stripping Voltammetry						X	
Atomic Absorption Spectroscopy						X	
Catalytic Surface Oxidation	X	X					
Chemical Colorimetric Kits	X	X	X	X	X	X	X
Chemical Reaction-Based Test Papers	X	X	X	X		X	
Detector Tubes	X	X					
Electrochemical Detector Kits			X	X		X	
Electromagnetic	X	X	X	X	X	X	X
Explosimeter	X	X					
Fiber Optic Chemical Sensors	X		X		X		
Field Bioassessment	X	X	X	X		X	X
Flame-Ionization Detector	X	X		X	X		

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Continued

	Halogenated VOCs	Nonhalogenated VOCs	Halogenated SVOCs	Nonhalogenated SVOCs	Fuels	Metals and Metalloids	Explosives
Fluorescence Spectrophotometry						X	
Fourier Transform Infrared Spectroscopy	X	X			X		
Free Product Sensors	X			X	X		
Gas Chromatography/Mass Spectrometry	X	X	X	X	X		X
Ground Penetration Radar			X	X	X	X	
Immunoassay Colorimetric Kits	X	X	X	X	X	X	X
Inductively Coupled Plasma-Atomic Emission Spectroscopy						X	
Infrared Spectroscopy	X	X	X	X	X		
Ion Chromatography						X	
Ion Mobility Spectrometer	X	X	X	X	X		X
Ion Trap Mass Spectrometry	X	X	X	X			
Laser-Induced Breakdown Spectroscopy						X	
Laser-Induced Fluorescence/Cone Penetrometer	X	X	X	X	X		
Magnetometry						X	
Near Infrared Reflectance/Transmittance Spectroscopy	X	X					
Particle-Induced X-Ray Emissions						X	
Photo Ionization Detector	X	X	X	X	X		
Piezoelectric Sensors	X	X					
Raman Spectroscopy/Surface-Enhanced Raman Scattering (SERS)	X	X	X	X	X		
Resistivity/Conductivity					X	X	
Room-Temperature Phosphorimetry			X	X			
Scattering/Absorption LIDAR	X	X					
Semiconductor Sensors	X	X					
Soil-Gas Analyzer Systems	X	X	X	X	X		X
Solid/Porous Fiber Optic	X	X	X		X		
Synchronous Luminescence/Fluorescence	X	X	X	X	X		
Thin-Layer Chromatography				X			
Toxicity Tests	X	X	X	X		X	X
Titrimetry Kits					X		
Ultraviolet Fluorescence	X	X		X			
Ultraviolet Visible Spectrophotometry	X	X		X	X		
X-Ray Fluorescence	X		X			X	X

What Technologies May Be Used to Remediate at Brownfields Sites?

Various treatment technologies may be used to remediate contamination at brownfields sites. Table A-3 contains information on treatment technologies that are available for remediating the contaminants presented in Table A-1. Descriptions of the remedial technologies are included at the end of this appendix beginning on page A-15.

Table A-3. Technologies for Treating Contaminants Found at Brownfields Sites

	Halogenated VOCs	Nonhalogenated VOCs	Halogenated SVOCs	Nonhalogenated SVOCs	Fuels	Metals and Metalloids	Explosives
Air Sparging	G	G			G		
Bioremediation	S/G	S/G	S/G	S/G	S/G		S/G
Chemical Treatment	S/G	S/G	S/G	S/G	S/G	S/G	S/G
Electrokinetics	S/G	S/G	S/G	S/G		S/G	
Flushing	S/G	S/G	S/G	S/G	S/G	S/G	
Incineration	S	S	S	S	S		S
In-Well Air Stripping	G	G					
Mechanical Soil Aeration	S						
Multi Phase Extraction	S/G	S/G	S/G	S/G	S/G		
Open Burn/Open Detonation							S
Permeable Reactive Barrier	G	G	G	G	G	G	G
Physical Separation			S	S		S	
Phytoremediation	S/G	S/G	S/G	S/G	S/G	S/G	S/G
Pump and Treat	G	G	G	G	G	G	G
Soil Vapor Extraction	S	S			S		
Soil Washing	S	S	S	S	S	S	S
Solidification/Stabilization	S	S	S	S	S	S	S
Solvent Extraction	S	S	S	S	S	S	S
Thermal Desorption	S	S	S	S	S		S
Thermal Treatment (in situ)	S/G	S/G	S/G	S/G	S/G		
Vitrification	S	S	S	S	S	S	

Notes:
S and G indicate the media that can be treated using each technology type
S = Soils, sediments, and sludges
G = Groundwater, leachate, and surface water

What Are the Contaminant Groups Presented in Tables A-1, A-2, and A-3?

The following general contaminant groups are included in Tables A-1, A-2, and A-3:

- Halogenated VOCs
- Nonhalogenated VOCs
- Halogenated SVOCs
- Nonhalogenated SVOCs
- Fuels
- Metals and metalloids
- Explosives

Descriptions of the seven contaminant groups are included below to provide supplemental information about the characteristics and specific constituents of the groups.

Halogenated VOCs

VOCs are hydrocarbon compounds that evaporate readily at room temperature A halogenated VOC is a VOC that has a halogen (fluorine, chlorine, bromine, or iodine) attached to it. Locations where halogenated VOCs may be found include burn pits, chemical manufacturing plants and disposal areas, contaminated marine sediments, disposal wells and leach fields, electroplating and metal finishing shops, firefighting training areas, hangars and aircraft maintenance areas, landfills and burial pits, leaking storage tanks, radioactive and mixed waste disposal areas, oxidation ponds and lagoons, dry cleaning shops, grain storage sites, paint stripping and spray booth areas, pesticide and herbicide mixing areas, solvent degreasing areas, surface impoundments, and vehicle maintenance areas. Typical halogenated VOCs encountered at many sites include those listed below.

1-Chloro-2-propene	Carbon tetrachloride	Hexachlorobutadiene
1,1-Dichloroethane	Chlorodibromomethane	Hexachlorocyclopentadiene
1,1-Dichloroethylene (Vinylidene chloride)	Chloroethane	Hexachloroethane
1,1,1-Trichloroethane	Chloroform	Monochlorobenzene
1,1,1,2-Tetrachloroethane	Chloromethane	Neoprene
1,1,2-Trichloroethane (Vinyl trichloride)	Chloropropane	Pentachloroethane
1,1,2,2-Tetrachloroethane (Acetylene tetrachloride) (Perchloroethylene)	Cis-1,2-dichloroethylene	Tetrachloroethylene
1,2-Dichloroethane	Cis-1,3-dichloropropene	Trans-1,2-dichloroethylene
1,2-Dichloropropane (Propylene dichloride)	Dibromochloropropane	Trans-1,3-dichloropropene
1,2,2-Trifluoroethane (Freon 113)	Dibromomethane	Trichloroethylene
2-Butylene dichloride	Dichloromethane (Methylene chloride)	Trichlorotrifluoroethane
Bromodichloromethane	Ethylene dibromide	Vinyl chloride
Bromoform	Fluorotrichloromethane (Freon 11)	
Bromomethane	Glycerol trichlorohydrin	

Nonhalogenated VOCs

A nonhalogenated VOC is a VOC that does not have a halogen (fluorine, chlorine, bromine, or iodine) attached to it. Locations where nonhalogenated VOCs may be found include burn pits, chemical manufacturing plants and disposal areas, contaminated marine sediments, disposal wells and leach fields, electroplating and metal finishing shops, firefighting training areas, hangars and aircraft maintenance areas, landfills and burial pits, leaking storage tanks, radioactive and mixed waste disposal areas, oxidation ponds and lagoons, paint stripping and spray booth areas, pesticide and herbicide mixing areas, solvent degreasing areas, surface impoundments, and vehicle maintenance areas. Typical nonhalogenated VOCs (excluding fuels, BTEX, and gas-phase contaminants) encountered at many sites include those listed below:

1-Butanol (n-Butyl alcohol)	Carbon disulfide	Methanol
4-Methyl-2-pentanone (Methyl isobutyl ketone)	Cyclohexanone	Methyl ethyl ketone
Acetone	Ethanol	Styrene
Acrolein	Ethyl acetate	Tetrahydrofuran
Acrylonitrile	Ethyl ether	Vinyl acetate
Aminobenzene	Isobutanol	

Halogenated SVOCs

SVOCs are hydrocarbon compounds with boiling points greater than 200°C. A halogenated SVOC is an SVOC that has a halogen (fluorine, chlorine, bromine, or iodine) attached to it. Locations where halogenated SVOCs may be found

include burn pits and other combustion sources, chemical manufacturing plants and disposal areas, contaminated marine sediments, disposal wells and leach fields, electroplating and metal finishing shops, firefighting training areas, hangars and aircraft maintenance areas, landfills and burial pits, leaking storage tanks, radioactive and mixed waste disposal areas, oxidation ponds and lagoons, dry cleaning shops, grain storage sites, pesticide and herbicide mixing areas, solvent degreasing areas, surface impoundments, vehicle maintenance areas and wood preservation sites. Typical halogenated SVOCs (excluding fuels and explosives) encountered at many sites include those listed below:

1,2-Bis(2-chloroethoxy) ethane	3,3-Dichlorobenzidine	Chlorobenzilate
1,2-Dichlorobenzene (o-Dichlorobenzene)	4-Bromophenyl phenylether	Chlorphenothane
1,2,4-Trichlorobenzene	4-Chloroaniline	Hexachlorobenzene
1,3-Dichlorobenzene (m-Dichlorobenzene)	4-Chlorophenyl phenylether	Hexachlorobutadiene
1,4-Dichlorobenzene (p-dichlorobenzene)	Bis(2-chloroethoxy)ether	Hexachlorocyclopentadiene
2-Chloronaphthalene	Bis(2-chloroethoxy)methane	p-Chloro-m-cresol
2-Chlorophenol	Bis(2-chloroethoxy)phthalate	Pentachlorobenzene
2,3,7,8-Tetrachlorodibenzo-p-dioxin	Bis(2-chloroethyl)ether	Pentachlorophenol
2,4-Dichlorophenol	Bis(2-chloroisopropyl)ether	Polychlorinated biphenyls
2,4,5-Trichlorophenol	Chlordane	Quintozene
2,4,6-Trichlorophenol	Chlorobenzene	Tetrachlorophenol

Pesticides are a subgroup of halogenated SVOCs. Typical pesticides encountered at many sites include those listed below.

Aldrin	4,4′-DDD	Endosulfan sulfate	Heptachlor epoxide
BHC-alpha	4,4′-DDE	Endrin	Malathion
BHC-beta	4,4′-DDT	Endrin aldehyde	Methylparathion
BHC-delta	Dieldrin	Ethion	Parathion
BHC-gamma	Endosulfan I	Ethyl parathion	Toxaphene
Chlordane	Endosulfan II	Heptachlor	

Nonhalogenated SVOCs

A nonhalogenated SVOC is an SVOC that does not have a halogen (fluorine, chlorine, bromine, or iodine) attached to it. Locations where nonhalogenated SVOCs may be found include burn pits, chemical manufacturing plants and disposal areas, contaminated marine sediments, disposal wells and leach fields, electroplating and metal finishing shops, firefighting training areas, hangars and aircraft maintenance areas, landfills and burial pits, leaking storage tanks, radioactive and mixed waste disposal areas, oxidation ponds and lagoons, pesticide and herbicide mixing areas, solvent degreasing areas, surface impoundments, and vehicle maintenance areas and wood preservation sites. Typical nonhalogenated SVOCs (excluding fuels and explosives) encountered at many sites include those listed below:

1-Aminonaphathalene	Anthracene	Diphenylenemethane (Fluorene)
1,2-Benzacenaphthene	Benzidine	Ethion
1,2-Diphenylhydrazine	Benzo(a)anthracene (Tetraphene)	Ethyl parathion
2-Aminonaphthalene	Benzo(a)pyrene	Indeno(1,2,3-c,d)pyrene
2-Methylnaphthalene	Benzo(b)fluoranthene	Isophorone
2-Nitroaniline	Benzo(k)fluoranthene	Malathion
2-Nitrophenol	Benzoic acid	Methylparathion

Continued on next page

Continued

2,3-Phenylenepyrene	Benzyl alcohol	Naphthalene
2,4-Dinitrophenol	Bis(2-ethylhexyl)phthalate	n-Nitrosodimethylamine
3-Nitroaniline	Butyl benzyl phthalate	n-Nitrosodi-n-propylamine
4-Nitroaniline	Chrysene	n-Nitrosodiphenylamine
4-Nitrophenol	Dibenzofuran	Parathion
4,6-Dinitro-2-methylphenol	Diethyl phthalate	Phenanthrene
Acenaphthene	Dimethyl phthalate	Phenyl naphthalene
Acenaphthylene	Di-n-butyl phthalate	Pyrene
Allyldioxybenzene methylene ether	Di-n-octyl phthalate	

Fuels

Fuels are a general class of chemicals created by refining and manufacturing petroleum or natural gas for use in combustion processes to generate heat or other energy. Fuels include nonhalogenated VOCs, nonhalogenated SVOCs, or both. Sites where fuel contamination may be found include aircraft, storage and service areas, burn pits, chemical disposal areas, contaminated marine sediments, disposal wells and leach fields, firefighting training areas, hangars and aircraft maintenance areas, landfills and burial pits, leaking storage tanks, solvent degreasing areas, surface impoundments, and vehicle maintenance areas. Typical fuel contaminants encountered at many sites include those listed below:

1-Pentene	2,3,4-Trimethylhexane	Benzo(k)fluoranthene	n-Decane
1,2,3,4-Tetramethylbenzene	2,3,4-Trimethylpentane	Chrysene	n-Dodecane
1,2,4-Trimethylbenzene	2,4-Dimethylphenol	Cis-2-butene	n-Heptane
1,2,4-Trimethyl-5-ethylbenzene	2,4,4-Trimethylhexane	Creosols	n-Hexane
1,2,4,5-Tetramethylbenzene	3-Ethylpentane	Cyclohexane	n-Hexylbenzene
1,3,5-Trimethylbenzene	3-Methyl-1-butene	Cyclopentane	n-Nonane
2-Methyl-1,3-butadiene	3-Methyl-1-pentene	Dibenzo(a,h)anthracene	n-Octane
2-Methyl-2-butene	3-Methyl-1,2-butadiene	Dimethylethylbenzene	n-Pentane
2-Methyl-butene	3-Methylheptane	Ethylbenzene	n-Propylbenzene
2-Methylheptane	3-Methylhexane	Fluoranthene	n-Undecane
2-Methylnaphthalene	3-Methylpentane	Fluorene	o-Xylene
2-Methylpentane	3,3-Dimethyl-1-butene	Ideno(1,2,3-c,d)pyrene	Phenanthrene
2-Methylphenol	3,3,5-Trimethylheptane	Isobutane	Phenol
2,2-Dimethylheptane	4-Methylphenol	Isopentane	Propane
2,2-Dimethylhexane	Acenaphthene	Methylcyclohexane	p-Xylene
2,2-Dimethylpentane	Anthracene	Methylcyclopentane	Pyrene
2,2,4-Trimethylheptane	Benzene	Methylnaphthalene	Pyridine
2,2,4-Trimethylpentane	Benzo(a)anthracene	Methylpropylbenzene	Toluene
2,3-Dimethylbutane	Benzo(a)pyrene	m-Xylene	Trans-2-butene
2,3-Dimethylpentane	Benzo(b)fluoranthene	Naphthalene	Trans-2-pentene
2,3,4-Trimethylheptane	Benzo(g,h,i)perylene	n-Butane	Vinyl benzene

Metals and Metalloids

Metals are one of the three groups of elements distinguished by their ionization and bonding properties, along with metalloids and nonmetals. Metals have certain characteristic physical properties: they are usually shiny, have a high density, are ductile and malleable, usually have a high melting point, are usually hard, and conduct electricity and heat well. Metalloids have properties that are intermediate between those of metals and nonmetals. There is no unique way of distinguishing a metalloid from a true metal, but the most common way is that metalloids are usually semiconductors rather than conductors. Locations where metals and metalloids may be found include artillery and small arms impact areas, battery disposal areas, burn pits, chemical disposal areas, contaminated marine sediments, disposal wells and leach fields, electroplating and metal finishing shops, firefighting training areas, landfills and burial pits, leaking storage tanks, radioactive and mixed waste disposal areas, oxidation ponds and lagoons, paint stripping and spray booth areas, sand blasting areas, surface impoundments, and vehicle maintenance areas. Typical metals and metalloids encountered at many sites include those listed below.

Aluminum	Calcium	Mercury	Tin
Antimony	Chromium	Molybdenum	Titanium
Arsenic	Cobalt	Nickel	Vanadium
Barium	Copper	Potassium	Zinc
Beryllium	Iron	Selenium	Zirconium
Bismuth	Lead	Silver	
Boron	Magnesium	Sodium	
Cadmium	Manganese	Thallium	

Explosives

Most commonly, artificial explosives are chemical explosives manufactured for use as explosives and propellants. Sites where explosive contaminants may be found include artillery impact areas, contaminated marine sediments, disposal wells, leach fields, landfills, burial pits, and TNT washout lagoons. Typical explosive contaminants encountered at many sites include those listed below.

2,4-DNT (2,4-Dinitrotoluene)	Nitroglycerine
2,6-DNT (2,6-Dinitrotoluene)	Nitroguanidine
AP (Ammonium perchlorate)	Picrates
DNB (Dinitrobenzenes)	RDX (Cyclo-1,3,5-trimethylene-2,4,6-trinitramine)
HMX (1,3,5,7-Tetranitro-1,3,5,7-tetraazocyclooctane)	Tetryl (N-Methyl-N,2,4,6-tetranitrobenzeneamine)
Nitroaromatics	TNB (Trinitrobenzenes)
Nitrocellulose	TNT (2,4,6-Trinitrotoluene)

What Are the Treatment Technologies Identified in Table A-3?

Table A-3 contains information on treatment technologies for remediating brownfields sites. Descriptions of these remedial technologies are presented below.

Air Sparging involves injection of air or oxygen into a contaminated aquifer. Injected air traverses horizontally and vertically in channels through the soil column, creating an underground stripper that removes volatile and semivolatile organic contaminants by volatilization. The injected air helps to flush the contaminants into the unsaturated zone. Soil Vapor Extraction (SVE) usually is implemented in conjunction with air sparging to remove the generated vapor-phase contamination from the vadose zone. Oxygen added to the contaminated groundwater and vadose zone soils also can enhance biodegradation of contaminants below and above the water table.

Bioremediation involves use of microorganisms to degrade organic contaminants in soil, sludge, solids, and groundwater either in situ or ex situ. It can also be used to make metals or metalloids less toxic or mobile. When organic contaminants are being treated, the microorganisms break down contaminants by using them as a food source by cometabolizing them with a food source. Aerobic processes require an oxygen source, and the end products typically are carbon dioxide and water. Anaerobic processes are conducted in the absence of oxygen, and the end products can include methane, hydrogen gas, sulfide, elemental sulfur, and nitrogen gas. Ex situ bioremediation technologies for groundwater typically involve treating extracted groundwater in a bioreactor or constructed wetland. In situ techniques stimulate and create a favorable environment for microorganisms to grow and use contaminants as a food and energy source or to cometabolize them. Generally this process involves providing some combination of oxygen, nutrients, and moisture and controlling the temperature and pH. Microorganisms that have been adapted for degradation of specific contaminants are sometimes applied to enhance the process. For treatment of metals and metalloids, the process involves biological activity that promotes formation of less toxic or mobile species by creating ambient conditions that will cause such species to form or by acting directly on the contaminant. The treatment may result in oxidation, reduction, precipitation, coprecipitation, or another transformation of the contaminant.

Chemical treatment, also known as chemical reduction/oxidation (redox), typically involves redox reactions that chemically convert hazardous contaminants into compounds that are nonhazardous, less toxic, 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 reactant is reduced (gains electrons). The oxidizing agents used for treatment of hazardous contaminants in soil include ozone, hydrogen peroxide, hypochlorites, potassium permanganate, Fenton's reagent (hydrogen peroxide and iron), chlorine, and chlorine dioxide. This method may be applied in situ or ex situ to soils, sludges, sediments, and other solids and may also be applied to groundwater in situ or ex situ chemical treatment using pump and treat technology. Chemical treatment may also include use of ultraviolet (UV) light in a process known as UV oxidation.

Electrokinetics is based on the theory that a low-density current will mobilize contaminants in the form of charged species. A current passed between electrodes is intended to cause aqueous media, ions, and particulates to move through soil, waste, and water. Contaminants arriving at the electrodes can be removed by means of electroplating or electrodeposition, precipitation or coprecipitation, adsorption, complexing with ion exchange resins, or pumping of water (or other fluid) near the electrodes.

For **Flushing**, a solution of water, surfactants, or cosolvents is applied to soil or injected into the subsurface to treat contaminated soil or groundwater. When soil is being treated, injection is often designed to raise the water table into the contaminated soil zone. Injected water and treatment agents are recovered together with flushed contaminants.

Both on-site and off-site **Incineration** involves use of high temperatures (870 to 1,200°C or 1,600 to 2,200°F) to volatilize and combust (in the presence of oxygen) organics in hazardous wastes. Auxiliary fuels are often used to initiate and sustain combustion. The destruction and removal efficiency of properly operated incinerators exceeds the 99.99 percent requirement for hazardous waste and can meet the 99.9999 percent requirement for PCBs and dioxins. Off-gases and combustion residuals generally require treatment. On-site incineration is typically a transportable unit; for off-site incineration, waste is transported to a central facility.

For **In-well air stripping**, air is injected into a double-screened well, causing the VOCs in the contaminated groundwater to be transferred from the dissolved phase to the vapor phase in air bubbles. As the air bubbles rise to the surface of the water, the vapors are drawn off and treated by a SVE system.

Mechanical soil aeration involves agitation of contaminated soil by using tilling or other means to volatilize contaminants.

Multi-phase extraction involves use of a vacuum system to remove various combinations of contaminated groundwater, separate-phase petroleum product, and vapors from the subsurface. The system typically lowers the water table around a well, exposing more of the formation. Contaminants in the newly exposed vadose zone are then accessible for vapor extraction. Once above ground, the extracted vapors or liquid-phase organics and groundwater are separated and treated.

Open burn (OB) and Open detonation (OD) operations are conducted to destroy excess, obsolete, or unserviceable (EOU) munitions and other items containing explosives, propellants, and other energetic materials. In OB

operations, materials are destroyed by self-sustained combustion, which is ignited by an external source, such as a flame, heat, or a detonation wave. In OD operations, materials are destroyed by detonation, which generally is initiated by an energetic charge.

Permeable reactive barriers, also known as passive treatment walls, are installed across the flow path of a contaminated groundwater plume, allowing the water portion of the plume to flow through the wall. These barriers allow passage of water while prohibiting movement of contaminants by means of treatment agents within the wall such as zero-valent metals (usually zero-valent iron), chelators, sorbents, compost, and microbes. The contaminants are either degraded or retained in a concentrated form by the barrier material, which may need to be replaced periodically.

Physical separation processes use physical properties to separate contaminated and uncontaminated media or to separate different types of media. For example, different-sized sieves and screens can be used to separate contaminated soil from relatively uncontaminated debris. Another application of physical separation is dewatering of sediments or sludge.

Phytoremediation is a process in which plants are used to remove, transfer, stabilize, or destroy contaminants in soil, sediment, or groundwater. The mechanisms of phytoremediation include enhanced rhizosphere biodegradation (which takes place in soil or groundwater immediately around plant roots), phytoextraction (also known as phytoaccumulation, the uptake of contaminants by plant roots and the translocation and accumulation of contaminants into plant shoots and leaves), phytodegradation (metabolism of contaminants within plant tissues), and phytostabilization (production of chemical compounds by plants to immobilize contaminants at the interface of roots and soil). The term phytoremediation applies to all biological, chemical, and physical processes that are influenced by plants (including the rhizosphere) and that aid in the cleanup of contaminated substances. Phytoremediation may be applied in situ or ex situ to soils, sludges, sediments, other solids, or groundwater.

Pump and treat involves extraction of groundwater from an aquifer and treatment of the water above the ground. The extraction step is usually conducted by pumping groundwater from a well or trench. The treatment step can involve a variety of technologies such as adsorption, air stripping, bioremediation, chemical treatment, filtration, ion exchange, metal precipitation, and membrane filtration.

Soil vapor extraction (SVE) is used to remediate unsaturated (vadose) zone soil. A vacuum is applied to the soil in order to induce a controlled flow of air and remove volatile and some semivolatile organic contaminants from the soil. SVE usually is performed in situ; however, in some cases, it can be used as an ex situ technology.

For **Soil washing**, contaminants sorbed onto fine soil particles are separated from bulk soil in a water-based system based on particle size. The wash water may be augmented with a basic leaching agent, surfactant, or chelating agent or by adjustment of pH to help remove contaminants. Soils and wash water are mixed ex situ in a tank or other treatment unit. The wash water and various soil fractions are usually separated by means of gravity settling.

Solidification/stabilization (S/S) reduces the mobility of hazardous substances and contaminants in the environment through both physical and chemical means. The S/S process physically binds or encloses contaminants within a stabilized mass. S/S can be performed both ex situ and in situ. Ex situ S/S requires excavation of the material to be treated, and the treated material must be disposed of. In situ S/S involves use of auger or caisson systems and injector head systems to add binders to contaminated soil or waste without excavation, and the treated material is left in place.

Solvent extraction involves use of an organic solvent as an extractant to separate contaminants from soil. The organic solvent is mixed with contaminated soil in an extraction unit. The extracted solution is then passed through a separator, where the contaminants and extractant are separated from the soil.

For **Thermal desorption**, wastes are heated so that organic contaminants and water volatilize. Typically a carrier gas or vacuum system transports the volatilized organics and water to a gas treatment system, usually a thermal oxidation or recovery system. Based on the operating temperature of the desorber, thermal desorption processes can be categorized in two groups: high-temperature thermal desorption (320 to 560°C or 600 to 1,000°F) and low-temperature thermal desorption (90 to 320°C or 200 to 600°F). Thermal desorption is an ex situ treatment process. In situ thermal treatment is discussed below.

In situ thermal treatment is an in situ treatment process that uses heat to facilitate contaminant extraction through volatilization and other mechanisms or to destroy contaminants in situ. Volatilized contaminants are typically removed from the vadose zone using SVE. Specific types of in situ thermal treatment include conductive heating, electrical resistive heating, radio frequency heating, hot air injection, hot water injection, and steam-enhanced extraction. In situ thermal treatment is usually applied to a contaminated source area but may also be applied to a groundwater plume.

Vitrification involves use of an electric current to melt contaminated soil at elevated temperatures (1,600 to 2,000°C or 2,900 to 3,650°F). Upon cooling, the vitrification product is a chemically stable, leach-resistant, glass and crystalline material similar to obsidian or basalt rock. The high-temperature component of the process destroys or removes organic materials. Radionuclides and heavy metals are retained within the vitrified product. Vitrification may be conducted in situ or ex situ.

APPENDIX B

Appendix B

LIST OF ACRONYMS and GLOSSARY OF KEY TERMS

µg/L	Microgram per Liter
ABA	American Bar Association
AFCEE	Air Force Center for Environmental Excellence
AHERA	Asbestos Hazard Emergency Response Act
ANL	Argonne National Laboratory
ASAP	Adaptive Sampling and Analysis Program
ASC	Accelerated Site Characterization
ASHAA	Asbestos School Hazard Abatement Act
ASHARA	Asbestos School Hazard Abatement Reauthorization Act
ASTM	American Society for Testing and Materials
BRAC	Base Realignment and Closure
BTEX	Benzene, Toluene, Ethylbenzene, and Xylene
BTSC	Brownfields and Land Revitalization Technology Support Center
BV	Bioventing
CAA	Clean Air Act
CAP	Corrective Action Plan
CCl_4	Carbon Tetrachloride
CEC	CERCLA Education Center
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CERCLIS	Comprehensive Environmental Response, Compensation, and Liability Information System
CLU-IN	EPA Hazardous Waste Clean-up Information Web Site
COR	Close-Out Report
CSM	Conceptual Site Model
CWA	Clean Water Act
DNAPL	Dense Nonaqueous-Phase Liquid
DoD	Department of Defense
DOE	Department of Energy
DOI	Department of Interior
DQO	Data Quality Objective
DSS	Decision Support Software
EAD	Environmental Assessment Division
ECOS	Environmental Council of the States
EDOCKET	EPA's Online Public Access and Comment System
EISB	Enhanced In Situ Bioremediation
ELI	Environmental Law Institute
EPA	U.S. Environmental Protection Agency
EPA REACH IT	EPA REmediation And CHaracterization Innovative Technologies Online Searchable Database
EPCRA	Emergency Planning and Community Right-to-Know Act
ERIS	Environmental Research Institute of the States
ESC	Expedited Site Characterization
ESD	Environmental Sciences Division
EST	Eastern Standard Time
ESTCP	Environmental Security Technology Certification Program
ET	Evapotranspiration
ETV	Environmental Technology Verification
FATE	EPA Field Analytic Technologies Encyclopedia
FDIC	Federal Deposit Insurance Corporation
FRTR	Federal Remediation Technologies Roundtable
FY	Fiscal Year
GAC	Granular Activated Carbon
GC/MS	Gas Chromatography / Mass Spectrometry
GNET	Global Network of Environment and Technology
GWRTAC	Ground-Water Remediation Technologies Analysis Center
HRS	Hazard Ranking System
HSRC	Hazardous Substance Research Center
HTRW-CX	Hazardous, Toxic and Radioactive Waste Center of Expertise
ICMA	International City / County Management Association
ICTS	Institutional Controls Tracking System
IDC	Interagency DNAPL Consortium
IINERT	In-Place Inactivation and Natural Ecological Restoration Technologies
ISB	In Situ Bioremediation
ISBN	International Standard Book Number
ISO	In Situ Oxidation
ITRC	Interstate Technology and Regulatory Council
LNAPL	Light Nonaqueous-Phase Liquid
LTM	Long-Term Monitoring
LUST	Leaking Underground Storage Tank
MCL	Maximum Contaminant Level
MCX	Mandatory Center of Expertise
MGP	Manufactured Gas Plant
MNA	Monitored Natural Attenuation
MPE	Multi-Phase Extraction
MSL	Mine-Scarred Land
MtBE	Methyl tertiary Butyl Ether
NAPL	Nonaqueous-Phase Liquid
NAS	Naval Air Station
NASA	National Aeronautics and Space Administration

NATO/CCMS	North Atlantic Treaty Organization/ Committee on the Challenges of Modern Society
NERL	National Exposure Research Laboratory
NETTS	National Environmental Technology Test Sites
NEWMOA	Northeast Waste Management Officials' Association
NFESC	Naval Facilities Engineering Service Center
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NPV	Net Present Value
NSB	Naval Submarine Base
NSCEP	National Service Center for Environmental Publications
OB	Open Burn
OD	Open Detonation
OECA	Office of Enforcement and Compliance Assurance
OERR	Office of Emergency and Remedial Response
ORD	Office of Research and Development
ORP	Office of Radiation Programs
OSRTI	Office of Superfund Remediation and Technology Innovation
OSW	Office of Solid Waste
OSWER	Office of Solid Waste and Emergency Response
OUST	Office of Underground Storage Tanks
P&T	Pump and Treat
PAC	Powdered Activated Carbon
PAH	Polycyclic Aromatic Hydrocarbon
PBMS	Performance-Based Measurement System
PCB	Polychlorinated Biphenyl
PCE	Tetrachloroethene
PCP	Pentachlorophenol
PCR	Polymerase Chain Reaction
PDF	Portable Document Format
POTW	Publicly Owned Treatment Works
PRB	Permeable Reactive Barrier
PRP	Potentially Responsible Party
QA	Quality Assurance
QC	Quality Control
RAO	Remedial Action Optimization
RBCA	Risk-Based Corrective Action
RCRA	Resource Conservation and Recovery Act
redox	Reduction/Oxidation
RFP	Request for Proposal
RfR	Ready for Reuse
ROD	Record of Decision
RPM	Remedial Project Manager
RPO	Remedial Process Optimization
RSE	Remedial System Evaluation
RTDF	Remedial Technology Development Forum
SAP	Sampling and Analysis Plan
SCAPS	Site Characterization and Analysis Penetrometer System
SCM	Sampling, Characterization and Monitoring
SCRD	State Coalition for Remediation of Drycleaners
SEAR	Surfactant-Enhanced Aquifer Remediation
SenTIX	Sensor Technology Information Exchange
SERDP	Strategic Environmental Research and Development Program
SITE	Superfund Innovative Technology Evaluation
SMARTe	Sustainable Management Approaches and Revitalization Tools electronic
SOP	Standard Operating Procedure
SPCC	Spill Prevention, Control, and Countermeasures
SRI	Superfund Redevelopment Initiative
S/S	Solidification/Stabilization
SSEB	Southern States Energy Board
SVE	Soil Vapor Extraction
SVOC	Semivolatile Organic Compound
TAB	Technical Assistance to Brownfields Communities
TBA	Targeted Brownfields Assessments
TCE	Trichloroethene or Trichloroethylene
TOSC	Technical Outreach Services for Communities
TOSNAC	Technical Outreach Services for Native American Communities
TPH	Total Petroleum Hydrocarbons
TRAINEX	Training Exchange
TSCA	Toxic Substances Control Act
TSE	Targeted Site Efforts
TSP	Technical Support Project
UIC	Underground Injection Control
USACE	U.S. Army Corps of Engineers
UST	Underground Storage Tank
UV	Ultraviolet
UXO	Unexploded Ordnance
VCP	Voluntary Cleanup Program
VEB	Vertical Engineered Barrier
VOC	Volatile Organic Compound
WGA	Western Governors' Association

Following is a list of specialized terms that pertain to the cleanup of brownfields sites.

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 is used to remove organic compounds from wastewater. *See also Carbon Adsorption*.

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. Air sparging is often used in conjunction with soil vapor extraction systems. *See also Soil Vapor Extraction*.

Air Stripping
Air stripping is a treatment technology that removes or "strips" volatile organic compounds (VOC) from contaminated groundwater or surface water. As air is forced through the water, VOCs are volatilized. *See also Volatile Organic Compound*.

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

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 Creosote*.

Biopile
Biopile is an aerated static pile composting process in which soil is mixed with amendments on a treatment area that includes leachate collection systems and aeration with blowers or vacuum pumps. It is used to reduce concentrations of petroleum constituents through the use of biodegradation. Moisture, heat, nutrients, oxygen, and pH can be controlled to enhance biodegradation.

Bioreactor
Bioreactors use microorganisms in attached or suspended biological systems to degrade contaminants in water. In suspended biological systems, such as activated sludge, fluidized beds, or sequencing batch reactors, contaminated water is circulated in an aeration basin where microbes aerobically degrade organic matter and produce carbon dioxide, water, and biomass. In attached systems, such as rotating biological contactors and trickling filters, a microbial population is 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 and disposed of.

Bioremediation
Bioremediation refers to treatment processes that use microorganisms 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 contaminated soil or groundwater in the location in which it is found. For ex situ bioremediation processes, contaminated soil is excavated or groundwater is pumped to the surface before they can be treated.

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

Bioslurping
Bioslurping is the adaptation 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. *See also Vadose Zone*.

Bioventing
Bioventing is an in situ remediation technology that stimulates the natural biodegradation of aerobically degradable compounds in soil by the injection of oxygen into the subsurface. Bioventing has been used to remediate releases of petroleum products, such as gasoline, jet fuels, kerosene, and diesel fuel. *See also Bioremediation and Soil Vapor Extraction*.

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.

Brownfields Cleanup Grants
Brownfields Cleanup Grants provide direct funding for cleanup activities at certain properties with planned green space, recreational, or other nonprofit uses.

Brownfields Job Training Grants
Brownfields Job Training Grants provide funding for environmental training for residents of brownfields communities.

Brownfields Revolving Loan Fund Grants
Brownfields Revolving Loan Fund Grants provide funding to capitalize loans that are used to clean up brownfields sites.

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

Carbon Adsorption
Carbon adsorption is a remediation technology that removes contaminants from air or water through physical adsorption into the carbon grain. Carbon is "activated" to improve adsorption through a process that creates porous particles that have large internal surface areas. A number of commercial grades of activated carbon are available to meet the requirements of specific applications.

Carbon Tetrachloride
Carbon tetrachloride is a colorless, highly volatile liquid that has a strong ethereal odor similar to that of chloroform. It mixes sparingly with water and, when heated to decomposition, emits highly toxic fumes of phosgene. Carbon tetrachloride is used primarily as a chemical intermediate in the production of the refrigerants Freon 11 and 12. It also has been used as a general solvent in industrial degreasing operations and as an industrial solvent in the manufacture of cables and semiconductors.

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, Polychlorinated Biphenyls (PCB), 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 Reduction/Oxidation
Chemical treatments typically involve chemical 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. This method can be applied in situ or ex situ to soils, sludges, sediments, and other solids and also can be applied for the in situ treatment of groundwater.

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

Clean Water Act (CWA)
The 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.

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.

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*.

Conceptual Site Model (CSM)
A CSM, a key element used in facilitating cleanup decisions during a site investigation, is a planning tool that organizes information that already is known about a site and identifies the additional information necessary to support decisions that will achieve the goals of the project. The project team then uses the CSM to direct field work that focuses on the information needed to remove significant unknowns from the model. The CSM serves several purposes - as a planning instrument; as a modeling and data interpretation tool; and as a means of communication among members of a project team, decision-makers, stakeholders, and field personnel.

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.

Contaminant
A contaminant is any physical, chemical, biological, or radiological substance or matter present in any media at concentrations that may pose a threat to human health or the environment.

Corrosivity
Corrosive wastes include those that are extremely acidic or alkaline 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
The term data quality refers to all features and characteristics of data that bear on its ability to meet the stated or implied needs and expectations of the user.

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.

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, also known as multi-phase extraction, is a technology that uses a vacuum system to remove various combinations of contaminated groundwater, separate-phase petroleum product, and vapors from the subsurface. The system lowers the water table around a well, exposing more of the formation. Contaminants in the newly exposed vadose zone then are accessible to soil vapor extraction. Once above ground, the extracted vapors or liquid-phase organics and groundwater are separated and treated. *See also Soil Vapor Extraction*.

Dynamic Underground Stripping
Dynamic underground stripping is a process that employs vapor extraction during underground steaming and electrical heating. The heat, supplied by steam and electricity, vaporizes contaminants trapped in the soil. Once vaporized, the contaminants are removed by vacuum extraction. The process is monitored and guided by underground imaging.

Dynamic Work Plan
A dynamic work plan is a work plan that allows project teams to make decisions in the field about how site activities will progress. Dynamic work plans provide the strategy for the way in which dynamic field activities will take place. As such, they document a flexible, adaptive sampling and analytical strategy. Dynamic work plans are supported by the rapid turnaround of data collected, analyzed, and interpreted in the field.

Easement
An easement is a right to use the land of another for a specific purpose, such as a right-of-way or a utility.

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*.

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.

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*.

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.

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*.

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.

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 analysis for VOCs and semivolatile organic compounds (SVOC). 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.

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 conduct heat well, are fire resistant, and are 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 Resource Conservation and Recovery Act (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.

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.

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

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

Hyperaccumulator
A hyperaccumulator is a metallophyte that accumulates an exceptionally high level of a metal to a specified concentration or to a specified multiple of the concentration found in nonaccumulators. The term is used in reference to plants used in Phytoremediation. *See also Phytoremediation*.

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.

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 Thermal Treatment
In situ thermal treatment is a treatment process that involves heating contaminated soil in place to vaporize organic contaminants in the soil. The surface area to be treated is usually covered with silicone rubber mats to provide insulation and to form a vapor barrier.

In Situ Vitrification
In situ vitrification is a soil treatment technology that stabilizes metal and other inorganic contaminants in place at temperatures of approximately 3,000°F. Soils and sludges are fused to form a stable glass and crystalline structure with very low leaching characteristics.

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.

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. *See also Emerging Technology and Established Technology*.

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.

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. Zoning and deed restrictions are examples of institutional controls.

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.

Lampblack
Lampblack is a finely divided, bulky, black soot, at one time the most important black pigment used in the manufacture of printing inks. It is one of several gas plant residues found at manufactured gas plant (MGP) sites. *See also Manufactured Gas Plant*.

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.

Land Revitalization Initiative
The Land Revitalization Initiative was undertaken by EPA in partnership with states, tribes, territories, and a broad range of stakeholders to restore land to productive economic and green space uses. In April 2003, EPA announced the Land Revitalization Agenda to incorporate land reuse into the RCRA, brownfields, and underground storage tank (UST) hazardous waste cleanup programs.

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 has been used in the manufacture of gasoline, paints, and other substances. *See also Heavy Metal*.

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.

Long-Term Monitoring (LTM)
LTM typically is performed to verify that contaminants at a site pose no risk to human health or the environment and that natural processes are reducing contaminant levels and risk as predicted.

Manufactured Gas Plant (MGP)
MGPs were operated nationwide from the early 1880s through the mid-1900s. MGPs produced gas from coal or oil for lighting, heating, and cooking. The gas manufacturing and purification processes conducted at the plants yielded residues that included tars, sludges, lampblack, light oils, spent oxide wastes, and other hydrocarbon products. Although many of the byproducts were recycled, excess residues containing polycyclic acromatic hydrocarbons (PAH), petroleum hydrocarbons, benzene, cyanide, metals, and phenols remained at MGP sites.

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.

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

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

Methanogenic
The term methanogenic refers to anaerobic oxidation of petroleum hydrocarbons, as well as fermentation of hydrocarbons to methane.

Methyl tertiary Butyl Ether (MtBE)
MtBE, a synthetic chemical, is a volatile, flammable, colorless liquid. MtBE has a relatively high vapor pressure and is water soluble to a significant degree. MtBE usually is produced in a refinery by mixing a feedstock of isobutylene with methanol. The isobutylene is derived by steam-cracking during production of olefin and fluid-cracking during production of gasoline. Concern about them arises from its potential contamination of groundwater as a result of releases from underground storage tanks of gasoline that contains oxygenates. *See also Oxygenates*.

Mine-Scarred Lands (MSL)
MSLs are lands, associated waters, and surrounding watersheds where extraction, beneficiation, or processing of ores and minerals, including coal, has occurred. MSLs have become a persistent problem in many communities because of the economic, social, and environmental challenges of cleaning up and reusing such lands. The Brownfields Law expanded the definition of brownfields to include MSLs, making these properties eligible for benefits under the Brownfields Program.

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.

Monitored Natural Attenuation
The term MNA refers to the remedial approach that allows natural processes to reduce concentrations of contaminants to acceptable levels. MNA involves physical, chemical, and biological processes that act to reduce the mass, toxicity, and mobility of subsurface contamination. Physical, chemical, and biological processes involved in MNA include biodegradation, chemical stabilization, dispersion, sorption, and volatilization.

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 Hazard Ranking System (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*.

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

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

Oxygenate
Oxygenates are chemicals derived from hydrocarbons that are added to fuels to increase the oxygen content of those fuels to improve combustion, thereby reducing emissions, such as carbon monoxide and other pollutants. Examples of oxygenates include methyl tertiary butyl ether (MtBE), ethyl tertiary butyl ether, tertiary amyl methyl ether, ethanol, and other ethers and alcohols. *See also Methyl tertiary Butyl Ether*.

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.

Pentachlorophenol (PCP)
PCP, a chemical compound containing carbon, chlorine, oxygen, and hydrogen, is a chemical now used primarily as a wood preservative but which was previously used as a herbicide, defoliant, algicide, fungicide, and disinfectant.

Performance-Based Measurement System (PBMS)
EPA defines a 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 selecting 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 (PRB)
PRBs, also known as passive treatment walls, are installed across the flow path of a contaminated plume. As groundwater flows through the PRB, contaminants are either degraded or retained in a concentrated form by the reactive material. Examples of reactive media include zero-valent metals, chelators, sorbents, and microbes.

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 Site Assessment
Environmental site assessments, or all appropriate inquiries, are conducted to evaluate existing environmental problems from past operations and potential environmental problems from current or proposed operations at a site. The practice of conducting site assessments is intended to satisfy one requirement for obtaining protection from CERCLA liability for potential property owners. Most environmental site assessments are called Phase I assessments because they are conducted in conformance with ASTM E1527-00 Standard Practice for Environmental Site Assessments: Phase 1 Environmental Site Assessment Process. Phase I site assessments include:

- An inspection of the property
- A review of pertinent records for evidence of current and past use of the property and adjacent properties
- Interviews with current owners and occupants as well as local government officials
- Evaluation of information gathered and development of a report
- In some cases, samples are collected of building materials to determine if PCBs, asbestos, or lead are present

The need for additional sampling to confirm contamination or to determine the nature and extent of contamination leads into a "Phase II" assessment.

Phase II Environmental Site Assessment
Environmental site assessments are conducted to evaluate existing environmental problems from past operations and potential environmental problems from current or proposed operations at a site. The primary objective of conducting a Phase II assessment is to confirm and evaluate the environmental conditions identified in the Phase I environmental site assessment or transaction screening process. During the Phase II, additional investigation and sampling is needed to determine the nature and extent, source, and significance of contamination following a Phase I environmental assessment for the purpose of supporting subsequent cleanup and reuse decisions.

Phenol
A phenol is one of a group of organic compounds that are byproducts of petroleum refining, tanning, and textile, dye, gas, and resin manufacturing.

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.

Phytotechnology
The term phytotechnology refers to technologies that use living plants. *See also Phytoremediation*.

Phytotoxic
The term phytotoxic is used to describe a substance that is harmful to plants.

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.

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.

Polycyclic 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.

Potassium Permanganate
Potassium permanganate is a crystalline compound that is soluble in water, acetone, and methanol, but is decomposed by ethanol. It is used widely as a powerful oxidizing agent, as a disinfectant in a variety of applications, and as an analytical oxidant reagent in redox titrations.

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*.

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 (P&T)
P&T is a general term used to describe remediation methods that involve the pumping of groundwater to the surface for treatment. P&T 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*.

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

Ready for Reuse (RfR) Determination
An RfR is a new type of document developed by EPA to provide potential users of Superfund sites with an environmental status report that documents a technical determination made by EPA in consultation with states, tribes, and local governments. The environmental status report indicates whether all or a portion of a property can support specific types of uses and remain protective of human health and the environment. The RfR guidance was issued by EPA in February 2004.

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.

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.*

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*.

Representative Sampling
The term representative sampling refers to a portion of material or water that is as nearly identical in content and consistency as possible to that in a larger body of material or water being sampled. To prevent segregation and to provide a level of accuracy, the sample is representative of the volume and nature of the material being sampled.

Resin
Resins are solids or semi-solids, originally of plant origin, used principally in lacquers, varnishes, inks, adhesives, synthetic plastics, and pharmaceuticals. Man-made resins, also called synthetic plastics, have a wide range of applications from manufacturing of household goods to architectural and industrial uses.

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.

RCRA Brownfields Prevention Initiative
The RCRA Brownfields Prevention Initiative supports the design of pilot projects to test approaches that better integrate reuse considerations into the corrective action cleanup process. The initiative also addresses concerns that application of RCRA to cleanup activities may slow the progress of cleanup efforts.

RCRA Brownfields Prevention Targeted Site Efforts (TSE) Initiative
The RCRA Brownfields Prevention TSE Initiative is intended to focus short-term attention and support on sites where cleanup has been delayed or slowed and to serve as a catalyst for completing the cleanup at such sites in order to prevent them from becoming brownfields sites. The initiative applies to sites where significant potential for redevelopment and reuse exists and where limited EPA support would be required to bring the Sites to the next level of cleanup.

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.

Return to Reuse Initiative
The Return to Reuse Initiative was announced by EPA on November 10, 2004. This initiative focuses on NPL sites that were cleaned up before EPA's current emphasis on considering reuse during response activities, many of which remain vacant. Under this initiative, EPA is committed to reviewing remedies in place to determine whether there are relatively modest ways to alter the remedy, without triggering changes to the ROD, to encourage reuse of these sites.

Reuse Assessment
A reuse assessment involves the collection and evaluation of information to develop assumptions about reasonably anticipated future land uses at Superfund sites. It provides a tool for implementing the Superfund land use directive and can involve a review of available records, visual inspections of the site, and discussions with local government officials, property owners, and community members about potential future land uses.

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.

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 Standard Guide E 1739 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*.

Sampling and Analysis Plan (SAP)
A SAP documents the procedural and analytical requirements for a one-time or time-limited project that involves the collection of samples of water, soil, sediment, or other media to characterize areas of potential environmental contamination. A SAP contains all the elements of a quality assurance project plan and a field sampling plan that must be provided to meet the requirements for any project funded by the EPA under which environmental measurements are to be taken.

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.

Semivolatile Organic Compound (SVOC)
SVOCs, composed primarily of carbon and hydrogen atoms, have boiling points greater than 200°C. Common SVOCs include PCBs, PAHs, and phenols. *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.

Site Characterization and Analysis Penetrometer System (SCAPS)
SCAPS was developed by the Division of the Naval Command, Control, and Ocean Surveillance Center, in collaboration with the U.S. Army and the U. S. Air Force. SCAPS, a cone penetrometer testing system, coupled with laser-induced fluorescence, measures fluorescence with optical fibers. The measurement is made through a sapphire window on a probe that is pushed into the ground with a truck-mounted cone penetrometer testing platform. *See also Cone Penetrometer and Laser-Induced Fluorescence/Cone Penetrometer*.

Six-Phase Soil Heating
Six-phase soil heating is an in situ thermal technology for the remediation of contamination of soil and groundwater. The process splits conventional electricity into six electrical phases for the electrical resistive heating of soil and groundwater. Each electrical phase is delivered to one of six electrodes placed in a hexagonal array. The voltage gradient between phases causes an electrical current to flow through the soil and groundwater. Resistivity causes the temperature to rise. As the soil and groundwater are heated uniformly to the boiling point of water, the water becomes steam, stripping volatile and semivolatile contaminants from the pore spaces. In addition, removal of the soil moisture increases the air permeability of the soils, which can further increase the rate at which contaminants are removed.

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.

Small Business Liability Relief and Brownfields Revitalization Act
The Small Business Liability Relief and Brownfields Revitalization Act – also known as the Brownfields Law - was passed in January 2002. With the passage of this act, EPA assistance was expanded to provide greater support for brownfields cleanup and reuse. The law modified EPA's brownfields grants and technical assistance program by increasing EPA funding authority up to $200 million per year; providing grants for assessments, revolving loan funds, direct cleanups, and job training; expanding the entities, properties, and activities eligible for brownfields grants; expanding the Brownfields Program's applicability to sites with petroleum contamination such as abandoned gas stations; and providing authority for brownfields training, research, and technical assistance. In addition, the Brownfields Law changed and clarified Superfund liability for prospective purchasers, innocent landowners, and contiguous property owners. The law also provided liability protection for certain small-volume waste contributors and municipal solid waste contributors.

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 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.

Solubility
Solubility is a measure of the amount of solute that will dissolve in a solution. It is the ability or tendency of one substance to dissolve into another at a given temperature and pressure and is generally expressed in terms of the amount of solute that will dissolve in a given amount of solvent to produce a saturated solution.

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*.

Standard Operating Procedure (SOP)
An SOP is a step-by-step procedure that promotes uniformity in operations to help clarify and augment such operations. SOPs document the way activities are to be performed to facilitate consistent conformance to technical and quality system requirements and to support data quality. The use of SOPs is an integral part of a successful quality system because SOPs provide individuals with the information needed to perform a job properly and facilitate consistency in the quality and integrity of a product or end result. SOPs also provide guidance in areas in which the exercise of professional judgment is necessary and specify procedures that are unique to each task.

Steam Injection
Steam injection is a remediation technology that uses the addition of steam to the subsurface to heat the soil and groundwater and drive off contaminants. The technology was developed by the petroleum industry to enhance recovery of oils from reservoirs, and has been adapted by the remediation industry for use in the recovery of organic contaminants from the subsurface.

Strategic Environmental Research and Development Program (SERDP)
SERDP is an environmental research and development program headed by the U.S. Department of Defense in partnership with the U.S. Department of Energy and EPA. The program focuses on cleanup, compliance, conservation, pollution prevention, and unexploded ordnance technologies. SERDP also provides demonstration opportunities at national test sites and conducts annual symposia and workshops to encourage technology transfer.

Subsurface
Underground, beneath the surface.

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 the Comprehensive Environmental Response Compensation and Liability Act (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 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 Measurement and Monitoring Program, and the Technology Transfer Program.

Superfund Redevelopment Initiative (SRI)
The SRI reflects EPA's commitment to consider reasonably anticipated future land uses when making remedy decisions for Superfund hazardous waste sites so that sites can be cleaned up to be protective of human health and the environment under the future uses of the land.

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

Surfactant Flushing
Surfactant flushing is a technology used to treat contaminated groundwater. Surfactant flushing of NAPL 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*.

Systematic Planning
Systematic planning is a planning process that is based on the scientific method. It is a common-sense approach designed to ensure that the level of detail in planning is commensurate with the importance and intended use of the data, as well as the available resources. Systematic planning is important to the successful execution of all activities at hazardous waste sites, but it is particularly important to dynamic field activities because those activities rely on rapid decision-making. The data quality objective (DQO) process is one formalized process of systematic planning. All dynamic field activities must be designed through the use of systematic planning, whether using DQO steps or some other system. *See also Data Quality Objective*.

"Test Methods for Evaluating Solid 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.

Tetrachloroethene
Tetrachloroethene is a nonflammable manufactured chemical widely used for dry cleaning fabrics and in metal degreasing operations. It also is used as a starting material (building block) for the production of other manufactured chemicals. Other names for tetrachloroethene include PERC, tetrachloroethylene, perchloroethylene, and PCE.

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 emission treatment system. The technology is most effective for 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 Polycyclic Aromatic 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 Hydrocarbons (TPH)
TPH refers to a measure of concentration or mass of petroleum hydrocarbon constituents present in a given amount of air, soil, or water.

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 United States. 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.

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

Triad Approach
The Triad approach is a three-pronged approach designed to encourage modernization of data collection, analysis, interpretation, and management in order to support cleanup decisions for hazardous waste sites. The three parts of the Triad approach include systematic planning, a dynamic work strategy, and use of real-time measurement tools to allow on-site analysis of samples. The Triad approach enables project managers to minimize uncertainty while expediting site cleanup and reducing project costs. Systematic planning is a common-sense approach used to ensure that the level of detail of project planning matches the intended use of the data being collected. The dynamic work strategy relies on real-time data to reach decision points. The logic for decision-making is identified, and responsibilities, authority, and lines of communication are established. Real-time measurement is made possible by use of on-site analytical tools and rapid sampling platforms, on-site interpretation and management of data, and supports on-site decision-making.

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

Uncertainty
The term uncertainty refers to the inherent unknown quantities present in all scientific and technical decisions. Uncertainties can arise from incomplete knowledge of the nature and extent of contamination, an inability to predict a technology's performance under site-specific conditions, or new or changing regulatory requirements.

Underground Injection Control (UIC)
UIC is the prevention of contamination from fluids disposed through underground injection. Regulated under the Safe Drinking Act, the UIC program was established to prevent contamination of underground sources of drinking water. In addition to banning certain types of injection, the program establishes minimum requirements for the siting of injection wells and the construction, operation, maintenance, monitoring, testing, and closure of wells.

Underground Storage Tank (UST)
An UST is a tank and any underground piping connected to a tank that is used to contain gasoline or other petroleum products or chemical solutions and that is placed in such a manner that at least 10 percent of its combined volume is underground.

USTFields Initiative
The USTFields Initiative undertaken by EPA's Office of Underground Storage Tanks (OUST) focuses on improving cleanups at sites affected by petroleum contamination and encouraging redevelopment of these sites.

Unexploded Ordnance (UXO)
The term exploded ordnance refers to any munition, weapon delivery system, or ordnance item that contains explosives, propellants, and chemical agents. UXO consists of the same items after they: (1) have been armed or otherwise prepared for action; (2) have been launched, placed, fired, or released in such a manner as to constitute a hazard to operations, installations, personnel, or material; and (3) remain unexploded by design, by malfunction, or for any other reason.

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.

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; trichloroethene; and benzene toluene ethylbenzene and xylene (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.

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 National Priorities List (NPL). Under a VCP, 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*.

Zoning
Zoning is the exercise of the civil authority of a municipality to regulate and control the character and use of property.

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 Office of Superfund Remediation and Technology Innovation and the Office of Research and Development. The individuals are available to assist cleanup and redevelopment efforts at brownfields sites.

The points of contact listed are current, according to information available at the time of publication.

State Brownfields Contacts C-2

EPA Regional Brownfields Coordinators C-7

An online list of regional contacts is available at *www.epa.gov/swerosps/bf/regcntct.htm*

EPA Technical Support Contacts C-8

State Brownfields Contacts

ALABAMA

www.adem.state.al.us/

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Land Division
AL Department of Environmental Management
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Montgomery, AL 36109
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ALASKA

www.dec.state.ak.us/

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ARIZONA

www2.ev.state.az.us/index.html

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ARKANSAS

www.adeq.state.ar.us/hazwaste/

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CALIFORNIA

www.calepa.ca.gov/

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COLORADO

www.state.co.us/gov_dir/cdphe_dir/hm

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CONNECTICUT

http://dep.state.ct.us/

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DELAWARE

http://sirb.awm.dnrec.state.de.us/

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FLORIDA

www.dep.state.fl.us/

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www.dnr.state.ga.us/dnr/environ

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HAWAII

www.hawaii.gov/health

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IDAHO

www2.state.id.us/deq

Dean Nygard
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ILLINOIS

www.epa.state.il.us/

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INDIANA

www.ai.org/idem/oer/index.html

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IOWA

www.state.ia.us/epd

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www.epa.gov/r02earth/superfnd/brownfld/bfmainpg.htm

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www.epa.gov/reg3hwmd/brownfld/hmpage1.htm

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www.epa.gov/region4/index.html

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APPENDIX D

Appendix D

HOW TO ORDER DOCUMENTS

Each resource described in this document can either be viewed or downloaded online at *www.brownfieldstsc.org*. Many of the documents are provided in portable document format (pdf). Printed or hard copy versions of the publications are available from a variety of EPA sources. Visit the EPA Information Sources Web site for publications at *www.epa.gov/epahome/publications.htm* to obtain additional information on sources of publications. Some of the information contained on the Web site is included below.

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