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Technical/Regulatory Guidance

Green and Sustainable Remediation: A Practical Framework

November 2011

Prepared by
The Interstate Technology & Regulatory Council
Green and Sustainable Remediation Team

ABOUT ITRC

The Interstate Technology and Regulatory Council (ITRC) is a public-private coalition working to reduce barriers to the use of innovative environmental technologies and approaches so that compliance costs are reduced and cleanup efficacy is maximized. ITRC produces documents and training that broaden and deepen technical knowledge and expedite quality regulatory decision making while protecting human health and the environment. With private- and public-sector members from all 50 states and the District of Columbia, ITRC truly provides a national perspective. More information on ITRC is available at www.itrcweb.org.

ITRC is a program of the Environmental Research Institute of the States (ERIS), a 501(c)(3) organization incorporated in the District of Columbia and managed by the Environmental Council of the States (ECOS). ECOS is the national, nonprofit, nonpartisan association representing the state and territorial environmental commissioners. Its mission is to serve as a champion for states; to provide a clearinghouse of information for state environmental commissioners; to promote coordination in environmental management; and to articulate state positions on environmental issues to Congress, federal agencies, and the public.

GSR-2

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While all team members listed below contributed to the team's efforts, the co-leaders recognize the team members identified with the symbols *, †, or §, as deserving special recognition as follows:

* notable writing contributions
† took a leadership role during document production
§ multiyear active member of the team

The team recognizes the following states' support of team leadership and technical regulatory guidance preparation:

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EXECUTIVE SUMMARY

The Interstate Technology & Regulatory Council (ITRC) Green and Sustainable Remediation (GSR) Team has developed this guidance document to assist the remediation industry with the integration of green and sustainable practices into existing site investigation and remediation programs. The document provides a generalized framework intended to be flexible and scalable to each phase of the remedial process. The GSR Team intends for users of the document to implement this approach as-is or adapt it to their specific program and state and federal regulatory environment.

This technical and regulatory guidance document is intended to be used in conjunction with the overview document developed by the GSR Team and titled *Green and Sustainable Remediation: State of the Science and Practice* (ITRC 2011a). A survey of the states was conducted as part of the research and development of these documents, which provided the GSR Team with valuable input on the status of GSR integration across the United States. Additional information was provided by federal partners of ITRC, detailing their position and the level of GSR integration into their respective organizations.

This document provides an introduction to GSR, including definitions of key terms specific to the concept of GSR, followed by a description of the process of planning a GSR evaluation and the implementation of GSR concepts during each remediation phase, from site investigation through site closeout. Finally, the document describes the types of tools available to the GSR practitioner. Several case studies are included in Appendix C to assist in conceptualizing GSR integration into each type of cleanup program.

The user will find the three aspects of GSR consisting of environmental, social, and economic considerations depicted in the introduction to define the process of sustainable site decision making. The GSR concepts communicated in this document will help state programs develop guidance and eventually formal GSR policy and may help some federal agencies that have not developed programs formulate a GSR policy.

The GSR planning process described in this document outlines a process to adequately prepare for a GSR evaluation, including the identification and engagement of stakeholders. The GSR Team identified three levels of GSR evaluations to provide users with a set of options to make GSR evaluations applicable to a wide array of project types. The GSR implementation process described in this document takes the user through each remedial phase, demonstrating opportunities for GSR applications and describing the documentation necessary to demonstrate the use of GSR approaches.

The description of tools provided in this document is intended to guide users in the selection of a tool that is best suited to their project in consideration of the three levels of GSR evaluations provided herein. The GSR overview document identified a number of metrics and tools that combined provide the user with numerous options for GSR evaluations. These tools and metrics range from simple to complex and may be applied as appropriate to meet the needs of a specific

project. Users must select the metrics and tools that will best assist them in the decision-making process, depending on their site-specific requirements and conditions.

This technical and regulatory guidance is the culmination of the work of the ITRC GSR Team, which has membership from a range of perspectives in GSR. The team urges users of this document to explore the wide range of GSR resources that are now available and to use these resources to select the combination of approaches, tools, and metrics that best meets the needs of their specific project. This guidance document will help users navigate the range of GSR information that is currently available.

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GREEN AND SUSTAINABLE REMEDIATION: A PRACTICAL FRAMEWORK

1. INTRODUCTION

Green and sustainable remediation (GSR) has emerged as a beneficial approach to optimize all phases of site remediation, from site investigation to project closeout. This document was developed by the ITRC GSR Team to provide a guide for users interested in the application of GSR approaches. It provides important background information on GSR, including an approach to GSR planning and implementation and tools to conduct GSR evaluations. The document uses an original approach developed by the GSR Team but also provides references to a number of key documents and initiatives that supplement this document and will also be helpful.

This section provides key background information related to GSR, including a problem statement, key definitions, and GSR's relationship to other ITRC teams and products. In addition, this section summarizes a survey of state interest, state and federal perspectives, and related GSR guidance.

Section 2 describes the GSR planning process; Section 3 describes the GSR implementation process. Together, these two processes represent the GSR framework developed by the ITRC GSR Team. Section 4 describes a wide array of tools that can be used to conduct GSR evaluations.

Finally, this document contains several key appendices. Appendices A and B contain the survey of state interest questionnaire and responses, Appendix C provides a set of case studies highlighting the application of GSR approaches, Appendix D lists contact information for the ITRC GSR Team, and Appendix E defines acronyms used in this document.

The ITRC GSR Team previously published the technology overview *Green and Sustainable Remediation: State of the Science and Practice* (ITRC 2011a), referred to in this document as the GSR overview document, which provides an introduction to the topic of GSR and serves as a key predecessor and reference to this technical and regulatory guidance document.

1.1 Problem Statement

The ultimate goal of remediation is to protect human health and the environment. To meet this goal, many remedies have been focused on site-specific risks and may not have been developed in consideration of external social and economic impacts beyond identified environmental impacts. By identifying approaches that address environmental, social, and economic impacts, projects can be improved while still meeting regulatory objectives.

The GSR planning and implementation framework provided herein intends to provide the user with a generalized approach for integrating environmental, social, and economic considerations into site management decisions.

1.2 Applicability

This document is intended to apply to any remediation program in the United States. It can be used by state regulators, federal employees, and the private sector, including consultants and industrial and commercial companies. The GSR framework may be used in part or in its entirety. The GSR framework may be used for a particular project phase or used as a model for development of internal GSR guidance, and it can be applied at small or large sites or projects. The GSR framework and associated evaluations provided in this document are intended to supplement the various phases of site remediation, from investigation through to long-term monitoring (LTM). It is not intended to supplant any regulatory requirement. This document may be given concurrence by any user but may not comprehensively align with existing guidance due to variations in existing rules and statutes. The ITRC GSR Team intends for users of this document to tailor their GSR evaluation process to their individual program of interest using this document as a guide.

1.3 Definitions

The GSR overview document provides several GSR-specific definitions. The following section provides definitions of terms key to this technical and regulatory guidance document. These definitions were discussed extensively by the GSR Team and represent consensus-based definitions. While the definitions in this section capture fundamental GSR tenets, they are subject to interpretation by the user depending on the context in which they will be implemented. The GSR Team anticipates further maturation of the definitions provided below as the topic of GSR evolves.

1.3.1 Sustainability

"Sustainability" is a general concept with a wide array of existing definitions. As noted in the GSR overview document, common themes of sustainability include the holistic consideration of environmental, social, and economic impacts of an activity and evaluation of these impacts on future generations. Figure 1-1 depicts sustainable development, similar to that adopted in 2005 by the International Union for Conservation of Nature (IUCN) and published in *The Future of Sustainability: Re-Thinking Environment and Development in the 21st Century* (IUCN 2006).

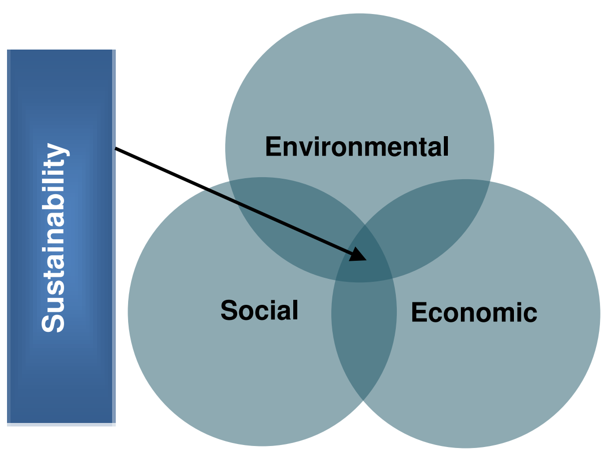


Figure 1-1. Sustainability schematic. *Source*: Based on IUCN 2006.

1.3.2 Green Remediation

"Green remediation" is the practice of considering all environmental effects of remedy implementation and incorporating options to minimize the environmental footprints of cleanup (EPA 2011a). The application of green remediation approaches can involve the use of best management practices (BMPs) or "environmental footprint" analyses to reduce the impact of a remedial action on the environment.

1.3.3 Green and Sustainable Remediation

The ITRC GSR Team's consensus-derived definition of "green and sustainable remediation" is the site-specific employment of products, processes, technologies, and procedures that mitigate contaminant risk to receptors while making decisions that are cognizant of balancing community goals, economic impacts, and environmental effects.

Building on IUCN's concept of sustainability, Figure 1-2 displays the GSR team's conceptualization of the evolution of GSR and the current movement toward integration of social and economic considerations. The left schematic in Figure 1-2 presents the theoretical balance of environmental, social, and economic aspects of sustainability; the center schematic depicts how GSR is presently bringing together all three aspects of site contaminant investigation and cleanup activities. The schematic to the right in Figure 1-2 depicts the potential growth of GSR to provide greater recognition of the economic and social aspects of sustainability in remedial decision making. The term "economic" as used this document includes both economic impact to a community and the cost of project.

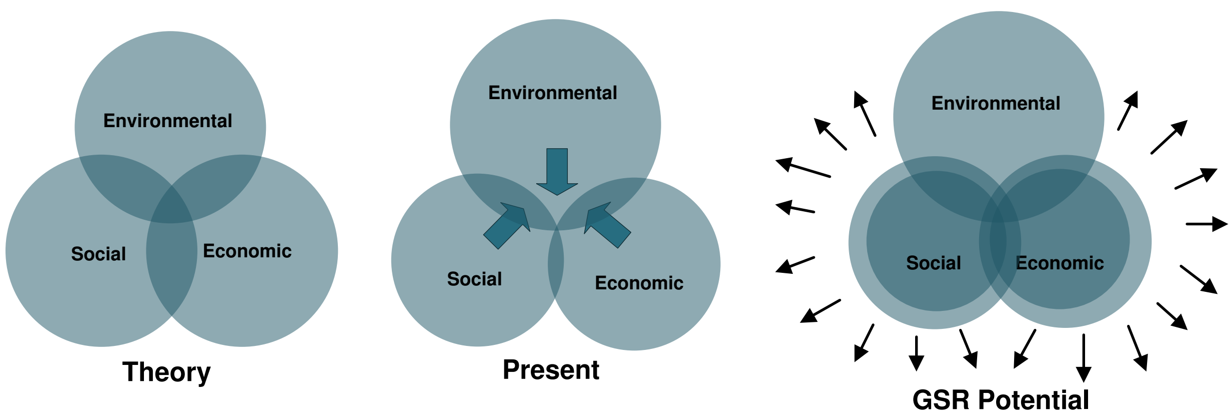


Figure 1-2. Schematic representation of GSR concept development.

Ultimately, persons conducting GSR evaluations should target a balance, as shown in Figure 1-3, integrating the three elements of GSR to the maximum degree possible, continuously aiming for the most-sustainable investigation and remedial approach.

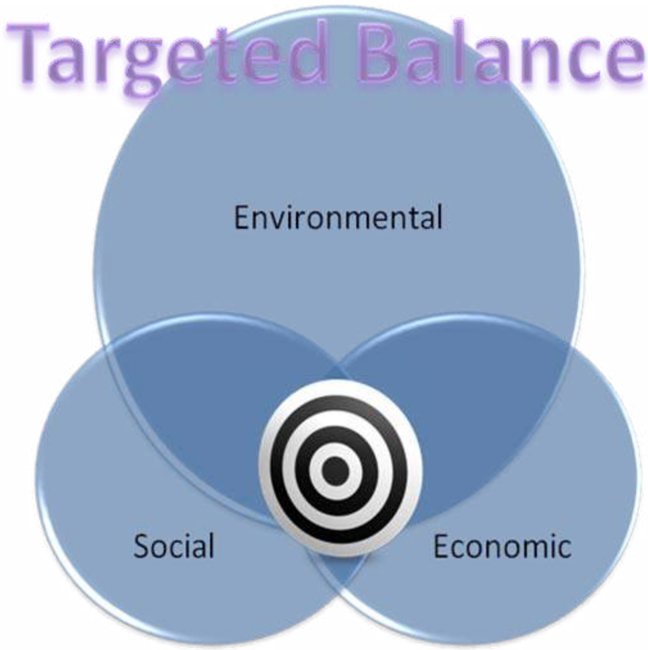


Figure 1-3. GSR targeted balance.

1.3.4 Greenwashing

"Greenwashing" refers to situations where GSR options have not been evaluated and backup documentation is lacking yet there is still a claim that GSR approaches have been implemented. Similar to greenwashing, misuse of the terms "sustainable" or "sustainability" may hamper integration and acceptance of GSR concepts into the environmental industry.

Whether it is the responsible party, consultant, or state regulator performing the GSR evaluation, the user should be prepared to provide documentation of evaluations where GSR was considered in the decision-making process. Assumptions used in the GSR evaluation should be based on publically available, documented, and/or generally accepted sources and approaches. The user is highly encouraged to validate, or at least substantiate through documentation, any claims of a GSR performance, no matter the stage of cleanup or level of evaluation being performed.

In the future, the potential for greenwashing may be lessened through development of a certification process using specific assigned levels of green and sustainable measures. This type of GSR evaluation certification could one day be likened to the U.S. Green Building Council's (USGBC) Leadership in Energy and Environmental Design (LEED) certification process (USGBC 2011). The GSR concept is likely to gain acceptance, use, and credibility through the development of such a certification.

1.4 Relationship to Other ITRC Teams and Products

ITRC efforts on other topics have relevance to the GSR topic. The following describes the work of several other ITRC teams. As previously mentioned, this technical and regulatory guidance document is a companion to the GSR overview document (ITRC 2011a), which provided important background information to the development of this document. The overview document provides key definitions; an inventory of GSR-related efforts being undertaken by a wide array of governmental entities and other organizations; a summary of key GSR metrics; and additional information on GSR resources, methods, and tools.

1.4.1 The Triad Approach

According to *Technical and Regulatory Guidance for the Triad Approach: A New Paradigm for Environmental Project Management* (ITRC 2003), referred to as the Triad technical and regulatory guidance document:

> The concepts embodied in the three legs of the Triad approach are (1) systematic project planning, (2) dynamic work strategies, and (3) real-time measurement technologies. The Triad approach can be thought of as an initiative to update the environmental restoration process by providing a better union of scientific and societal factors involved in the resolution of contamination issues. It does this by emphasizing better investigation preparation (systematic project planning), greater flexibility while performing field work (dynamic work strategies), and advocacy of real-time measurement technologies, including field-generated data.

Employment of the techniques introduced in the Triad technical and regulatory guidance document (ITRC 2003) correlates directly to reducing resource expenditures throughout the investigation and cleanup process. As further noted in that document:

> The EPA and other practitioners have shown across a variety of project types that implementation of the Triad approach will result in significant improvements in both investigation quality and cost-efficiency. Cost and time savings result primarily from reducing the number of investigation field mobilizations needed to complete the characterization. . . . Significant cost and time savings can result because characterization can focus on uncertainties that impact appropriate remedial action selection, design, and associated cost estimation. Improved investigation quality arises from better focus on project goals, increased sample coverage of the site, fewer unexplored site uncertainties, flexibility for field activities to adjust to unexpected conditions, and sophisticated data management tools to analyze and communicate the findings.

In terms of GSR, the Triad approach reduces field mobilizations, results in fewer samples being shipped for laboratory analysis, reduces resampling, and generates less waste than a number of other sampling approaches. Resultant benefits include the reduction of mobilizations and laboratory shipping, which may lead to the reduction of transportation-related air emissions, including greenhouse gas (GHG) emissions.

1.4.2 Direct-Push Well Technology

The Use of Direct Push Well Technology for Long-Term Environmental Monitoring in Groundwater Investigations (ITRC 2006b) is referred to here as the direct-push well technical and regulatory guidance document. The use of direct-push wells results in the reduction of investigation-derived waste (IDW), which reduces the need to transport and dispose of waste.

Additionally, the speed of installation results in fewer field mobilizations and less time expended at a site. As stated in the direct-push well technical and regulatory guidance document, “The primary distinction between a direct-push well and a conventionally installed groundwater monitoring well is that a direct-push well can be installed without first having to construct an open borehole. The primary advantage of direct-push wells is the cost saving that is associated with the speed and ease of installation. Due to their lower costs, faster installation, decreased contaminant exposure, and decreased waste production, direct-push wells are a desirable alternative to conventionally drilled wells.”

1.4.3 Remediation Process Optimization

Remediation process optimization (RPO) provides opportunities for applying GSR approaches to existing, already under way, site remediation projects. As defined in *Remediation Process Optimization: Identifying Opportunities for Enhanced and More Efficient Site Remediation* (ITRC 2004), RPO is the systematic periodic evaluation of site remediation processes and procedures to ensure that a remediation system is operated in the most efficient and cost-effective way possible while ensuring it is protective of human health and the environment. RPO can be conducted in any phase of the site remediation process but is most commonly applied in the operations and maintenance (O&M) phase. RPO conducted in the O&M phase is an excellent opportunity to identify areas where green and/or sustainable remediation practices can be applied.

For example, if a site no longer needs continuous, 24-hour power, perhaps solar panels can provide sufficient power. At a site in New Jersey, the New Jersey Department of Environmental Protection (NJDEP) has switched from a centralized, blower-driven landfill gas collection system that operated continuously at more than 5 horsepower (hp) of electricity to passive venting with solar powered igniters, commonly call “stick flares.”

Other agencies have included green and sustainable options when conduction RPOs: the U.S. Air Force (USAF) Center for Engineering and the Environment (AFCEE) links RPO to green and sustainability opportunities. AFCEE provides a description of this effort on its “Sustainable Remediation” program web page (AFCEE 2011). The U.S. Environmental Protection Agency (EPA) frequently uses the U.S. Army Corps of Engineers (USACE) to conduct optimization studies at EPA-lead Superfund project sites. USACE uses a process that includes remediation system evaluation (RSE) checklists as posted on its program site (USACE 2010b). USACE has recently been charged by EPA to include green and sustainable considerations when conducting RSEs on Superfund projects.

1.4.4 Performance Based Environmental Management

Improving Environmental Site Remediation Through Performance-Based Environmental Management (ITRC 2007) is referred to here as the performance-based environmental management (PBEM) technical and regulatory guidance document. PBEM is a strategic, goal-oriented uncertainty management methodology that is implemented through effective planning and timely decision-logic focused on the desired end results. It promotes accelerated attainment of cleanup objective in an efficient manner while ensuring the protection of human health and the environment. The entire remediation process is considered as a holistic process that stretches between initial release reported to all the way through the remedy completion. In this process, eight main elements of the remediation process are discussed in detail, which are important in developing and implementing a systematic cleanup process that is iteratively evaluated to ensure the successful achievement of the remediation goals. GSR process builds on the PBEM principles while considering the overall remediation from a comprehensive perspective, adding the green and sustainable elements to achieving these remediation goals.

1.4.5 Project Risk Management for Site Remediation

Project Risk Management for Site Remediation (ITRC 2011b) is referred to here as the project risk management technical and regulatory guidance document. Remediation risk management (RRM) techniques can be used to find project management efficiencies. RRM is the process for anticipating and mitigating uncontrollable project activities or circumstances that may result in negative consequences to remediation system performance. Managing remedy performance risk should be an integral part of a remediation program's overall management. RRM is an integrated program management tool that cuts across the entire program, addressing and interrelating cost, schedule, and performance/operational risks. The goal is to make everyone involved in the program aware that performance risk should be a consideration in the planning, design, and execution of remediation activities. Accordingly, the project risk management technical and regulatory guidance document (ITRC 2011b) describes potential benefits of the use of RRM:

> The benefits of remediation risk management include improved likelihood of project success, reduction of adverse secondary impacts on the environment (such as the depletion of natural resources or ecological habitat), and, in some cases, reduced time and cost to achieve site closure and post-closure goals. These concepts are closely aligned with GSR approaches. Coordinating RRM with GSR may provide the project team with synergistic opportunities. RRM produces better planning that can be communicated to stakeholders to emphasize high-priority issues and concerns at the site (e.g., sustainability, long-term liability, accelerated schedule). This will reassure stakeholders that their concerns are being taken seriously and that steps are being taken to mitigate the potential effects of these project risks.

1.4.6 Life-Cycle Cost Analysis

Life Cycle Cost Analysis (ITRC 2006a) is referred to here as the life-cycle cost-analysis technology overview document. In the context of this document, "life-cycle cost analysis" is defined as a method of comparing the costs of remediation alternatives by going beyond the initial implementation costs of each alternative to estimate the present worth of the total annual cost of ownership in today's dollars and amortizing those costs over the life of the project. Life-cycle cost analysis can be used to compare the net present value of different remediation alternatives, evaluate the cost-effectiveness of a remediation system, and perform a cost/benefit analysis of remediation alternatives. The life-cycle cost-analysis technology overview document (ITRC 2006a) uses two hypothetical sites to demonstrate the life-cycle cost-analysis process.

1.5 Survey of State Interest

The ITRC GSR Team conducted a survey of state interest to evaluate perspectives and opportunities or barriers to GSR. Appendix A summarizes the GSR state survey and addendum results; Appendix B contains the survey questionnaire. Responding states generally did not report any regulatory barriers to implementing GSR practices or tools. The states expressed enthusiasm for understanding and implementing GSR approaches, with particular interest in identifying and using metrics for GSR applications. Most respondents to the survey sought a guidance document that focuses on a practical methodology to incorporate GSR practices into the phases of the traditional site remediation process.

1.6 State Regulatory Perspectives

As captured in the GSR overview document (ITRC 2011a), the degree of GSR implementation varies significantly across the United States. The variation occurs not only in the implementation of GSR practices but also in the degree to which policies and strategies have been formalized. The spectrum of GSR inclusion across programs also varies dependent on management staff exposure, knowledge, and authority to implement as significant shifts in environmental priorities are experienced in a financially strained economic scenario. The GSR overview document summarizes specific state activities going on during the period when the document was under development. In addition, the user will find the state survey responses useful to understand the various levels of implementation across the country.

This document provides an important primer for those agencies currently initiating GSR programs. In addition, the document describes emerging issues related to GSR that may be of interest to programs with experienced GSR staff. As noted in the GSR overview document (ITRC 2011a), the GSR initiative is currently voluntary for most states; however, under Executive Order 13514, *Federal Leadership in Environmental, Energy, and Economic Performance*, a variety of sustainability considerations are to be addressed by each federal agency. This directive could have implications for states that use federal funds for remediation and other types of projects.

1.7 Federal Agency Perspectives

1.7.1 U.S. Environmental Protection Agency

1.7.1.1 Overview

As part of its mission to protect human health and the environment, EPA is dedicated to developing and promoting innovative cleanup strategies that restore contaminated sites to productive use, reduce associated costs, and promote environmental stewardship. EPA strives for cleanup programs that use natural resources and energy efficiently, reduce negative impacts on the environment, minimize or eliminate pollution at its source, and reduce waste to the greatest extent possible in accordance with the EPA’s strategic plan for compliance and environmental stewardship (EPA 2006).

There are no statutory or regulatory requirements to use green remediation principles and concepts, as the need for green remediation was not anticipated at the time most environmental statutes were enacted. However, the federal government has recognized the need to reduce energy use and address key sustainability issues such as GHG emissions, water conservation, and storm-water management as stated in Executive Order 13423, *Strengthening Federal Environmental, Energy, and Transportation Management*, and Executive Order 13514, *Federal Leadership in Environmental, Energy, and Economic Performance*.

Green remediation is intended to improve the efficiency and effectiveness of the selected remedy, as well as to reduce the use of resources, but EPA has been clear that green remediation is not an additional criterion that could somehow be used to reduce the potential for meeting cleanup levels. Rather, EPA believes that green remediation principles are accommodated within the existing criteria applied to Superfund and other federally regulated sites.

EPA's regulatory programs and initiatives actively support site remediation and revitalization resulting in beneficial site reuse, such as commercial operations, industrial facilities, housing, greenspace, and renewable energy development. EPA has been examining opportunities to integrate practices into the decision-making processes and implementation strategies that result in site reuse. In doing so, EPA recognizes that incorporation of greener cleanup principles can help increase the overall benefits of cleanup.

1.7.1.2 Program initiatives

In September 2008, the EPA Office of Superfund Remediation and Technology and Innovation (OSRTI) formed a workgroup of headquarters and regional staff which developed the *Superfund Green Remediation Strategy* ("the Strategy," EPA 2010a). The Strategy sets out current plans of the Superfund program to reduce GHG emissions and other negative environmental impacts that might occur during remediation of a hazardous waste site or non-time-critical removal actions. The Strategy is not intended to be a comprehensive document; rather, it will change over time as more is learned about how to improve cleanup activities. The current version of the Strategy outlines ten key action items and recommends related activities to promote green remediation. Action items fall into three overarching categories: policy and guidance development, resource development and program implementation, and program evaluation.

In developing these action items, the workgroup highlighted several needs that are important to implementation:

- clarify how green remediation practices fit within the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the National Oil and Hazardous Substances Pollution Contingency Plan
- improve our understanding of potential resource and energy demands for many Superfund remedies
- develop a consensus on metrics that can be used to measure and evaluate green remediation actions

The Strategy contains recommendations to develop white papers that clarify major issues such as the extent to which the Superfund program can incorporate green remediation practices under existing laws and regulations. The Strategy also includes a recommendation to pursue follow-on directives that help foster greater use of green remediation practices at Fund-lead (i.e., sites where cleanup is funded and led by EPA), state-lead, potentially responsible party–lead, and federal facility sites.

Finally, the Strategy includes the recommendation to establish a process for quantifying achievements regarding Superfund's commitment to reduce the demands that site cleanups place on the environment. Regional summaries, site-specific data, and trend information are being collected and used to establish a solid baseline on the environmental demands made prior to Strategy implementation.

OSRTI is in the process of updating the Strategy as a "living" document to reflect refined agency policy, modified activities within the key actions, and other developments as green remediation matures. EPA conducted specific outreach activities to solicit and promote input on further refining this Strategy and focusing this effort. The Strategy's next version will include aspects specific to EPA's Emergency Response/Removal Program.

EPA has also developed and released for comment on September 16, 2011 a "footprint methodology" document (EPA 2011b), which is scheduled to go final in late December 2011. An important consideration associated with green remediation is quantifying the footprint of the cleanup action on the environment and then taking steps to reduce that footprint while meeting regulatory requirements. Two concepts are central to quantifying the environmental footprint of a cleanup. The first is to establish those parameters (or metrics) that are to be quantified, and the second is to establish a straightforward methodology for quantifying those metrics. The term "footprint," which is commonly applied to quantifying the emissions of CO_2 (i.e., "carbon footprint"), refers to the quantification or measure of a specific metric that has been assigned some meaning. The term "footprint" can be expanded to other environmental metrics such as energy use, water use, land use, and air emissions to represent the effects a remedy may have on the environment.

The footprint methodology presents green remediation metrics associated with environmental cleanups and a methodology for quantifying those metrics. The organization of this document and the metrics presented are consistent with EPA's five core elements of green remediation, described at www.cluin.org/greenremediation (EPA 2011a).

The information needed and the process of obtaining the information for this methodology are the same used while developing remedy alternatives, designing a remedy, or optimizing a remedy. For this reason, it is highly suggested that the footprint analysis be conducted in concert with one or more of these other activities.

In addition to green remediation programs under the Superfund program, EPA has also initiated the Land Revitalization Program, which relates to Superfund, Resource Conservation and Recovery Act (RCRA), brownfields, underground storage tank (UST), and federal facilities restoration. The Land Revitalization Program's mission is to "[r]estore land and other natural resources into sustainable community assets that maximize beneficial economic, ecological, and social uses and ensure protection of human health and the environment" (EPA 2011c).

1.7.1.3 Green remediation resources

EPA has developed and compiled an extensive amount of information on green remediation, currently including the green remediation primer (EPA 2008); the www.clu-in.org website; profiles of projects; Internet seminars; archived discussions (www.clu-in.org); technical support for federal and state project managers; contract toolkit for regional remedial action contracts (RACs); renewable energy fact sheets; National Association of Remedial Project Managers (NARPM) eight-hour training; and Office of Solid Waste and Emergency Response (OSWER) RE-Powering America's Land Initiative (EPA 2009c). All these resources can be accessed at www.clu-in.org/greenremediation.

EPA identified five core elements of a green cleanup to assist with the identification and selection of technologies and approaches to lower the environmental footprint of a remedial action. Figure 1-4 identifies these core elements and their relationship to green remediation practices. In addition, EPA's "Greener Cleanups" website (www.epa.gov/oswer/greencleanups/index.html) provides extensive information on green remediation, including tools, case studies, and links and resources, as well as a BMP Toolkit.

1. Minimize total energy use and maximize use of renewable energy
   - Minimize energy consumption (e.g., use energy-efficient equipment)
   - Power cleanup equipment through on-site renewable energy sources
   - Purchase commercial energy from renewable resources
2. Minimize air pollutants and greenhouse gas emissions
   - Minimize the generation of greenhouse gases
   - Minimize generation and transport of airborne contaminants and dust
   - Use heavy equipment efficiently (e.g., diesel emission reduction plan)
   - Maximize use of machinery equipped with advanced emission controls
   - Use cleaner fuels to power machinery and auxiliary equipment
   - Sequester carbon on site (e.g., soil amendments, revegetate)
3. Minimize water use and impacts to water resources
   - Minimize water use and depletion of natural water resources
   - Capture, reclaim, and store water for reuse (e.g., recharge aquifer, drinking water irrigation)
   - Minimize water demand for revegetation (e.g., native species)
   - Employ best management practices for storm water
4. Reduce, reuse, and recycle material and waste
   - Minimize consumption of virgin materials
   - Minimize waste generation
   - Use recycled products and local materials
   - Beneficially reuse waste materials (e.g., concrete made with coal combustion products replacing a portion of the Portland cement)
   - Segregate and reuse or recycle materials, products, and infrastructure (e.g., soil, construction and demolition debris, buildings)
5. Protect land and ecosystems
   - Minimize areas requiring activity or use limitations (e.g., destroy or remove contaminant sources)
   - Minimize unnecessary soil and habitat disturbance or destruction
   - Minimize noise and lighting disturbance

Figure 1-4. EPA's core elements of green cleanup.

1.7.1.4 Emerging initiatives

In late 2010, EPA Administrator Lisa Jackson asked the National Research Council (NRC) to conduct a study on how to make sustainability operational at the EPA. The study was released as the "Green Book" in September 2011 (NRC 2011) and can be found on the National Academies website at www.nap.edu/catalog.php?record_id=13152.

On September 15, 2011 Administrator Jackson wrote a letter to NRC noting that the study recognized that many of today's environmental challenges often encompass social and economic dimensions. The letter stated that sustainable solutions "…demand a more integrated, innovative and forward-thinking response." The way to do this is to "…build upon the ways the EPA has already incorporated sustainability into its work." The study provides an operational framework for integrating sustainability as one of the key drivers within the regulatory responsibilities of EPA. Specifically, the study set out to answer four key questions:

- What should be the operational framework for sustainability for EPA?
- How can the EPA decision-making process rooted in the risk assessment/risk management paradigm be integrated into this new sustainability framework?
- What scientific and analytical tools are needed to support the framework?
- What expertise is needed to support the framework?

NRC provided a number of recommendations to the EPA to answer the four questions, including the following (among others):

- setting 3–5 year goals with appropriate metrics
- developing tools (e.g., life-cycle analysis, environmental justice tools) that have the ability to analyze present and future consequences of alternative decision options on the full range of social, environmental, and economic indicators (three pillars)
- hiring multidisciplinary professionals who have a working knowledge in all three pillars and their application to environmental issues

Although it will take time and experience to incorporate sustainability broadly into EPA's culture and process, the committee anticipates that over time there will be an increasing use of the framework. In addition to engaging other agencies as EPA implements the framework, other stakeholders will also be important to engage, such as state regulators, local officials, industry, academia, community and advocacy groups, and the international community.

1.7.2 U.S. Air Force

AFCEE is the lead entity within USAF responsible for developing and promoting green and sustainable practices in the USAF Environmental Restoration Program (ERP). Introducing sustainability metrics into environmental restoration projects is not a new endeavor for USAF. Since the early 1990s, USAF has investigated and promoted inherently sustainable remediation approaches such as monitored natural attenuation (MNA) and enhanced in situ bioremediation. Incorporating technologies such as these into an environmental restoration project can often reduce the environmental impact of the remediation activity. More recently, USAF has begun to take a more holistic approach to evaluating remedial operations. This approach expands on traditional evaluations by placing significant emphasis on additional variables, including minimization of energy and water use and reuse. USAF also considers social and economic factors that could impact a selected remedy and the manner in which it is implemented.

USAF has pursued sustainability in its ERP through such approaches as environmental restoration program optimization, LTM optimization, groundwater modeling, PBEM, and RRM. These programs work to include GSR approaches and technologies in remediation selection and design, optimize existing remediation and monitoring systems, and provide a holistic and systematic results-based assessment of restoration programs to expedite site closure. To further encourage GSR, USAF is including requirements in contractual language; regionalizing contracts to optimize monitoring programs; eliminating high-energy engineered remediation systems; drafting guidance for USAF remedial project managers (RPMs); providing training, education, and outreach for USAF RPMs and their environmental partners; and partnering with other organizations and federal agencies to facilitate GSR principles being included in USAF environmental restoration projects.

In addition to programs and initiatives to encourage the application of GSR principles in the USAF ERP, AFCEE and its partners have developed several tools. One of the tools developed is the Sustainable Remediation Tool™ (SRT™), which serves two general purposes: planning for future implementation of remediation technologies at a particular site and providing a means to evaluate optimization of existing remediation systems or to compare remediation approaches based on sustainability metrics. The metrics calculated by the SRT include emissions to the atmosphere (CO_2, NO_x, SO_x, particulate matter [PM] less than 10 µm in aerodynamic diameter [PM10]); total energy consumed; change in resource service; technology cost; and safety/accident risk. All of these metrics can be expressed in "natural" units (e.g., tons of air pollutant emitted), and all but safety/accident risk can be normalized (monetized) to U.S. dollars to facilitate comparisons using a common denominator. Section 4 provides a complete description of SRT.

In addition to the SRT, AFCEE developed the Performance Tracking Tool (PTT) that is integral to the AFCEE's promotion of sustainable remediation methods. PTT is a Microsoft Excel™–based tool which can be used to evaluate the historic performance of a remedial system (e.g., mass removal) and compare it to expected performance to determine whether the contaminant mass is being reduced at the anticipated rate and whether the O&M costs are consistent with projections. Knowing this performance information can help the RPM determine whether systems need to optimized, switched to a different treatment approach, or removed from operation. Technologies currently included in the PTT are pump and treat, dual-phase extraction, solvent extraction, soil vapor extraction, bioslurping, and MNA. The PTT has been applied in several instances showcasing how results from the tool can lead to more sustainable, efficient, and cost-effective remediation solutions. The PTT is available at no cost for users from www.afcee.af.mil/resources/restoration/erp-o.

In addition to the SRT and the PTT, AFCEE is developing CleanSWEEP (Clean Solar and Wind Energy in Environmental Programs), a design and decision tool for alternative energy use at remediation sites. The initial version of the tool will focus on all types of remediation systems with power requirements of 1–20 kW. A large subset of groundwater pumping, soil vapor extraction/bioventing, and sparging systems operate within this range of power demand. The tool evaluates the two most commonly available forms of renewable energy (photovoltaic-solar and wind energy systems) and uses existing DOE databases to estimate solar and wind potential. The tool is easily applicable to remote sites. Remediation systems with low energy requirements over long periods as well as those systems which do not require continuous operation can be analyzed using this tool. The tool uses Microsoft Excel and is simple enough to be used "out of the box" with only a small amount of training; however, it sophisticated enough to make go/no-go and simple design recommendations for small to midsized systems. It is also appropriate as a screening tool for large and complex systems. CleanSWEEP will be available to the public at no cost in the spring of 2012 and will complement the application of other GSR tools.

As GSR implementation is becoming prevalent within USAF through the application of tools and approaches as described above, AFCEE is deliberately including GSR language in its contracts, including its performance-based remediation (PBR) contracts. Sustainable practices are required elements in the remedy implementation contracts along with basic elements such as understanding the work and relevant experience. Specific language such as "net positive social and environmental benefit," "incorporate life-cycle sustainability assessment into selection process," "promote new and innovative technologies to conserve natural resources," and "have low energy and low carbon footprint" are often included in the contracts. For PBR contracts, GSR is included in the selection criteria, giving those firms who include GSR in their remediation approach an advantage over those that do not. AFCEE is also seeking innovative solutions that include GSR principles through its Broad Agency Announcement under the AFCEE Technology Transfer Program.

In summary, AFCEE is on the leading edge of GSR development. It is promoting GSR within the USAF ERP through demonstrating and validating GSR technologies, developing GSR and other performance tools for evaluating these technologies, and providing guidance on incorporating GSR language in contracts. This effort is expected to lead to a more sustainable use of resources, including water and energy, throughout USAF. It has the potential to expand to other agencies and USAF programs as well as benefit overall USAF installations and local communities.

1.7.3 U.S. Navy

The Naval Facilities Engineering Command (NAVFAC) is approaching implementation of GSR as part of the Navy's existing optimization program. The Navy's guidance documents for optimization are being updated to include GSR considerations. In addition, a guidance document describing GSR evaluation and application at Navy sites has been developed and is available on the Navy's "Green and Sustainable Remediation" portal (NAVFAC 2011). Navy policy to implement the guidance at Navy sites is expected to be published in 2011.

In August 2009, the Department of Navy Optimization Workgroup issued a GSR fact sheet (NAVFAC 2009), according to which GSR reviews should be considered during the remedy selection, design, and remedial action optimization phases. These reviews are opportune times to evaluate incorporating GSR practices into the cleanup strategies for Navy sites. Recognizing the importance of GSR considerations during remedy selection, a NAVFAC directive requires all feasibility studies to include GSR evaluations of all the included alternatives. The fact sheet summarizes the need for considering sustainable practices by Navy RPMs, lays out GSR metrics, and discusses methods to quantify the environmental footprints of remedial technologies and to reduce the footprint. The fact sheet describes the following general approach to be used by Navy RPMs to consider GSR:

- determine which sustainability metrics should be considered for the site
- establish and apply a methodology to quantify or characterize each metric
- obtain consensus regarding how metrics are weighed against each other and against traditional criteria in selecting the remedial approach
- identify methods to reduce environmental footprint of remedy components
- prioritize, select, and document what footprint reduction methods should be implemented with consideration of the overall net environmental benefit and available funding

The Navy has developed a list of metrics to consider and evaluate while planning and optimizing remediation projects: energy consumption, GHG emissions, criteria pollutant emissions, water impacts, ecological impacts, resource consumption, worker safety, and community impacts.

The Navy partnered with Battelle Memorial Institute, the U.S. Army, and USACE to develop a GSR tool called SiteWise™. Built on a Microsoft Excel platform, SiteWise assesses the remedy footprint of a remedial alternative/technology in terms of a consistent set of metrics, including GHG emissions; energy use; air emissions of criteria pollutants, including NO_x, SO_x, and PM; water consumption; resource consumption; and worker safety. SiteWise allows GSR evaluations to be conducted of remedial alternatives including associated remedial investigations (RIs), remedial action construction, remedial action operations (RA-Os), and LTM. SiteWise and an online training module are available on the Navy's "Green and Sustainable Remediation" portal (NAVFAC 2011). Section 4 provides a complete description of SiteWise.

1.7.4 U.S. Army

As a component of the Department of the Army, USACE issued the interim guidance *Decision Framework for Incorporation of Green and Sustainable Practices into Environmental Remediation Projects* (USACE 2010a) in March 2010. The interim guidance provides a decision tree with detailed references and information for considering and incorporating green and sustainable practices across the environmental remediation life cycle and directly addresses projects in the Formerly Used Defense Sites (FUDS) Program, the environmental remediation program that USACE administers for the Army.

The USACE Huntsville Center Environmental and Munitions Center of Expertise (EM CX) is currently conducting a study for the Department of Army Office of the Assistant Chief of Staff for Installation Management (OACSIM). In this study, green and sustainable practices are being identified in 12 Army environmental remediation projects, with the consideration and incorporation of the identified practices by the project teams then followed and documented. The projects span the Army components (National Guard, Army Environmental Command, Base Realignment and Closure Program, and FUDS), the Installation Restoration and Military

Munitions Response programs, and the phases within the environmental remediation life cycle. Results from the study will be used to consider and develop Army-wide GSR guidance and policy, as well as development of approaches that project teams can used to incorporate GSR into Army environmental remediation projects. The study is expected to be completed March 2012.

As indicated in Section 1.7.3, the Army and USACE also codeveloped and cofunded, along with the Navy and Battelle, the SiteWise GSR software, as well as participating in USACE/Navy/ Battelle training on the software. The SiteWise software is also the primary tool being used for quantitative GSR assessment of environmental remedial options in the OACSIM study.

GSR is also being coordinated within the larger USACE sustainability efforts through the creation of a green remediation focus area within the USACE Center for Advancement of Sustainability Innovation (CASI), a center within the USACE Construction Engineering Research Laboratory. EM CX heads the GSR focus area within CASI.

1.7.5 U.S. Department of Energy

The mission of the U.S. Department of Energy (DOE) is to advance the national, economic, and energy security of the United States; promote scientific and technological innovation in support of that mission; and ensure the environmental cleanup of the national nuclear weapons complex. This mission involves environmental and public protection responsibilities for both the cleanup of legacy waste and for the ongoing operation of the complex.

DOE is committed to conducting its mission in a sustainable manner, consistent with Executive Order 13514, *Federal Leadership in Environmental, Energy and Economic Performance*, and DOE's Strategic Sustainability Performance Plan (SSPP), "Discovering Sustainable Solutions to Power and Secure America's Future" (as required by E.O. 13514).

As part of the department's ongoing efforts to achieve the sustainability goals required in the Executive Orders and the SSPP, departmental elements should consider opportunities for minimizing environmental impacts of cleanup activities through the use of GSR practices. In the SSPP, DOE commits to incorporating "green remediation practices into its environmental cleanup program."

Green remediation practices, also known as green and sustainable remediation practices, build on the department's current environmental practices and employ strategies for cleanups that use natural resources and energy efficiently, reduce GHG emissions and waste generation as much as possible, minimize or eliminate pollution at its source, and protect and benefit the community at large. GSR considers all environmental effects throughout the life cycle of a cleanup project, including planning, design, remedy implementation, operation, and long-term maintenance.

GSR is not new to DOE, nor are GSR practices limited to a single departmental element. DOE has used GSR to enhance sustainability across many project phases (i.e., site investigation; remedy evaluation, design, and construction; operation; monitoring; and site closeout). This experience includes the use of improved soil sampling approaches to properly define soil quantities and reduce the total volume of material requiring remediation; the use of containment strategies consisting of subaqueous cap materials to minimize the risk of polychlorinated biphenyl uptake by bottom-dwelling fish, eliminating the need for the removal of more than 100,000 cubic yards of contaminated sediment; the evaluation of soil and debris to identify materials that can be diverted for recycling rather than disposal; and the use of innovative in situ treatment technologies such as zero-valent iron to reduce the need for the active pumping and treatment systems. DOE's approach has successfully reduced the quantities of materials requiring removal, avoided the use of energy, reduced GHG emissions, and provided a number of other positive environmental benefits, all while maintaining the protectiveness of the remedies and achieving the designated remedial action objectives.

1.7.6 U.S. Department of the Interior

The U.S. Department of the Interior (DOI) supports GSR. Although there are no strategies or formal training in place, DOI is exploring different sustainable practices and how to effectively implement them. Through benchmarking with other agencies and research, DOI is evaluating different methods that might apply at common cleanup sites throughout DOI. Some methods being considered include using renewable energy at sites with long-term energy needs, bioremediation and phytoremediation techniques, changes in land management practices, and techniques that reduce the carbon footprint of specific remedial activities. DOI will share its findings with all its land management bureaus.

1.7.7 Air National Guard

The Air National Guard (ANG) has implemented GSR in a two-pronged approach. First, it has developed a GSR policy (ANG 2009) that requires its contractors to consider GSR in all phases of remediation work. The second element of ANG's program is to evaluate the implementation of GSR practices as part of RPO. Approximately 10 ANG installations receive an RPO evaluation each year, and ANG selects those bases which would benefit from an in-depth GSR evaluation, including those that have long-term remedial technologies in place or are undergoing LTM. ANG has been successful in applying GSR to several installations, resulting in reductions in operating costs, switching from a pump-and-treat system to MNA, and evaluating the installation of renewable energy technologies at some sites.

1.8 Related GSR Guidance

1.8.1 ASTM International Green and Sustainable Site Assessment and Cleanup

ASTM International is currently developing two new standard guides for greener (WK35161) and more sustainable (WK23495) cleanup. The goal of the standard guides is first to provide useful information on environmental/green, economic, and social aspects that can be used within the site assessment and cleanup process and also to present a scalable framework to include these aspects within the decision-making process under various cleanup programs, thus addressing GSR practices. When published, the guides are anticipated to be complementary to and not supersede, federal, state, and local regulations.

1.8.2 Sustainable Remediation Forum

The Sustainable Remediation Forum (SURF) has created a framework that enables sustainability considerations to be integrated and balanced throughout the remediation project while continuing to ensure long-term protection of human health and the environment and achieving public and regulatory acceptance. The framework is one of three documents published by SURF in the summer 2011 issue of *Remediation Journal*. These documents—"Framework for Integrating Sustainability into Remediation Projects" ("SURF Framework," Holland et al. 2011), "Metrics for Integrating Sustainability Evaluations into Remediation Projects (Butler et al. 2011), and "Guidance for Performing Footprint Analyses and Life-Cycle Assessments for the Remediation Industry" (Favara et al. 2011)—are posted on the SURF website at www.sustainableremediation.org.

The goals of the SURF Framework are to accomplish the following:

- be accessible and helpful to all stakeholders involved in remediation projects
- be applicable to different phases of a remediation project
- be applicable to different regulatory programs in the United States

The SURF Framework provides a systematic, process-based, holistic approach for the consideration, application, and documentation of sustainability parameters during the remediation process in a way that complements and builds on existing sustainable remediation guidance documents. By using the framework, site-specific parameters, stakeholder concerns, and preferred end use(s) and future use(s) can be evaluated throughout the remediation life cycle and balanced with sustainability parameters.

The SURF Framework describes an approach for the following:

- performing a tiered sustainability evaluation
- updating the conceptual site model (CSM) based on the results of the sustainability evaluation
- identifying and implementing sustainability impact measures
- balancing sustainability and other considerations during the remediation decision-making process

1.8.3 Sustainable Remediation Forum—UK

SuRF-UK is the United Kingdom's Sustainable Remediation Forum, an initiative set up to progress the UK understanding of sustainable remediation. In March 2010 SuRF-UK published *A Framework for Assessing the Sustainability of Soil and Groundwater Remediation* ("SuRF-UK Framework," SuRF-UK 2009). This framework provides the essential link between the principles of sustainable development and the criteria (environmental, social, and economic) for selecting optimum land use design with sustainable remediation strategies and treatments. The SuRF-UK Steering Group successfully engaged with a wide range of stakeholders across a broad range of organizations working in contaminated land and brownfield management during the development of the framework. The SuRF-UK Framework highlights the importance of considering sustainability issues associated with remediation from the outset of a project and identifies opportunities for considering sustainability at a number of key points in a site's (re)development or risk management process. The following is one key paragraph that differentiates the SuRF-UK Framework from the EPA green remediation approach:

> A key difference between Green Remediation and the approach taken by SuRF-UK is that SuRF-UK seeks to consider remediation activities as part of the broader sustainable development objectives of the project, rather than simply to select the most "environmentally friendly" technology to achieve a given remedial objective. SuRF-UK considers that certain remedial activities and objectives may be "unsustainable" regardless of the energy source used to achieve them. In these circumstances, the SuRF-UK Framework recommends reconsideration of the fundamental remedial objectives, which is beyond the scope of Green Remediation. Nevertheless, lessons learned through the Green Remediation initiative may be extremely valuable at the SuRF-UK technology selection stage. (SuRF-UK 2009)

1.8.4 Network for Industrially Contaminated Land in Europe

The Network for Industrially Contaminated Land in Europe (NICOLE) is a leading forum on contaminated land management in Europe, promoting cooperation between industry, academia, and service providers on the development and application of sustainable technologies. In September 2010, NICOLE published *Sustainable Remediation Road Map* (NICOLE 2010), which is intended to provide users, including owners/operators of contaminated land and all their stakeholders, with a single, structured process to start working together and implementing best practices in sustainable remediation across a wide range of regulatory and policy frameworks.

2. GSR PLANNING

GSR planning is considered the starting point for integrating GSR principles and practices into a project. The GSR planning process can be used in preparing proposals, contracts, and project scoping, as well as in evaluating and optimizing ongoing or completed projects. This section presents the GSR planning process, and Section 3 identifies how GSR is implemented. The descriptions and examples provided here reveal the interlinked relationship between GSR planning (Section 2) and GSR implementation (Section 3).

Figure 2-1. GSR planning process.

As depicted in Figure 2-1, the GSR planning process consists of five generalized steps that can be performed to varying degrees during each phase of the project. After completing the applicable steps, a GSR evaluation may be performed and/or GSR activities implemented. Consistent with other concepts in this document, the steps of the GSR planning process are flexible and do not have to be performed in a linear fashion. The steps may change order or become iterative for reasons such as stakeholder input, changes in site conditions, etc. Tailoring each step to site-specific circumstances also allows the level of effort to be appropriately scaled during each phase of the cleanup project. Sections 2.1–2.5 describe each step of the GSR planning process.

2.1 Evaluate/Update Conceptual Site Model

The CSM synthesizes and summarizes what is already known about a site that is pertinent to decision-making requirements. It is a depiction and narrative of how the contaminants released at a site interact with the environment and potential human and ecological receptors. It is built on all currently available information about site conditions that could influence future remedy selection, design, or performance. The traditional elements and function of the CSM are beyond the scope of this document but are discussed further in the ITRC PBEM process (ITRC 2007). This CSM is not to be confused with the conceptual models used in human health and ecological risk assessments or hydrological modeling.

Because the CSM forms the basis for defining and implementing an effective overall strategy for the site, it should evolve throughout the life cycle of the cleanup project. When new information and valid data become available, the CSM should be evaluated and updated accordingly. This action alone is considered a relevant activity in the GSR planning process. However, evaluating and updating the CSM also offers the opportunity to incorporate nontraditional information that would be relevant to various elements of GSR. Some examples of relevant GSR information may include the following:

- on-site or nearby areas of ecological significance
- nearby disposal facilities
- nearby recycling facilities
- on-site wastewater treatment capabilities
- the site is on an electrical grid powered by renewable energy
- access steam generation on site or nearby
- on-site beneficial reuse of groundwater
- air emissions/pollutant sources
- on-site renewable energy
- community assets on or adjacent to the site (e.g., green space)
- nonimpacted soil reuse

The CSM is an important communication tool for regulators, contractors, stakeholders, and the public. By incorporating relevant GSR information, such as the examples listed above, the CSM provides a convenient format to reflect potential opportunities where GSR can be considered and possibly implemented.

2.2 Establish GSR Goals

Establishing goals is a key element of GSR planning. GSR goals can be influenced by a number of factors, including the need to meet corporate sustainability objectives or stakeholder requirements, response to a regulatory policy, or response to a desire to lower the potential impacts from a project and make it more sustainable. Identifying and understanding the driver(s) for a project can help identify key project goals. Drivers are discussed further in Sections 2.2.1 and 2.2.2.

The site setting and project-specific circumstances may help to identify GSR opportunities (and constraints) and shape appropriate GSR goals. For example, the economic impacts of development may be more important at a brownfield site than at a remote site that provides significant ecological value. A remediation site that is located close to an off-site disposal facility may be a better candidate for excavation of contaminated soils. A site located next to an industrial facility with excess steam generation may be a good candidate for thermal remediation.

GSR goals should be developed early during the planning process. The following are examples of GSR goals:

- design a low-energy approach to the remedy
- incorporate social and economic considerations into the remedy selection process
- reduce IDW
- reduce energy consumption by 20% during remedy optimization
- minimize the duration of facility operations shutdown within the vicinity of remedy construction activities

GSR goals can also be structured in response to EPA's green remediation core elements of energy, air, water, land and ecosystems, materials, and waste (EPA 2011a). These elements address the environmental component of sustainability. Therefore, if using EPA's core elements, planners should consider whether the greener cleanup aspects of the project attain their sustainability goals.

2.2.1 Regulatory and Corporate Drivers

Regulatory guidance/policy at the local, state, or federal level may be the driver for incorporating GSR into a project. Examples of regulatory drivers include the EPA regional greener cleanup policies (www.clu-in.org/greenremediation/regions/index.cfm) and Executive Orders 13423 and 13514. A hypothetical example of a local driver could be a city with a well-established waste-reduction program that readily promotes reuse and recycling. Some corporations may have directives that are focused on "green" practices and sustainability, which can also serve as a driver. Researching a company's sustainability program can be a starting point for identifying potential corporate drivers.

2.2.2 Incentives as Drivers

Incentives may also serve as project drivers. Incentives should be investigated in parallel with the stakeholder identification process because incentives may benefit many or all stakeholders. Available incentives could include loans or grants. Several websites are available to assist in the identification of incentives. As an example, EPA's initiative RE-Powering America's Land (EPA 2009c) is encouraging renewable energy development on current and formerly contaminated land and mine sites when it is aligned with the community's vision for the site. This initiative identifies the renewable energy potential of these sites and provides other useful resources for communities, developers, industry, state and local governments, or anyone interested in reusing these sites for renewable energy development. Information about incentives associated with this program can be found at www.epa.gov/renewableenergyland/incentives.htm. In addition, DSIRE (Database of State Incentives for Renewables and Efficiency) provides a comprehensive source of information on state, local, utility, and federal incentives and policies that promote renewable energy and energy efficiency. Established in 1995 and funded by DOE, DSIRE is an ongoing project of the North Carolina Solar Center and the Interstate Renewable Energy Council. More information about DSIRE can be found at www.dsireusa.org. In addition, the Association of State and Territorial Solid Waste Management Officials (ASTSWMO) has summarized several types of current and proposed incentives at www.astswmo.org/Files/Policies_and_Publications/Sustainability/Greener_Cleanups/GCTF_Incentives_Paper_6-25-09.pdf (ASTSWMO 2009). EPA's CLU-IN website also identifies a number of other groups that provide incentives for green or sustainable initiatives. This list is provided at www.clu-in.org/greenremediation/subtab_b4.cfm (EPA 2011a).

2.3 Stakeholder Involvement

ITRC defines "stakeholders" as members of environmental organizations, community advocacy groups, or other citizens' groups that deal with environmental issues (ITRC 2011c). Likewise, tribal stakeholders are affiliated with, or are employees of, Indian tribes or are Native American, Alaska Native, or Native Hawaiian. These public and tribal stakeholders are the voices of the communities and tribes that are affected by environmental problems.

2.3.1 Stakeholder Identification

Stakeholder involvement begins with identifying all applicable stakeholders. Stakeholders can be identified by "mapping" a project's area of influence or impact to determine what groups, areas, or activities could be affected by the planned work. Specific examples of stakeholders may include federal and state regulators, local government, the site owner/operator, responsible parties, local residents affected by a site, the general community, and site contractors. Stakeholders with an interest in GSR could be a subset of all stakeholders. There may be stakeholders who have an interest in only GSR-related activities but not other ongoing site activities.

After all applicable stakeholders are identified, several key questions need to be answered: the role of each stakeholder group in the remediation project, the potential impact each stakeholder group will have on project decisions, when stakeholders will be engaged, how stakeholders will be engaged, and how information will be disseminated. Stakeholder engagement is not unique to GSR; many regulatory programs have clearly defined checkpoints and procedures, such as the RCRA permitting process. The RCRA stakeholder identification guidance is described on EPA's webpage at www.epa.gov/osw/hazard/tsd/permit/pubpart/manual.htm (EPA 1996). However, to be considered part of the GSR planning process, stakeholder engagement should occur more frequently than the minimum required by a regulatory program. Increased frequency of stakeholder engagement can promote better decision making in the remediation process, which is considered an attribute of the environmental component of GSR. For stakeholder involvement to be considered an attribute of the social component of GSR, additional communication and receipt of input on GSR-related efforts is necessary.

2.3.2 Communicating GSR with Stakeholders

In communicating GSR to stakeholders, it is important to begin by explaining that the overall objective of the cleanup action is to protect human health and the environment and that GSR is not meant to supplant existing rules, regulations, or remedial action objectives. As stated previously, GSR is not a means of justifying a no-action remedy or less remediation than necessary to achieve the remedial action objectives. Rather, stakeholders should understand that GSR considers and potentially reduces collateral impacts of the remediation process and seeks to identify approaches to the site remediation that can also address community needs. By discussing collateral impacts (e.g., particulate and GHG emissions, water consumption, waste generation, truck traffic, noise, etc.) as they relate to each applicable site remediation phase (e.g., investigation, remedy design, etc.), potential alternatives can be identified that address stakeholder concerns.

An open dialogue can be used to understand stakeholder values. Once identified, those values can be reflected in the development of the overall project approach. For example, if stakeholders are primarily concerned with construction disturbance or air emissions, GSR planning should consider ways to reduce these impacts during all applicable phases of the cleanup project. End use of the site should also be aligned with stakeholder needs. Obviously, end use and stakeholder needs depend on whether the site is active or abandoned.

Stakeholder involvement can be interpreted and fulfilled in many different ways and does not have to be time-consuming or complex. Section 3 provides various examples of when and how stakeholder involvement can occur during each phase of the cleanup project.

2.4 Select Metrics, GSR Evaluation Level, and Boundaries

For each of the GSR goals identified, appropriate metrics must be selected to assess, track, or evaluate those goals. Concurrent with the selection of metrics, consideration should be given to the level of detail to be conducted during the GSR evaluation. The level of detail will guide the metric selection process and the type of tools and resources that should be used to expedite the GSR evaluation. Finally, the boundaries to be applied to a GSR evaluation must also be considered. The following sections discuss the selection of metrics, GSR evaluation levels, and boundaries.

2.4.1 Metrics

Metrics are used to provide a basis for the evaluation of actions under consideration or those implemented during any phase of site remediation, from investigation to project closeout. Business process reengineering (Trimble n.d.) provides the following common approach to define a metric that is specific, measurable, actionable, relevant, and timely (SMART):

- Specific—Metrics are specific and targeted.
- Measurable—The data needed for an evaluation can be collected.
- Actionable—The metric is easy to understand and clear when performance is charted over time.
- Relevant—The metric is targeted to something that is important.
- Timely—The data are available when needed.

Some common considerations that may assist in metric selection include measurement approach, boundary conditions, contractual expectations, available funding, schedule, staff experience, and level of detail for the GSR evaluation. Metrics may be applicable to one or more components of GSR (i.e., environmental, social, and economic).

GSR planning involves not only identifying metrics but also determining how they will be measured. For example, water conservation or reuse may be a GSR goal at a site located in a water-scarce area. The selected metric could be gallons of water. However, different approaches can be used to measure those gallons, such as gallons saved per year relative to some baseline scenario or possible groundwater extraction rate relative to precipitation recharge.

Metrics may be objective or subjective. The following are examples of objective GSR metrics:

- GHG emissions—the quantity of GHG emissions calculated based on metered energy consumption (or predicted energy consumption from equipment specifications) and on-site and/or transportation-related fuel consumption
- energy consumption—the amount of energy used to conduct site activities (often calculated in support of the GHG emissions metric)
- recycling/waste minimization—the quantity of material that would have otherwise been disposed of as waste, but was either reused on site (e.g., fill material) or recycled off site
- resource consumption—the quantity of natural resources consumed on site or otherwise made unavailable for future use (e.g., groundwater extraction or soil disposal)

The following are examples of subjective GSR metrics:

- beneficial reuse of property—the post-cleanup use of the property (e.g., jobs created, public transit established, etc.)
- job creation/preservation—the jobs provided or preserved as a result of the cleanup project
- creation of community assets—the post-cleanup use of the property (e.g., parkland or open space created, habitat created or preserved, etc.).

Table 4-1 of the GSR overview document (ITRC 2011a) and the SURF metric toolbox (Butler et al. 2011) each provide extensive lists of GSR metrics that reflect environmental, social, and economic considerations.

2.4.2 GSR Evaluation Levels

ITRC has developed a three-level approach to conducting GSR evaluations as described in this technical and regulatory guidance document. These levels provide different levels of detail for GSR evaluations and embrace the concept that GSR evaluations are scalable to any type of project or site.

Level 1: BMPs. The objective of a Level 1 approach is to adopt BMPs based on common sense to promote resource conservation and process efficiency. The net impact on the environment, community, or economics is not evaluated with this approach. Furthermore, BMPs do not attempt to compare or quantify environmental tradeoffs (e.g., a process that uses less water but generates more waste). However, as part of BMP implementation, similar BMPs may be compared to one another and selected based on cost savings or other obvious benefits. Section 3 contains tables with example BMPs specific to each phase of site remediation (e.g., site investigation, etc.). BMPs can be defined as an approach or practice that when implemented improve an environmental, social, and/or economic aspect of a remedial project, during any phase from site investigation through to project closeout. BMPs have been identified by a number of organizations and can relate to qualitative or quantitative site improvements.

Level 2: BMPs + simple evaluation. A Level 2 evaluation combines the selection and implementation of BMPs with some degree of qualitative and/or semiquantitative evaluation. Qualitative evaluations may reflect tradeoffs associated with different remedial strategies or use value judgments for different GSR goals to determine the best way to proceed. Semiquantitative evaluations are those that can be completed by use of simple mathematical calculations or intuitive tools. For example, conversion factors, online calculators, and spreadsheet-based programs can be used in support of semiquantitative evaluations. Level 2 evaluations may require different remedial strategies and associated GSR approaches to be ranked or weighted in importance relative to each other. An initial effort should be done to weight and rank each approach which may be revised based on stakeholder input. Specific examples of tools and resources that can be used in Level 2 evaluations are described in Section 4.

Level 3: BMPs + advanced evaluation. A Level 3 evaluation combines the selection and implementation of BMPs with a rigorous quantitative evaluation. The evaluation often relies on life-cycle assessment (LCA) or footprint analysis approaches. Accordingly, Level 3 evaluations require more time and expense to complete than Level 2 evaluations. In addition, moderate to significant learning curves should be expected for practitioners who do not have experience in performing LCA-type evaluations. As with Level 2 analyses, if weighting is used, it is recommended that appropriate weights be developed prior to performing the evaluation. The distinction between Level 2 and Level 3 evaluation may not always be clear and requires professional judgment for identification. Section 4 provides specific examples of tools that can be used for Level 3 evaluations.

2.4.3 GSR Boundaries

GSR boundaries should be identified for each GSR evaluation. The GSR boundaries can be defined as the degree to which the GSR evaluation is conducted. A variety of factors influence the boundaries of a GSR evaluation, such as the overall approach to the evaluation and whether life-cycle considerations are to be addressed as well as the phase of the project, data availability, stakeholder considerations, timing, and budget.

As stated in the GSR overview document, "With respect to boundary conditions, the most rigorous approach is to consider full cradle-to-grave analysis for all materials used from the mining of raw materials to the ultimate disposal or reuse of residuals. A less rigorous approach could go back to the manufacturing step of the products consumed but would not consider the impacts of getting the materials to the manufacturer. An even less rigorous approach might consider only the impacts that occur on the site."

If users find that they are limited by any particular boundary, this should be clearly identified in the initial planning phase and in the reporting stage of the GSR evaluation. This approach presents and clarifies any potential misunderstandings of the GSR evaluation.

2.5 Document GSR Efforts

Documenting GSR efforts is an important part of determining whether or not GSR goals are being achieved at a site and communicating ongoing benefits/accomplishments to stakeholders. If GSR goals are not being achieved, stakeholders may want to consider repeating the GSR evaluation, reconsidering other action items, and/or revising the goals.

Documentation may consist of, but is not limited to, GSR-related information recorded during project planning and field work, a formal report that describes the results of a GSR evaluation, or progress updates that track GSR aspects of remedial operation/optimization. When documenting GSR evaluations, information would ideally include all assumptions, tools, resources, boundary conditions, and other key principles so the approach can be understood and the results can be reproduced and verified. Any constraints or barriers encountered should also be clearly documented. In practice, the level of effort and presentation format for documenting the results of a GSR evaluation vary with the level of detail selected in Section 2.4 as well as the stakeholder group for which the documentation is intended.

Section 3 provides further discussion and examples of documenting GSR efforts as it applies to each phase of the cleanup project.

2.6 Summary

The GSR planning process consists of five general steps that are meant to provide a conceptual structure for guiding the integration of GSR into each phase of the cleanup project. This GSR planning process is intended to be flexible and scalable to site circumstances. Figure 2-2 presents a hypothetical example of the use of the GSR planning process during the investigation phase of a brownfield project. As indicated on Figure 2-2, the GSR planning process steps are presented in a slightly different order than introduced in this section and as shown in Figure 2-1. The GSR implementation process is presented in Section 3, which describes how to evaluate, select, and implement GSR practices.

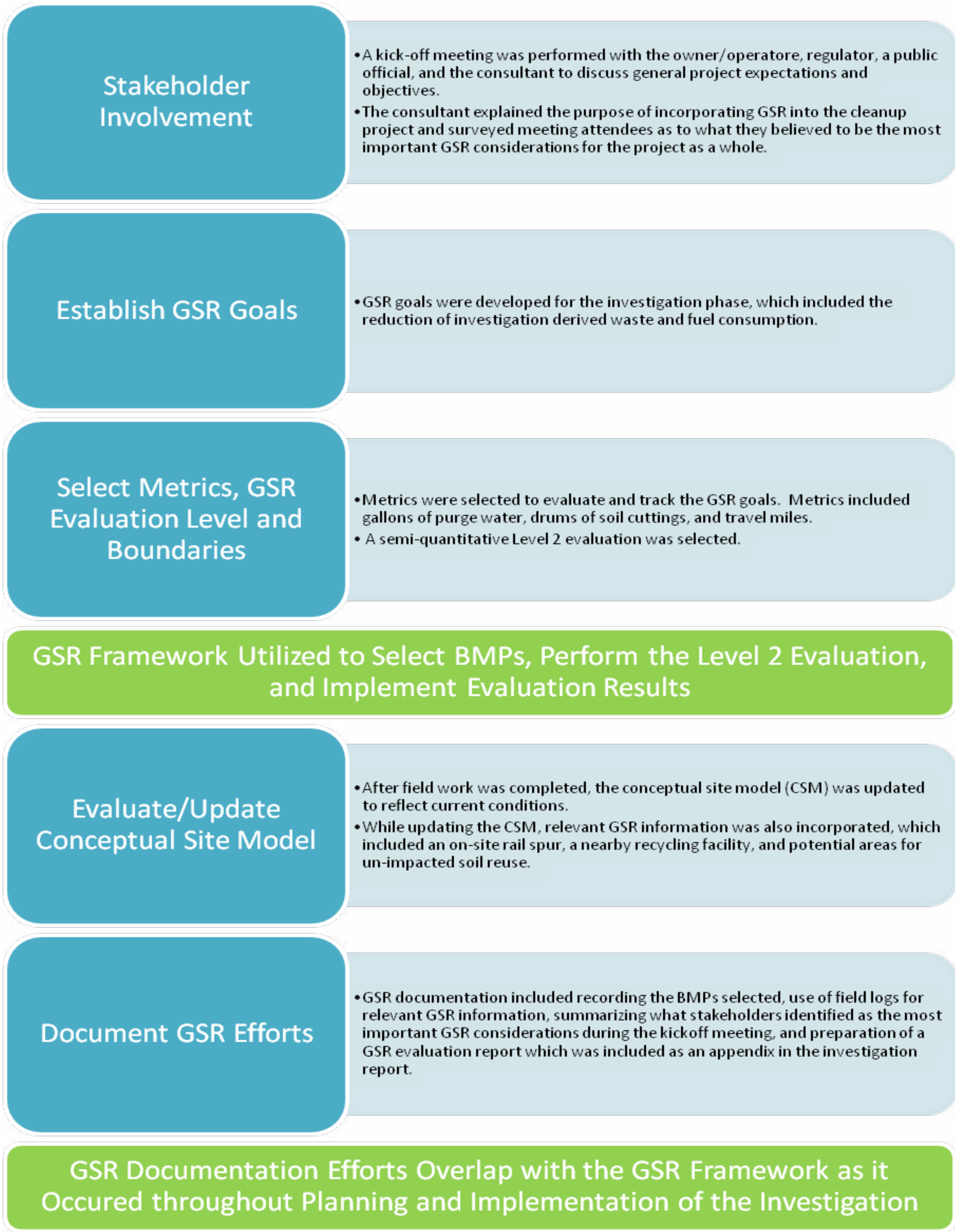


Figure 2-2. Hypothetical example of GSR planning process during the investigation phase of a brownfield project.

3. GSR IMPLEMENTATION

This section describes how to implement GSR in each phase of site remediation. As mentioned in Section 1 of this document, the ITRC GSR framework consists of the GSR planning process described in Section 2 combined with GSR implementation process described in this section. Figure 3-1 provides a schematic representation of ITRC's GSR framework. This section describes how to identify, evaluate, select, implement and track/document GSR practices in each phase of site remediation. During the GSR implementation process (Section 3) users should embrace the GSR planning process (Section 2) in each phase of site remediation by addressing the following:

- evaluate/update CSM
- establish GSR goals
- stakeholder involvement
- select metrics, GSR evaluation, and boundaries
- record GSR efforts

The phases of site remediation addressed in this section consist of the following:

- investigation
- remedy evaluation and selection
- remedy design
- remedy construction
- operations, maintenance, and monitoring
- remedy optimization
- closeout

Table 3-1 provides a cross-reference table for each phase of site remediation addressed in this section, identifying the corresponding name associated with certain state and federal regulatory programs.

Section 2 of this document described the GSR planning process and identified three levels that can be used to evaluate GSR practices: Level 1: BMPs, Level 2: simple evaluation in combination with BMPs, and Level 3: advanced evaluation in combination with BMPs.

The user does not need to complete every step in the GSR implementation process; however, the user should consider community and stakeholder input in each phase of site remediation. The social component of GSR is inherently driven by community and stakeholder input, and its consideration is central to the approach identified by ITRC in this document. If one singularly considers greener technologies, BMPs, or economically preferable remedies, the GSR evaluation will not be aligned with the intent of this document. However, those who perform the GSR planning process adequately will connect with the community and other stakeholders throughout the entire remediation process.

Appendix C provides case studies demonstrating the application of GSR approaches and illustrating how the approaches identified in this section can be implemented.

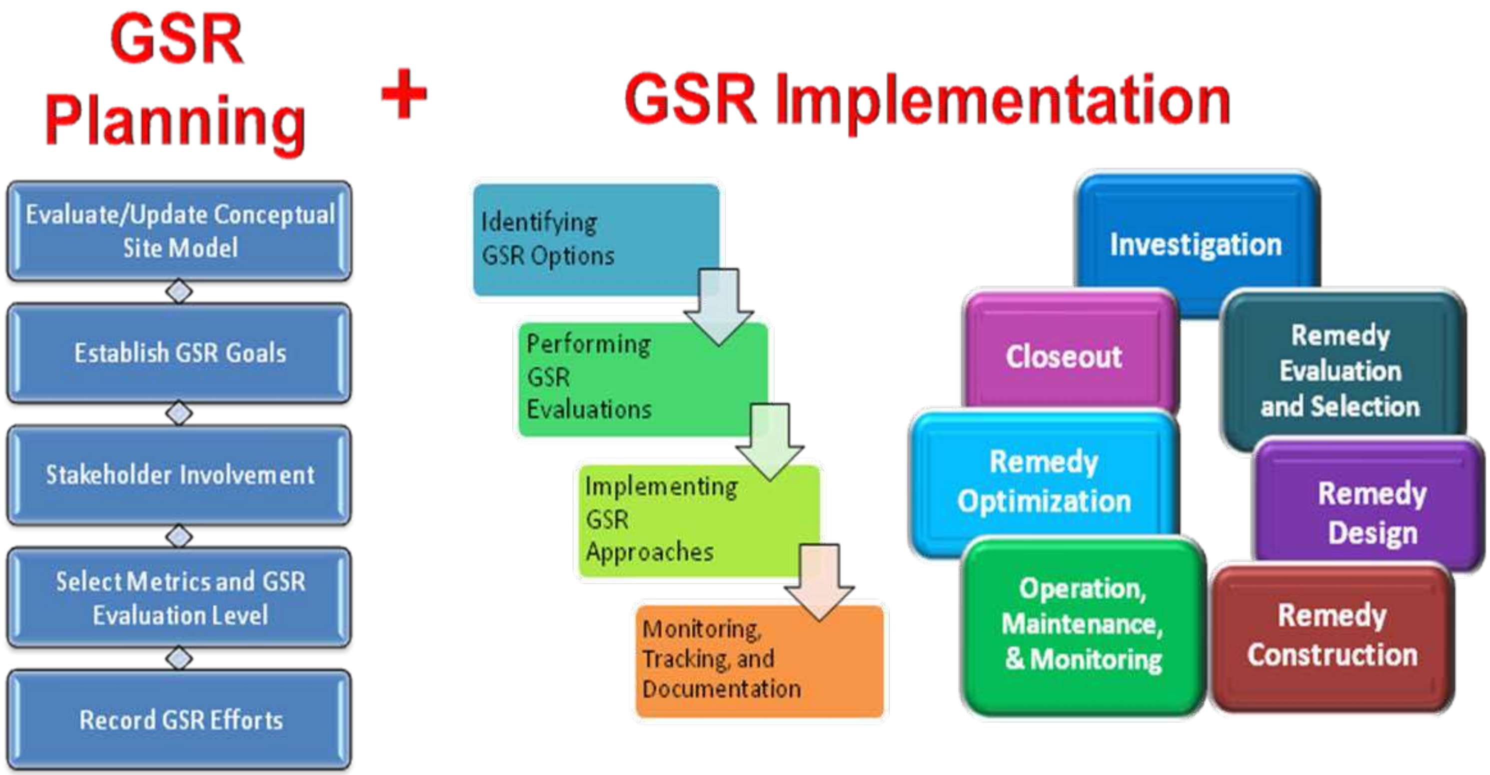


Figure 3-1. The ITRC GSR framework.

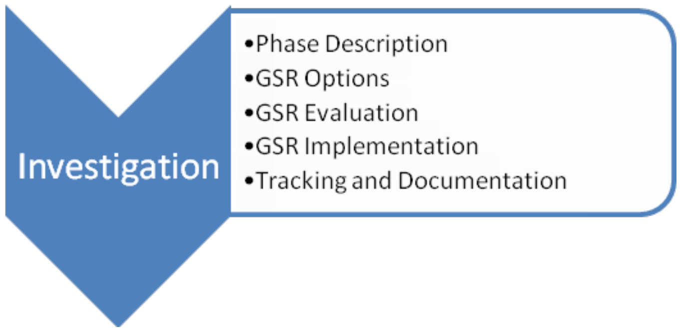
Table 3-1. Remedial phase descriptions for various regulatory programs

Remedial phase	RCRA	CERCLA	State programs	Leaking USTs
Investigation	RCRA Facility Investigation	Remedial Investigation (RI)	Site Assessment	RI, Secondary Investigation
Remedy evaluation and selection	Corrective Measures Study, Statement of Basis	Feasibility Study (FS), Proposed Plan, Record of Decision (ROD)	Remedial Alternative Evaluation	Conceptual Corrective Action Design, Corrective Action Plan
Remedy design	Corrective Measures Design, Corrective Measures Implementation Work Plan, Interim Measure	Remedial Design	Remedial Action Plan, Interim Source Removal Plan	Focused Investigation, Detailed Corrective Action Design
Remedy construction	Corrective Measures Implementation (CMI), Interim Measures Implementation Report	Remedial Action and Construction Completion	Construction Completion Report, Interim Source Removal Report	Corrective Action Implementation
Operation, maintenance, and monitoring	CMI, Corrective Action Effectiveness Reports	Post-Construction Completion, Five-Year Review	Remedial Action Status Report	Corrective Action O&M (includes System Performance Evaluation and Post-Shutdown Monitoring)
Remedy optimization	CMI	Five-Year Review, ROD Amendment, Explanation of Significant Differences	Remedial Action Plan Addendum	
Closeout	Corrective Action Completion Determination, Final CMI Report	National Priorities List (NPL) Deletion	No Further Action Proposal	Closure

This section provides a description of how to implement GSR approaches in each phase of site remediation. The following subsections focus on each phase and provide the following:

- phase description
- available GSR options in the context of the GSR levels introduced in Section 2
- how to conduct a GSR evaluation
- approaches to the implementation of GSR
- practices to track and document GSR activities

3.1 Investigation



3.1.1 Description of Investigation Phase

The site investigation phase is conducted to define the nature and extent of impacts to soil, groundwater, sediment, soil vapor, and other impacted media and to identify potential receptors. Systematic planning to establish clear objectives is necessary to prepare for the investigation. As stated previously, GSR approaches may provide the greatest benefit when employed early in the process. Therefore, investigation preparations should include GSR approaches to the degree possible to optimize the results.

3.1.2 Investigation Phase GSR Options

Conducting a site investigation using GSR approaches can result in a quantitatively greener project by consuming fewer resources and by producing lower emissions and wastes. It can effectively bring the community and other stakeholders into the project so that their views and needs are reflected throughout the site remediation process. Investigation phase GSR options can be identified or implemented using the following two approaches:

- *Level 1 BMPs*—BMPs are used to reduce the impact of a particular site investigation activity. For example, use of the Triad approach to fully delineate impacts in one mobilization can reduce the need for subsequent trips to the site. EPA provides an extensive list of these in *Green Remediation Best Management Practices: Site Investigation* (EPA 2009a).

- *Level 2 or 3 simple and advanced evaluations*—A Level 2 or 3 evaluation involves a simple or advanced comparison of site investigation options to identify an option with an incrementally lower impact to the environment and stakeholders/community. For example, a simple evaluation of the GHG emissions associated with different drilling options could be conducted to identify which one had lower emissions while still fully attaining project objectives. An advanced evaluation could include an LCA of site investigation options, including a comparison of the consumable materials used during a large-scale investigation.

Table 3-2 lists examples of overall approaches and BMPs to apply GSR to a site investigation. These approaches are organized to identify those that apply to the environmental, social, and economic aspects of site investigation.

Table 3-2. Investigation—example GSR approaches and BMPs

Environmental	Social	Economic
• Collect data to allow evaluation of off-site, on-site, and in situ treatment and management options • Collect data to understand risks associated with on-site treatment and containment of contaminated media • Identify methods to minimize generation of IDW • Use portable field analysis approaches and technologies to complete site characterization without multiple mobilizations • Identify recycling options for materials generated during site investigation • Identify methods that minimize impacts to ecosystem • Develop and refine CSM to identify all exposure pathways • Design field studies to minimize travel/number of trips to site	• Conduct community outreach/ notifications to communicate site conditions and risks and to engage in planning of site remediation and reuse options • Create key contacts list to facilitate communications/ notifications • Identify habitat restoration and other site reuse options for site	• Use field screening technologies to reduce mobilization and off-site sample shipping • Use local contractors and staff to minimize travel • Identify potential incentives for property redevelopment

3.1.3 GSR Evaluation

The GSR evaluation conducted during the investigation phase should, at a minimum, involve the use of one or more BMPs (Level 1). When going beyond Level 1, the user should identify GSR metrics to support the evaluation. Section 2 of this document discusses metrics and explains how they are selected and used. The GSR evaluation involves using these metrics to compare the relative performance of each site investigation option.

Table 3-3 provides an example of a GSR evaluation where a simple evaluation was conducted of two alternative site investigation options. Option 1 involves sample collection and the shipment of soil samples off site for analysis and two mobilizations to fully characterize the site. Option 2 involves use of a field analysis method to characterize soil samples on site using a mobile laboratory and only one mobilization to fully characterize the site. These two options were evaluated in terms of their ability to meet the selected metrics shown in Table 3-3. This example indicates that Option 2 is preferable. Both options have similar costs; however, Option 1 generates higher GHG emissions than to Option 2.

Table 3-3. Investigation—example of a simple GSR evaluation

GSR metric	Option 1: Off-site soil sample analysis	Option 2: On-site soil sample analysis (e.g., Triad approach)
Metric A: Minimize GHG emissions	Higher GHG emissions than Option 2 because of the need for two mobilizations to complete the site characterization	Lower GHG emissions compared to Option 1 due to single mobilization
Metric B: Minimize costs	Comparable cost to Option 2	Comparable cost to Option 1 due to setup of on-site laboratory capable of attaining data quality requirements

GSR evaluations can be more detailed than the example provided in Table 3-3 and may involve the evaluation of numerous quantitative metrics, including water consumption, air pollutant emissions, waste production, materials recycled, and more. To support these evaluations, a tool or set of tools can be used, as described in Section 4 of this document.

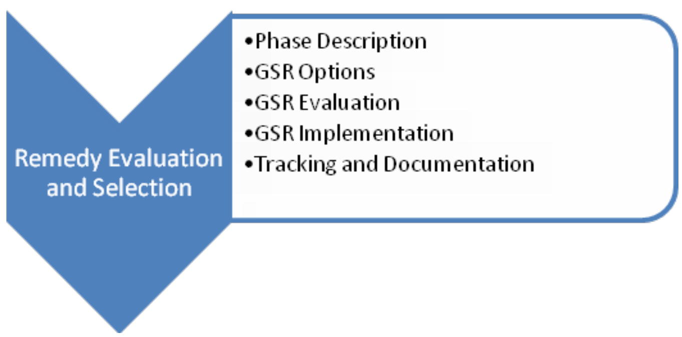
3.1.4 GSR Implementation Approaches

GSR implementation during a site investigation involves putting the selected GSR practices to work. One of the key steps of GSR implementation is to document the GSR requirements in procurement documents and field work plans so that contractors and staff performing tasks such as drilling and sample collection fully understand the GSR practices that were selected for the project. Furthermore, the field staff should be alerted to procedures selected as GSR techniques, making preparatory communication with field staff imperative.

3.1.5 Tracking and Documentation

The tracking and documentation associated with GSR during the investigation phase consists of identifying the GSR practices that were implemented. This should be reported in a section of the site investigation report. This section of the report should summarize the GSR approaches highlighting the environmental, community/stakeholder and economic benefits. Documentation of successful GSR approaches used during site investigation can then be carried forward into the remedy evaluation and selection phase of remediation as site-specific approaches that have been proven to be effective.

3.2 Remedy Evaluation and Selection



3.2.1 Description of Remedy Evaluation and Selection Phase

The remedy evaluation and selection phase of remediation is conducted to identify, screen, and select the most appropriate remedy to meet the site-specific remedial action objectives.

From a GSR perspective, the remedy evaluation and selection phase is an ideal point during the site remediation process to identify site remediation approaches and technologies with incrementally lower environmental impacts which attain the remedial action objectives and are aligned with community/stakeholder and economic development interests. This phase typically offers the greatest opportunity to capture the benefits associated with GSR approaches and influence the scope of the remedy design and remedy construction phases. The following are typical components of this phase and incorporate specific GSR options throughout the phase:

- *Baseline stakeholder engagement*—Conduct early in the remedy evaluation and selection phase to capture key points from the community and other interested stakeholders regarding site reuse preferences and constraints during the remedy construction phase (e.g., truck traffic, scheduling, etc.).

- *Identification of remedial action objectives*—Quantitative and nonquantitative objectives governing the site remediation which should include GSR considerations.
- *Identification of areas and volumes of impacted media to be remediated/managed*—The amount, volume, or area of soil, groundwater, and other media to be addressed in the site remediation. These quantities may be reduced by integrating GSR approaches.
- *Screening and selection of technologies to address each impacted media*—An evaluation of potentially applicable technologies. A simple or advanced evaluation of GSR approaches can be done at this point, and technologies which provide the greatest benefit can be identified.
- *Identification of technology-specific information*—Identifies specific technical information applicable to each technology (e.g., excavator size). This information is important input to an advanced (Level 3) GSR evaluation because it is needed to evaluate metrics, including energy use, GHG emissions, water use, and other important factors.
- *Development of site-wide remedial alternatives*—This task involves bringing together the technologies selected for each impacted media into site-wide alternatives. It could involve the use of one technology for soil and another for groundwater, etc. (e.g., excavation of soils and monitoring of groundwater). A simple or advanced evaluation of the alternatives can be done at this point to quantify the GSR benefits associated with each of the alternatives. A thorough evaluation should be conducted to address the site in a holistic manner to maximize potential reductions and benefits to the environment, including the social and economic aspects of the site remediation.
- *Post-remedy evaluation and selection stakeholder engagement*—Conducted after the site-wide remedial alternatives step to enable the community and other interested stakeholders to provide input on the alternatives.
- *Evaluation and selection of the optimal remedial alternative*—The preferred alternative which meets the remedial action objectives and provides optimal GSR performance is selected. The GSR metrics should be used to support this evaluation.

The extent to which the above components are addressed during this phase varies considerably based on the specific regulatory program driving the remediation project. For example, for a UST site regulated by a state petroleum-release program, many of these components may be streamlined, whereas for a CERCLA site, these components need to be specifically completed and documented. A further example of how the level of effort varies based on the regulatory program is the stakeholder engagement effort. On larger sites and where required by the specific regulatory program, this could involve meetings and presentations followed by open discussions; on smaller sites it could entail public notices being sent to nearby landowners and community officials, publishing notices in local newspapers, or site-specific signage. In all cases, the components listed above form the basis for the selection of the optimal approach.

3.2.2 Remedy Evaluation and Selection Phase GSR Options

There are a number of GSR options applicable to the remedy evaluation and selection phase. These involve the selection of lower-impact technologies and remedies and the use of BMPs and approaches that address the concerns and needs of the community and other stakeholders. These GSR options should be considered when remedial technologies are being screened and selected and during the evaluation of the remedial alternatives. While each remediation project must meet the established remedial action objectives, the appropriate application of GSR approaches should optimally result in the selection of technologies that have lower environmental impacts than conventional approaches, satisfy community concerns, and do not hinder economic development.

GSR options are considered generally at the following two levels during the remedy evaluation and selection phase:

- *Level 1 BMPs*—BMPs are used to optimize and improve the performance of a particular remedy or remedial approach to lower its impacts and achieve the project goals.
- *Level 2 or 3 simple and advanced evaluations*—Simple or advanced evaluations during the technology/remedy evaluation should lead to the selection of lower-impact remedies that attain community, stakeholder, and economical goals for the project and attain the remedial goals/remedial action objectives.

Table 3-4 provides examples of GSR approaches and BMPs specific to the remedy evaluation and selection phase. These GSR approaches and BMPs are organized identifying those that apply to the environmental, social, and economic aspects of a project.

Table 3-4. Remedy evaluation and selection—example GSR approaches and BMPs

Environmental	Social	Economic
• Evaluate on-site and in situ treatment and containment technologies to determine whether they provide lower impacts • Conduct energy use and GHG and air pollutant emissions calculations to compare performance of technologies • Identify opportunities to create habitat • Consider emerging technologies and renewable energy and other options to lower environmental impacts • Identify recycle and reuse options for residuals created during remedy implementation • Conduct project meetings using web-conferencing where appropriate • Use electronic reporting	• Communicate site remediation options and risk reduction achieved to stakeholders and community • Obtain input on site remediation alternatives and stakeholder/ community concerns/needs	• Determine short-term and long-term cost of site remediation alternatives contrasting with environmental and community benefits • Evaluate options to provide green space and/or restore properties for reuse • Create community assets (e.g., parks, open space, habitat) and/or link to community economic development plans • Design remedy to adapt to future site use plan

3.2.3 GSR Evaluation

A GSR evaluation conducted during the remedy selection phase can be integral to the evaluation of remedial technologies and alternatives. The GSR evaluation during this phase involves establishing GSR-related objectives and metrics and then comparing the relative performance of each technology or alternative. A simple assessment of remedial alternatives can be conducted for a variety of metrics, an example of which is demonstrated in Table 3-5.

Table 3-5. Remedy evaluation and selection—example of a simple GSR evaluation

GSR criteria	Remedial alternative 1: Excavation and off-site thermal treatment	Remedial alternative 2: In situ stabilization
Metric: Minimize truck traffic in local neighborhood during remedial action	Truck traffic in neighborhood is needed to implement this alternative	Minimal truck traffic in neighborhood
Metric: Minimize GHG emissions	A factor of 3 higher GHG emissions than Alternative 2	1/3 of the greenhouse gas emissions compared with Alternative 1

3.2.4 GSR Implementation Approaches

GSR implementation during the remedy selection phase principally involves selecting the optimal low-impact remedy that is also acceptable to the community and other stakeholders and achieves the environmental goals for the project. The remedy selection document (e.g., feasibility study or comparable document) identifies the remedy that has been selected after considering the appropriate GSR objectives and metrics. Remedy selection has a significant impact on the overall footprint of remedial phases that follow. As such, the remedy selection document should describe the expected benefits resulting from the GSR evaluation in addition to the anticipated overall remedy performance. Documentation of the GSR analysis is important so that subsequent decisions during remedy design phase of the project account for the GSR findings and can be used to refine GSR assumptions and track GSR progress.

3.2.5 Tracking and Documentation

GSR considerations during the remedy evaluation and selection phase should be documented during the preparation of the remedy selection document (FS or comparable document for various regulatory programs) and then checked to ensure that the GSR options were properly considered and documented and incorporated into the recommended/selected remedial alternative. The remedy selection document should include a brief description of the GSR evaluations conducted including the GSR objectives and metrics, the GSR approaches selected, a description of why the remedy was selected, and any identified barriers or uncertainties to address during the remedy design phase.

3.3 Remedy Design

3.3.1 Description of Remedy Design Phase

The remedy design phase is conducted to develop drawings and specifications that define the construction or implementation of the selected remedy. Depending on the regulatory program and the complexity/ scale of the selected remedy, the remedy design phase may require varying degrees of effort. Regulatory programs such as RCRA and CERCLA have specific guidelines and requirements for the remedy design phase. However, regardless of the regulatory program and complexity/scale of the selected remedy, there are opportunities to incorporate GSR elements into the design. In cases where GSR has been considered during the remedy evaluation and selection phase and included in the selected remedial alternative, the remedy design should include those selected GSR design approaches and BMPs.

3.3.2 Remedy Design Phase GSR Options

GSR options applicable to the remedy design consist of the following:

- *Level 1 BMPs*—Table 3-6 provides a list of specific BMPs that can be incorporated into the remedy design.
- *Level 2 or 3 Simple and Advanced Evaluations*—Level 2 or 3 evaluations include any other activities performed to improve the environmental, social, and/or economic aspects of the remedy.

Table 3-6 provides examples of GSR approaches and BMPs to apply to the remedy design phase. These GSR approaches and BMPs are organized according to their environmental, social, and economic aspects of a project.

Table 3-6. Remedy design—example GSR approaches and BMPs

Environmental	Social	Economic
• Identify low-energy and low-emission and low-water-intensive technologies and equipment • Minimize impacts to local natural resources and habitats • Maximize use of renewable energy and fuels • Minimize off-site transport of contaminated materials • Identify recycling options for materials generated during site remediation • Use on-site treatment and containment approaches • Design remote monitoring/ telemetry and system optimization features into long treatment systems • Ensure CSM is still representative • Use value engineering and optimization techniques to maximize design effectiveness • Design O&M to minimize life-cycle waste generation	• Engage community leaders in design meetings to obtain input on configurations and timing of site work • Communicate with or notify stakeholders of site remediation plan, including short-term community impacts and long-term risk reduction • Obtain input on community concerns/ needs	• Use on-site approaches to management of contamination to reduce costs of site remediation and potential long-term liabilities associated with off-site disposal • Conduct treatability/pilot studies to prove technologies before full-scale design • Use adaptive site-reuse approaches incorporating existing buildings into site reuse options • Maximize beneficial reuse of the site • Design O&M systems to minimize life-cycle costs

3.3.3 GSR Evaluations

GSR evaluations conducted during the remedy design phase consist of comparing equipment and remedial methods and/or comparing the overall GSR performance of the remedy options. These evaluations can consist of an evaluation of different BMPs or a comparison of different overall remedial approaches to the site remediation. Some BMPs and design approaches may not require an evaluation if they improve the selected remedy, the associated costs are acceptable, are consistent with good engineering practice, and help address community or stakeholder concerns.

During the remedy design phase, design criteria are established for each technology as well as for the entire remedy (e.g., performance requirements). GSR evaluations can be conducted of the various equipment and methods/technology options so that the most effective design is selected which meets the design criteria. A qualitative or quantitative evaluation may be conducted. The GSR evaluation results should be compared to help select the option with the greatest potential benefits. Section 4 describes GSR evaluation tools that can be used during remedy design.

3.3.4 GSR Implementation Approaches

GSR implementation during the remedy design phase involves incorporation of GSR approaches and BMPs into the design. This includes the identification of equipment and methods and, where needed, descriptions in the specifications of project operating requirements. Examples of such operating requirements could include collection of storm water for dust control, recycling of wastes, use of biofuels, and the documentation of gallons of fuel used and miles driven by vehicles and equipment.

3.3.5 Tracking and Documentation

The implementation of GSR approaches and BMPs does not occur until construction of the selected remedy; however, GSR efforts during the remedy design phase should be documented to ensure all relevant information is properly and clearly communicated in the drawings and specifications. The GSR approaches in the final design should be integrated directly into the design reviews and the final design documents, including specifications and drawings. Constraints and barriers of GSR implementation should be also identified in these documents.

3.4 Remedy Construction

3.4.1 Description of Remedy Construction Phase

The remedy construction phase consists of the implementation of the remedy as illustrated in the design drawings and specifications. Construction often includes installation of wells and subsurface treatment systems, excavation and other earth-moving activities, building of infrastructure to house treatment equipment, and a variety of other actions. In cases where GSR is an integral part of the remedy design, the application of GSR elements consists of the implementation of the remedy design, including all specified GSR approaches and BMPs. In other cases, where GSR is first being considered at the remedy construction phase, BMPs and operating practices should be identified to minimize the impacts associated with the selected remedy. As stated in Section 3.2.1, considering GSR approaches during the remedy evaluation and selection phase is the best approach to ensure that GSR is embedded in the project and becomes an integral part of the remedy construction phase.

Depending on the remedy, unintended environmental impacts can occur during the construction phase. Construction can involve mobilizing large, energy-intensive equipment to a site. Fuel consumption and air emissions as well as other impacts such as noise and dust may result from the remedy construction. The noise can be disruptive to the community. Because of the movement of the equipment and their moving parts, site workers are also at risk for injury and must be vigilant about safe work practices. During this phase of remediation, many materials are brought to the site for use in installations, and there is the possibility of it being wasted rather than used or recycled. Excavation activities can produce large quantities of waste soils and solids. Further, a local community's businesses can be disrupted and negatively impacted during construction if increased traffic impedes access to businesses. Thoughtful planning can help minimize many of the negative impacts that construction activities can cause.

3.4.2 Remedy Construction Phase GSR Options

GSR approaches employed during the remedy construction phase consist of those contained in the remedy design and BMPs selected after the preparation of the remedy design to minimize impacts of a particular construction activity. A simple or advanced evaluation of various construction sequencing options and/or equipment may also be completed. Table 3-7 provides examples of specific BMPs that can be incorporated in the remedy construction.

Table 3-7. Remedy construction—example GSR approaches and BMPs

Environmental	Social	Economic
• Minimize equipment engine idling • Control and mitigate dust, odors, noise, and light impacts • Conduct monitoring of air and, if needed, odors, noise, and light • Set up comprehensive on-site recycling program for all wastes and residuals • Select construction equipment and energy sources to minimize fuel/energy use and emissions	• Implement community notifications and/or conduct community meetings to inform of project progress • Post information on monitoring programs and project progress/ plans • Maximize use of local businesses for goods and services • Sequence construction activities to minimize noise and traffic impacts to the local community	• Consider benefits to the community in terms of economic benefits, not just cost savings • Maximize use of local businesses for goods and services

3.4.3 GSR Evaluations

GSR evaluations conducted during the remedy construction phase vary based on the extent to which GSR was considered and included in the remedy design. A tool or set of tools is typically needed to complete an advanced (quantitative) assessment of GSR metrics, as described in Section 4 of this document.

The following identify two situations that govern whether or not a GSR evaluation is conducted during the remedy construction phase:

- *GSR included in remedy design*—If GSR is an integral part of the remedy design, then during remedy construction it is likely that no specific GSR evaluations will be performed. The emphasis in this case will be to ensure that the GSR components of the design are properly implemented. The GSR components of the remedy will be included in the drawings and specifications and associated work plans.

- *GSR not included in remedy design*—If GSR is not included in the design, then efforts should be made to identify and/or quantify impacts avoided through the use of one or more BMPs and/or construction considerations. This GSR evaluation would involve evaluating the design to determine where BMPs can be applied and by evaluating options to lower the impact of the remedy construction. Comparisons can be made of the relative performance of certain elements of the remedy construction. For example, a GSR evaluation may be conducted to quantify the impact of using different construction equipment and/or sequencing options.

Table 3-8 provides an example of a GSR evaluation conducted to assess alternative remedy construction options. Two construction options were identified for an excavation activity: Option 1 required all equipment operators shut down the equipment if at idle for a period greater than 5 minutes; Option 2 allowed equipment to run during the entire work day. The GSR metrics used in this analysis consist of minimizing noise impacts to the local community, minimizing cost, and minimizing the use of fuel. For this example it was assumed that the equipment would run an average of 7½ hours each day under Option 1 and 8 hours each day under Option 2. The GSR evaluation indicates that Option 1 is preferable.

Table 3-8. Remedy construction—example GSR evaluation of alternative approaches

GSR metrics	Option 1: Idle reduction	Option 2: No idle reduction
Metric A: Minimize noise impacts to local community	Noise impacts to the community are assumed to occur from the use of equipment on site and, therefore, are less under Option 1	Noise impacts to the community are assumed to occur from the use of equipment on site and, therefore, are greater under Option 2
Metric B: Cost	Cost impacts are associated with fuel consumption during equipment use and, therefore, are less under Option 1	Cost impacts are associated with fuel consumption during equipment use and, therefore, are greater under Option 2
Metric C: Minimize energy (fuel) use	Energy impacts are associated with fuel consumption during equipment use and, therefore, are less under Option 1	Energy impacts are associated with fuel consumption during equipment use and, therefore, are greater under Option 2

3.4.4 GSR Implementation Approaches

GSR implementation during the remedy construction phase involves putting the selected GSR approaches and BMPs into practice. It is important that the construction personnel understand the specific GSR elements contained in the design. Although the GSR approaches and BMPs may be identified in the design documents, there may be a need for the contractor to prepare certain plans such as construction operations or sequencing plans. In these cases, these documents and field work plans should clearly identify the GSR elements of the project so it is clear the contractors performing the construction work fully understand the scope of work. The contractor plans should be carefully reviewed to be sure they include the GSR elements of the design.

3.4.5 Tracking and Documentation

Documenting the GSR approaches implemented during the remedy construction phase consists of reporting the GSR practices that have been implemented and the associated GSR benefits. Documentation of GSR approaches could be described in a section of a remedy completion report or another comparable document prepared for the project.

If it is desirable or required to understand the actual impacts or performance of a remedy, a series of measurements will need to be collected during remedy construction according to the GSR metrics that were previously established. The collection of actual data during remedy implementation can inform how closely the remedy performed relative to the design and document performance for reporting to stakeholders. The types of data that could be collected include the following:

- electricity use
- fuel used by on-site equipment
- miles traveled by trucks moving materials onto the site and off site
- miles traveled by field crews to and from the site
- water usage
- quantities of materials recycled
- quantities of materials reused

After implementation, these data can be analyzed using a GSR tool to determine the actual remedy performance and compared to the performance expectations established during the remedy design phase.

The construction completion report should include a section that identifies the BMPs implemented and their advantages, and it should highlight environmental, community/ stakeholder, and economic benefits. If a determination is made of the actual performance of the remedy, as discussed above, the results of this evaluation should also be included in the construction completion report.

3.5 Operation, Maintenance, and Monitoring

3.5.1 Description of Operation, Maintenance, and Monitoring Phase

The operation, maintenance, and monitoring phase includes the actions required to maintain treatment systems and monitor the performance of these systems. All remedial operations, including LTM, have sustainability impacts. Since remedial systems may be operated over long periods of time, their impacts can be cumulatively important. Large, energy-intensive systems such as pump and treat, multiphase extraction, and other in situ treatment systems can operate for years, creating a high percentage of the system's overall life-cycle footprint. At some sites, energy-intensive systems can be replaced with greener, lower-energy alternatives. Where extraction systems are required for plume containment and for the protection of other groundwater or surface-water resources, these systems should be routinely optimized to reduce energy use, material use, and waste generation. The surrounding community can provide valuable input on impacts they have experienced as a result of the remedial system operations. During this phase, they may have the opportunity to suggest adjustments to the system or process of operating and monitoring which could lessen the external impacts.

3.5.2 GSR Operation, Maintenance, and Monitoring Phase Options

GSR options during the operation, maintenance, and monitoring phase may include the use of BMPs and/or the replacement or optimization of existing systems to identify approaches that reduce energy use, material use, waste generation as well as address other issues or impacts (e.g., noise). Table 3-9 shows examples of BMPs for operation, maintenance, and monitoring. The implementation of GSR during the operations, monitoring, and maintenance phase can also be conducted as part of the remedy optimization phase, as discussed in Section 3.6.

Table 3-9. Operation, maintenance, and monitoring—example GSR approaches and BMPs

Environmental	Social	Economic
• Use telemetry to remotely collect operational data and reduce field mobilizations • Recycle sampling residuals (green chemistry principles) • Identify waste minimization measures • Use EPA's five core elements in remedy decision • Minimize/eliminate idling • Use fuel-efficient vehicles • Use lowest horsepower equipment to complete tasks • Use local/closest disposal facility	• Conduct stakeholder engagement via website and other public communication approaches, including mailings/other notifications • Maximize use of local businesses for goods and services • Evaluate stakeholder acceptance/community satisfaction with remedy	• Use low-energy-intensive approaches to reduce energy costs • Use on-site sample testing/screening approaches to reduce shipping/laboratory analytical costs • File electronic reports to reduce shipping costs

3.5.3 GSR Evaluations

During the operation, maintenance, and monitoring phase, a GSR evaluation might involve an evaluation of routine site practices to identify different approaches to meet GSR objectives and metrics. At a minimum, a GSR evaluation would identify impacts avoided through the use of one or more BMPs. A more detailed evaluation of different operating, maintenance, or monitoring technologies, procedures, or practices could also be conducted. For example, a site may have identified two different options for conducting LTM: continuing to conduct traditional monitoring or implementing passive diffusion bag samplers. A GSR evaluation might qualitatively or quantitatively evaluate the impact on GSR objectives and metrics (i.e., waste material generated, water usage, fuel use associated with trips to and from the site to conduct monitoring activities).

3.5.4 GSR Implementation Approaches

GSR implementation during operation, maintenance, and monitoring involves putting any identified BMPs into practice (e.g., changing equipment and operating procedures to complete tasks more efficiently and reduce the footprint of the remedy to achieve the GSR objectives) and following all the project procedures specified in the O&M manuals and contractual documents so the GSR benefits are realized during the project.

3.5.5 Tracking and Documentation

GSR monitoring and documentation during the operation, maintenance, and monitoring phase include, at a minimum, identification of the GSR approaches and associated benefits. This may involve collecting information or data on metrics such as energy and fuel use, waste generation, water use, and other identified GSR metrics. The metrics tracked and documented should be aligned with GSR metrics established in the GSR evaluation.

If it is desirable or required to understand the actual impacts or performance of a remedy, a series of measurements need to be collected during the operation, maintenance, and monitoring phase. The collection of actual data can inform how closely the remedy performed relative to the design and document performance for reporting to stakeholders.

3.6 Remedy Optimization

3.6.1 Description of Remedy Optimization Phase

Remedy optimization involves the evaluation of existing remediation systems to improve the performance, reduce the annual operating cost or environmental footprint, or other factors associated with the remediation system while ensuring that it is still protective of human health and the environment. A GSR evaluation during remedy optimization can be used to optimize existing remedies and identify opportunities to create sustainable remedies.

Remedy optimization may be conducted periodically (annually, biennially, or as part of a five-year review) or on an as-needed basis to ensure that the remediation system is running efficiently and is also being effective in removing contaminants to meet remedial action goals. During detailed remedy optimizations, nearly every aspect/component of the remediation system—equipment, personnel, energy, resources, monitoring, sampling and analysis of data—is reviewed to ensure optimal and appropriate use for current site conditions. Details of remedy optimization can be found in the ITRC RPO technology and regulatory guidance document (ITRC 2004). The principles of RPO can also be beneficial during other phases, including site investigation, remedy implementation, or LTM.

3.6.2 Description of Remedy Optimization GSR Options

The application of GSR elements in the remedy optimization phase focuses on minimizing the impacts associated with the current and future ongoing remedial actions needed to achieve project closeout. Considering GSR approaches early in the remediation process (e.g., site investigation, remedy evaluation and selection) is the best approach to reduce GSR impacts. However, at many existing systems, optimization provides an opportunity to include/add GSR options to existing systems. Optimization also provides a unique chance to replace existing systems with greener or more sustainable systems in specific cases where a system replacement is warranted.

A remedy optimization presents an excellent opportunity to evaluate and improve the sustainability of a given remedy. During the remedy selection phase of a project, several remedies are often evaluated to identify the optimal remedy from the standpoint of protectiveness, cost, time, and stakeholder acceptance. Conducting a GSR analysis during the remedy optimization phase has the added benefit of available site- and remedy-specific operations data. Some assumptions may still be required as part of the GSR analysis; however, a GSR analysis conducted using the remedy operational data is more accurate than one conducted during the remedy evaluation and selection phase.

Table 3-10 provides examples of specific GSR approaches and BMPs that can be incorporated into remedy optimization.

Table 3-10. Remedy optimization—example GSR approaches and BMPs

Environmental	Social	Economic
• Maximize efficiency and optimize existing systems to reduce carbon footprint, energy, and overall environmental impact of resource consumption • Identify alternative methods or technologies that are equally protective but use less energy and resources	• Notify stakeholders about remedial program efficiency in measurable terms (i.e., mass removed per dollar) • Communicate with stakeholders regarding optimization of remediation systems and reduced impacts on energy use and GHG production to achieve a net positive environmental impact	• Maximize efficiency of systems to reduce energy, maintenance costs, and overall operational time frame • Optimization reduces treatment costs and allows funding to be used for promoting green and sustainable solutions such as alternative energy conversions

3.6.3 GSR Evaluations

Remedy optimization efforts involve identifying options to improve the efficiency of treatment and monitoring systems. Because the process is based on identifying efficiencies, it is uniquely linked to implementing GSR approaches. A remedy optimization effort can lead to the implementation of GSR approaches. For example, one activity that is commonly conducted during remedy optimizations is an energy audit. All systems can benefit from an energy audit. For a small system, the audit may be as simple as checking the energy use trend of pumps or blowers to identify any inefficient equipment or operations. For a large pump-and-treat system this could include a full-scale audit completed by an energy expert. A systematic energy audit helps to identify the best targets for optimization of a system and the reduction of energy use. The results of an energy audit can be used to support the identification of GSR approaches that reduce the impact of the remedy operations.

3.6.4 GSR Implementation Approaches

Remedy optimization may lead to a decision to transition to a new remedial technology or continue with the same technology. As the size, shape, and concentration of a plume changes over time, the treatment system should be reconfigured to match current site conditions. For example, reduction in the horsepower of pumps and blowers is the most commonly applied method of treatment process optimization. For larger systems, the use of variable-frequency drive motors allows the system engineer to gradually increase or decrease flow rates to match site conditions in an energy-efficient manner. Additionally, in some cases, there may be opportunities to decrease the number of wells needed for plume containment and/or monitoring.

Remedy Optimization Leading to Reduced Energy Use

Influent volatile organic compound concentrations to an air stripper dropped from 200 ppb to 50 ppb after the first five years of operation. A 20 hp blower was found to no longer be needed to supply air to the air stripper; the unit could be downsized to 10 hp. The smaller motor saves 1.7 million kwh of electricity over 20 years and reduces life-cycle GHG emissions by approximately 1200 tons (based on 1.34 lbs of CO_2 per kwh delivered).

As recovered contaminant concentrations decrease over time, there may be an opportunity to reduce energy, material, and labor resources through a change in aboveground treatment processes. Another example of this is the change from thermal oxidation to vapor-phase activated carbon as soil gas concentrations are reduced in a soil vapor extraction system. GSR metrics such as energy use, costs, and waste generation can be compared to support such an analysis of options.

EPA's green remediation primer (EPA 2008) provides a discussion of how energy-intensive remedies such as pump and treat can be transitioned to more natural, low-energy treatment processes such as enhanced bioremediation, permeable reactive barrier walls, phytoremediation, engineered wetlands, and MNA. These transitions must be preceded by treatability testing and alternative remedy designs and often require a change to the existing decision documents. Based on the EPA primer, adequate source removal is also a prerequisite for transitioning to natural treatment processes at many sites. These transitions require planning, time, and money to complete, but the long-term reductions in energy use and collateral environmental impacts can be significant.

Before the transition to low-energy, natural processes, the contribution of natural processes to contaminant removal must be understood and limitations defined. EPA protocols and guidance are available for evaluating natural processes such as MNA. One of the key metrics for comparison to engineered remedies is the rate of contaminant removal that can be attributed to natural biodegradation. These estimates may be particularly useful for petroleum spills, where natural biodegradation and weathering processes can outperform engineered methods of remediation.

3.6.5 Tracking and Documentation

The tracking and documentation associated with the remedy optimization phase is based on the evaluation of existing and real-time data similar to the approach conducted during the operation, maintenance and monitoring phase. At a minimum, it includes documentation of GSR practices and benefits gained as a result of the remedy optimization. If the GSR evaluation includes detailed qualitative or quantitative analyses, then selected GSR metrics should be monitored and tracked and include at a minimum, energy and fuel usage relative to baseline, water conservation, GHG emission reduction relative to baseline, and changes in land value. Values that are monitored and tracked should be aligned with GSR metrics established in the GSR evaluation.

3.7 Project Closeout

3.7.1 Description of Project Closeout Phase

The project closeout phase involves the implementation of a set of planned actions to terminate site remediation activities, including the operation of treatment systems, when the remedial action objectives have been attained. Project closeout is the orderly transition from the remedial operations and maintenance phase to site closure. During project closeout any remaining environmental hazards are properly contained such that they remain inaccessible, isolated, and/or protected. Project closeout can lead to the implementation of the beneficial reuse of a site, if redevelopment or reuse activities have not previously been implemented. Project closeout requires that site conditions be accurately and comprehensively documented, property record and institutional controls be in place and clearly defined, and stakeholder inputs be reconciled. At the time of project closeout, any engineering or institutional controls that are part of the site remedy should be in place.

3.7.2 Project Closeout GSR Options

GSR approaches and BMPs can be implemented during the project closeout phase to lower the impact of final actions (e.g., engineering controls) and support reuse of the site. Many of the GSR activities during project closeout depend on the regulatory requirements for physical controls; sampling procedures and frequency; and systems including treatment, telemetry, and information management systems. Table 3-11 provides examples of GSR approaches and specific BMPs that can be incorporated into project closeout phase.

Table 3-11. Closeout—example GSR approaches and BMPs

Environmental	Social	Economic
• Ensure protectiveness of remedy through adaptive management • Ensure proper disposition and distribution of vital project information • Use telemetry to collect and transmit site monitoring data to reduce personnel-related impacts • Archive site information using electronic records • Recycle sampling residuals to reduce waste generation • Optimize waste minimization measures as a part of periodic reviews • Ensure that environmental receptors do not change over time • Recycle materials and equipment that are removed from the site	• Maintain ongoing stakeholder dialogue and inputs • Confirm land use and any institutional controls are in place • Periodically reevaluate societal needs for information and access to the site • Document community "lessons-learned" about the events leading to the site contamination and remediation • Review records and information management procedures to ensure content and availability • Ensure appropriate physical and institutional controls are functioning properly during periodic reviews • Maximize use of local businesses and employees to provide goods and services	• Identify potential future site reuse options • Evaluate conformance of land use with institutional controls • Employ local staff for post-closure site checks (e.g., site security monitoring, engineered controls checks, etc.) • File electronic reports to reduce shipping costs • Use on-site sample testing/ screening approaches to reduce waste generation costs • Use low-energy-intensive approaches to reduce energy costs associated with site controls • Identify reuse options for materials and equipment removed from the site

3.7.3 GSR Evaluations

GSR evaluations during the project closeout phase could include researching reuse and recycling options available for the materials and equipment removed from the site and implementing those viable. The evaluations should quantify the benefits by measuring the number, type, and if applicable, weight of the reused or recycled materials and equipment to support GSR reporting.

3.7.4 GSR Implementation Approaches

GSR implementation during the project closeout phase involves putting the recommendations from the GSR evaluation into practice during site closeout activities to reduce the footprint of site closeout and achieve GSR objectives. As with the construction phase of work, the GSR aspects of project closeout need to be incorporated into procurement documents and field work plans so that contractors performing the site closeout activities fully understand the GSR practices to be implemented.

3.7.5 Tracking and Documentation

As with the other phases of remediation, tracking and documenting project closeout activities should be aligned with the GSR metrics established for the project. For example, if GHG emissions is a metric that is evaluated during the remedy design, construction, and O&M phases, then data should be collected to enable reporting of that metric during the site closeout phase. Other examples of GSR metrics that may be important to track and document during this phase include the number, type, and if applicable, weight of any reused or recycled materials and equipment. Further, the locations where such materials were recycled and reused should be made a part of the site record. A sustainable component of the closeout phase may include working with neighborhood members to establish a restored native ecological setting to the site, where possible. Additionally, posting information on the success of remediation of the site may serve as a community reminder of the site's restoration and a learning opportunity for future generations to make local the impact of environmental stewardship.

4. GSR TOOLS

This section describes a range of simple and advanced tools that can be used to conduct a GSR evaluation. Best practices for any type of GSR evaluation are also described in this section, including the need for complete transparency throughout the GSR process and the need to evaluate the sensitivity of results.

4.1 Introduction to GSR Tools

As described in Section 2.4, the ITRC GSR Team has identified three GSR evaluation levels. Level 1 consists of selecting and implementing BMPs. The benefits associated with implementing BMPs may or may not be quantified. Levels 2 and 3 consist of implementing BMPs *and* conducting a simple or advanced GSR evaluation, respectively. There is a wide range of tools available for remediation professionals to use to conduct a GSR evaluation. Some tools have been developed exclusively for GSR while others have been developed for use in other industries and were repurposed to evaluate one or more aspects of GSR. Tools may be available publicly and at no cost, may require a license or per use fee, or may be proprietary and restricted to use within some private entity. Simple and advanced tools may combine aspects of qualitative, semiquantitative, and quantitative evaluations; however, advanced tools tend to be more quantitative in general. Key considerations for selecting the appropriate tool include the following:

- *Regulatory cleanup program*. Some cleanup programs have developed or endorsed specific tools for evaluating GSR. Other programs or program managers may be familiar with a particular tool.

- *Size of the remediation project.* Small sites are more likely to incorporate BMPs or simple GSR evaluations (Level 2) than are larger, more complex sites.

- *Site remediation phase.* Some GSR evaluations are conducted to estimate the impact of an existing remediation system or quantify the reduction or savings in GSR impacts associated with remedy improvements. For some sites, the GSR evaluation may be conducted to compare the impacts of various remedial alternatives at the remedial design phase. Tools may be needed to conduct a GSR evaluation in several phases of the remediation; thus, the selected tool must accommodate this need.

- *Selected GSR metrics*. Before selecting a tool, the site-specific metrics for evaluating GSR should be identified. Tables of environmental, social, and economic metrics that can be evaluated using each tool are provided in the following sections. In some cases, multiple tools or methods may be needed to evaluate all the selected GSR metrics. Simple metric evaluations may not require any tools.

- *Available technologies.* Some tools have technology-specific modules. The user enters information about the technology design parameters and materials to be used. The tool then calculates GSR impacts associated with that technology. Other tools may prompt the user for more general inputs and require the user to identify each technology component but provide flexibility for modeling GSR impacts associated with innovative or unusual technologies.

The appropriate tool or tools will ideally be selected by the project team with concurrence or approval from site regulators and other stakeholders in the GSR process. More information about GSR tools, including resources to help incorporate green power and other BMPs, can be found on EPA's website (EPA 2011a), in ITRC's GSR overview document (ITRC 2011a), and in Section 5 of the EPA green remediation primer (EPA 2008). Tools range from simple decision diagrams and Excel spreadsheets to more advanced and typically quantitative spreadsheets and software for evaluating the footprint or the life-cycle impact of a remedial activity.

4.2 Tools to Facilitate the Use of BMPs (Levels 1, 2, and 3)

Incorporating BMPs is one of easiest and most cost-effective ways to achieve GSR goals. As discussed in Section 2.4, however, the use of BMPs does not typically involve an evaluation of the tradeoffs associated with their implementation. For example, a BMP that reduces waste may require more energy. Resources that identify GSR BMPs include EPA's green remediation primer, greener cleanups website, CLU-IN website, and fact sheets (EPA 2011a); the U.S. SURF framework document (Holland et al. 2011); SuRF-UK framework (SuRF-UK 2009), and the ASTM standard guides. EPA regions and states have also developed lists of BMPs. Two examples of tools for selecting BMPs are described below.

The Illinois EPA developed the Greener Cleanups Matrix to identify ways to improve environmental remediation benefits. The matrix lists actions that can be taken during different phases of site remediation and the potential impacts on air, water, land, and energy. The matrix highlights the beneficial impact of BMPs on multiple metrics but does not capture tradeoffs associated with any BMPs. Figure 4-1 provides a snapshot of the matrix. The Illinois EPA website (Illinois EPA 2008) provides more information.

Another example of a simple tool for evaluating GSR is the toolkit for greener practices developed by the Minnesota Pollution Control Agency (MPCA 2010), which includes a decision tree and checklist of GSR factors to consider during remedy selection. Options to consider during remedy selection include the following:

- in situ treatment
- innovative and more efficient remedies
- constructed wetland treatment
- natural habitat restoration, enhancement or replacement—green space development
- deconstruction
- recyclable or recovered environmental material

For each of these six topics, MPCA provides a description of the goal, site circumstances where this practice would be favorable, case studies where the approach has been adopted, and a list of regulatory guidelines and resources for more information. The toolkit provides a similar set of factors to consider for operating businesses and at brownfield sites where redevelopment or renovation is planned. Figure 4-2 shows an excerpt from the toolkit. More information is provided on MPCA's website.

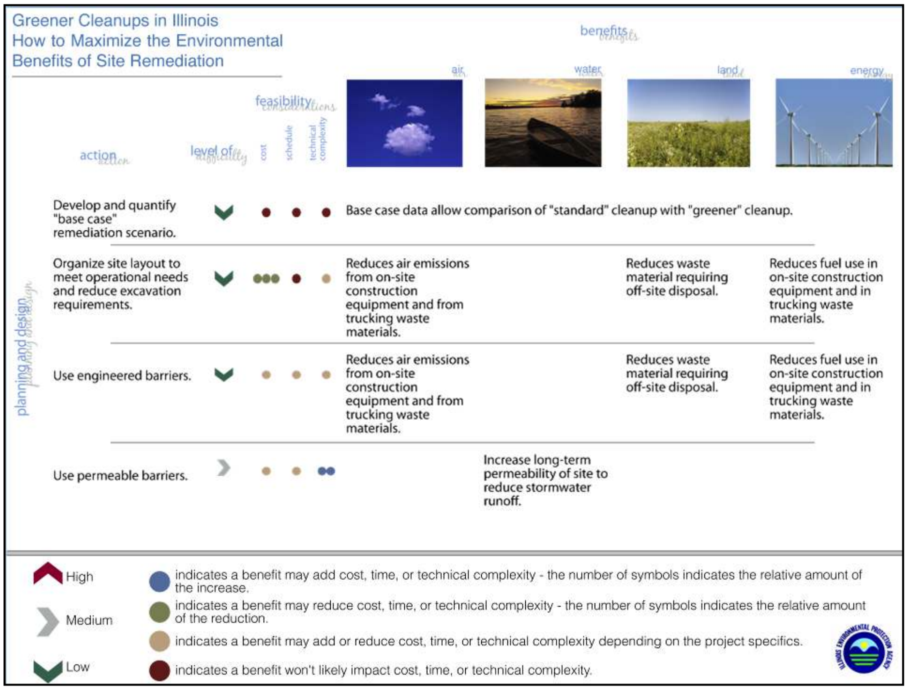


Figure 4-1. Snapshot of the Greener Cleanups Matrix.

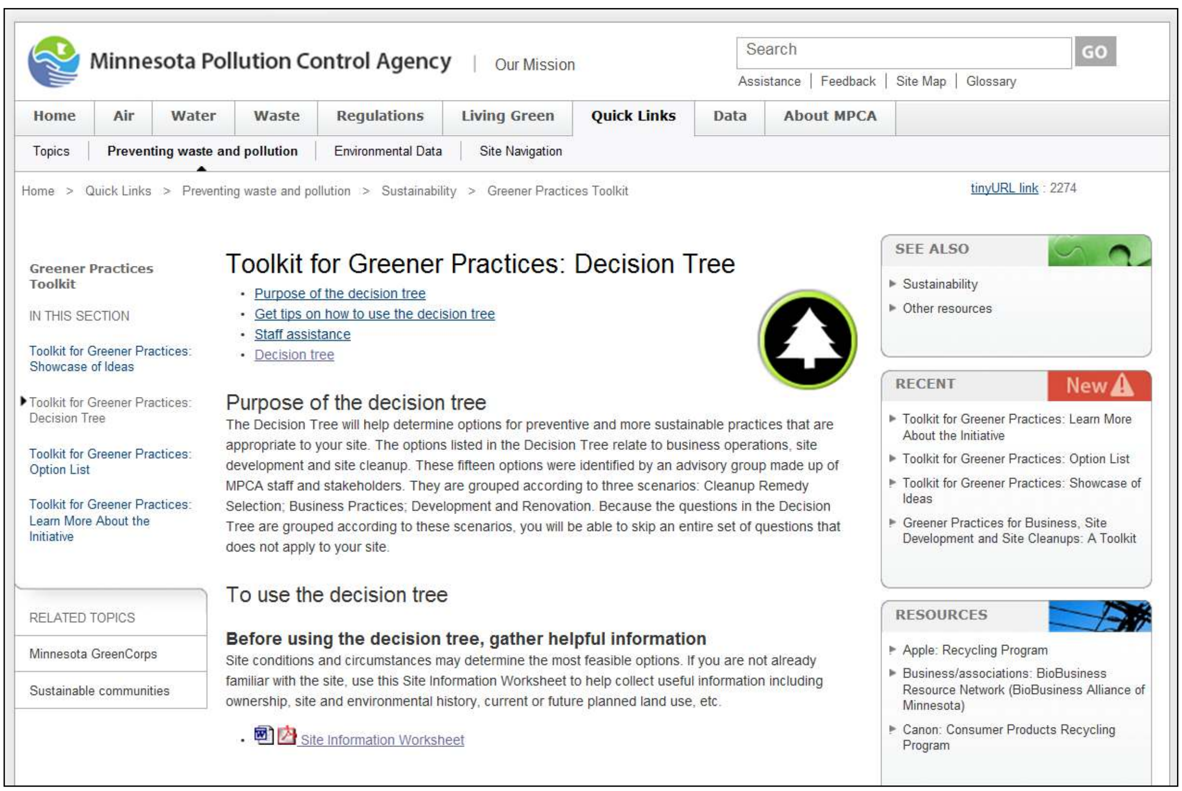


Figure 4-2. MPCA Toolkit for Greener Practices.

4.3 Tools for Simple GSR Evaluations (Level 2)

Simple GSR evaluations include matrices and decision trees to help evaluate multiple metrics and determine the greenest or most sustainable alternative. These tools can be immediately used by stakeholders with a broad background in environmental remediation. No specific training for these tools is necessary. Most of the tools are qualitative in nature. Some tools may have quantitative aspects (e.g., scoring, ranking, calculating a weighted average) but do not require an understanding of calculus or more advanced mathematical functions. Simple tools can be used to compare GSR impacts of several different remedial technologies during a screening or FS stage of remediation. Simple tools can also be used to compare GSR impacts of different conceptual designs of a chosen remedial technology. Finally, simple tools can also be useful during remedy optimization when comparing baseline impacts of an existing technology or process to the impacts of technology or process improvements. The state of California has developed a simple GSR assessment tool that is publicly available online. A brief description of the tool follows.

The Green Remediation Evaluation Matrix (GREM) is a matrix tool developed by the California Department of Toxic Substances (DTSC). GREM can be used to compare treatment alternatives in terms of their impact on energy, materials, air quality emissions, water, waste, and land use/ value. These are referred to as "environmental stressors." The tool is designed to account for all relevant environmental, economic, and social impacts of remediation. GREM consists of a spreadsheet (Figure 4-3) that lists each stressor, the affected media, and the mechanism/effect. Users can add other stressors or adverse impacts of the project to the list. For each stressor, the user is asked whether the remedial alternative will have an impact (yes or no), and if yes, to assign a qualitative or quantitative score (e.g., high/medium/low; 1–3) to those impacts. Scores are then compiled into a summary table and used to rank the remedial alternatives. As noted by California DTSC, this process is subjective. It is therefore critical to obtain stakeholder input during this process (California DTSC 2009). More detail on scoring and weighting methods is provided in Section 4.4. More information on GREM is available online in the DTSC Guidance document (California DTSC 2009). An online link to begin using the tool is available on the California DTSC website (California DTSC 2007).

4.4 Tools for Advanced GSR Evaluations (Level 3)

Advanced tools for GSR evaluations use more quantitative and rigorous methods of assessing environmental, social, and economic impacts of remediation. In contrast to Level 2 tools, some training is likely to be required before using one of these tools to conduct an analysis. Data inputs to these tools are more extensive and require the user to gather site-specific details and estimates. Level 3 tools can be used to evaluate GSR impacts of different technologies, processes, or implementation methods at any stage of site cleanup. Most Level 3 tools have been developed by universities, EPA, other federal agencies, or private industry. Some tools are publicly and freely available to the public; others require the user to purchase software. Several types of advanced tools are described in the following subsections, including carbon footprint tools, remedy footprint tools, net environmental benefit analyses (NEBAs), and LCA tools.

Green Remediation Evaluation Matrix (GREM)*				
Stressors	**Affected Media**	**Mechanism/Effect**	**Y/N****	**Score**
Substance Release/Production				
Airborne NO_x and SO_x	Air	Acid rain and photochemical smog		
Chlorofluorocarbon vapors	Air	Ozone depletion		
Greenhouse gas emissions	Air	Atmospheric warming		
Airborne particulates/toxic vapors/ gases/water vapor	Air	General air pollution/ toxic air/humidity increase		
Liquid waste production	Water	Water toxicity/sediment		
Solid waste production	Land	Land use/toxicity		
Thermal Releases				
Warm water	Water	Habitat warming		
Warm vapor	Air	Atmospheric humidity		
Physical Disturbances/Disruptions				
Soil structure disruption	Land	Habitat destruction/soil infertility		
Noise/odor/vibration/aesthetics	General environment	Nuisance and safety		
Traffic	Land, general environment	Nuisance and safety		
Land stagnation	Land, general environment	Remediation time, cleanup efficiency, redevelopment		
Resource Depletion/Gain (Recycling)				
Petroleum (energy)	Subsurface	Consumption		
Mineral	Subsurface	Consumption		
Construction materials (soil/concrete/ plastic)	Land	Consumption/reuse		
Land and space	Land	Impoundment/reuse		
Surface water and groundwater	Water, land (subsidence)	Impoundment/ sequester/reuse		
Biology resources (plants/trees/ animals/microorganisms)	Air, water, land/forest, subsurface	Species disappearance/ diversity reduction/ regenerative ability reduction		

* Use for evaluating one technology or remedial alternative as a checklist. Expand for alternative comparison by adding additional score columns for each alternative.

** State whether the impact applies or does not apply to the alternative and continue the evaluation.

Figure 4-3. Example of the California DTSC GREM Tool. *Source*: California DTSC 2009.

4.4.1 Carbon Footprint Tools

These tools are used to calculate the reduction in GHG emissions associated with some decision or change in activity. EPA has developed or cosponsored the development of several tools to determine the GHG impact of purchasing, manufacturing, and waste management actions. GHG quantification and reporting are typically voluntary for most environmental remediation projects. GHG reporting is mandatory for facilities that emit more than 25,000 metric tons of GHGs per year (EPA 2009b). General industry tools may be useful for a subset of environmental remediation projects. Tools that have been developed for environmental remediation activities typically include a way to assess GHG emissions, as described in Section 4.3.2.

Waste Reduction Model (WARM, EPA 2010b) calculates GHG emissions associated with various waste management practices, including source reduction, recycling, composting, combustion, and landfilling. The tool is useful for a wide range of municipal solid waste materials. Emission factors published by EPA are used to derive energy and CO_2 equivalents for different materials using WARM.

The GHG Calculator Tool was developed by EPA's Pollution Prevention (P2) Program to help entities quantify GHG reductions. The tool calculates GHG reductions (as CO_2 equivalents) associated with the following activities:

- electricity conservation or reduced energy use
- greener or renewable energy sources
- reduced fuel use and/or substitution of greener fuels
- reduced use of chemicals with global warming potential, i.e., green chemistry
- water conservation or reduced water use
- materials management (GHG reductions from green manufacturing processes and waste management scenarios)

The tool uses emission factors from the Climate Registry (Climate Registry 2009), from EPA's Climate Leaders GHG Inventory Protocol Core Module Guidance, and derived from published reports. More details are provided in the online Frequently Asked Questions guide (TRSP 2009). EPA periodically updates the emission factors used in the tool over time.

There is no universally accepted way of calculating a carbon footprint. Different tools may yield different results based on different emission factors, calculation methods, and/or boundaries. For example, industries may track GHG emissions associated with their own activities (e.g., fuel consumed by their vehicle fleet and facilities). Other industries may include GHG emissions associated with generating the electricity and steam that they purchase. As with any other tool, GHG emission calculator tools yield different results depending on the assumptions.

4.4.2 Remedy Footprint Tools

Government agencies and private industry have developed several tools intended to quantify the environmental, social, and economic impacts of environmental remediation activities. Two examples of free and publicly available tools are described below.

The SRT was developed on behalf of AFCEE by AECOM Environment; GSI Environmental, Inc.; and CH2M Hill to enable project managers and other environmental professionals incorporate green and sustainability concepts into remediation decision making and optimization activities. The SRT is a Microsoft Excel–based tool that includes a series of modules to estimate green and sustainable impacts of eight commonly used technologies for soil and groundwater remediation. Soil technologies include excavation, soil vapor extraction and thermal treatment, with three process options for thermal treatment. Groundwater technologies include pump and treat, enhanced in situ bioremediation, in situ chemical oxidation (ISCO), permeable reactive barriers, and MNA/LTM. The SRT quantifies a number of sustainability metrics, including GHG emissions, other criteria air pollutant emissions, energy consumption, technology cost, safety/accident risk, and change in resource service. It is based on detailed user input and site-specific criteria. Certain metrics calculated by the SRT can be normalized (converted) from their natural units of measure into U.S. dollars. The relative importance of the normalized metrics can be entered into the Stakeholder Round Table to arrive at a consensus among stakeholders regarding the value of each remedial technology. The SRT also can import input parameters and cost data from the RACER™ (Remedial Action Cost Engineering and Requirements) software application.

Two levels of analysis can be conducted using the SRT. ITRC considers both to be advanced GSR evaluations (i.e., Level 3 GSR analyses). The first level (Tier 1) would be considered appropriate for a preliminary FS and is based on generalized user input and default assumptions. The second level (Tier 2) is more appropriate for remedial design or treatment system optimization. It is based on more detailed user input and site-specific criteria. More information about SRT, including a free download of the tool, is available on AFCEE's website.

SiteWise is a stand-alone tool—developed jointly by the Battelle Memorial Institute, the U.S. Navy, the U.S. Army, and USACE and built on a Microsoft Excel platform—that assesses the remedy footprint of a remedial alternative/technology in terms of a consistent set of metrics, including GHG emissions; energy use; air emissions of criteria pollutants, including NO_x, SO_x, and PM; water consumption; resource consumption; and worker safety. The assessment is carried out using a building block approach where every remedial alternative is first broken down into modules that mimic the remedial phases in most remedial actions, including RIs, remedial action constructions, RA-Os, and LTM. Once broken down into various modules, the footprint of each module is individually calculated. It may be necessary to complete GSR evaluations for one or more remedial phases, depending on the GSR goals. For each of these phases, inputs are related to various remedial activities undertaken, such as production of material required by the remedy; transportation of the required materials, equipment, and personnel to and from the site; all on-site activities to be performed (e.g., equipment operation); and management of the waste produced by the activity. The different footprints are then combined to estimate the overall footprint of the remedial alternative. This building block approach reduces redundancy in the sustainability evaluation and facilitates the identification of specific activities that have the greatest remedy footprint. The basis for SiteWise calculations includes linked-in lookup tables with referenced footprint factors from government publications and databases. SiteWise also includes a footprint reduction module that allows the user to evaluate the cost and benefit of various footprint reduction methods such as renewable energy (photovoltaics, wind turbines, landfill gas microturbines, and renewable energy certificates), biodiesel, diesel oxidation catalyst, and variable-frequency drives.

Because SiteWise is not organized by technology, the structure is very flexible and can be used to support an evaluation of any environmental technology or activity. SiteWise and an online training module are available on the Navy's "Green and Sustainable Remediation" portal (NAVFAC 2011).

A handful of other remedy footprint tools have been developed by private industry and consulting firms and may offer several advantages to their users. For example, tools may include a wider variety of technology modules or metrics. Tools may be tailor-made for specific types of sites (e.g., retail petroleum sites, landfills) and offer more details on the site settings and technologies likely to be used at these sites. Other tools may be set up to make it easier to quantify GSR benefits associated with managing a portfolio of different sites. More information on these tools is provided in Appendix A of ITRC's GSR overview document (ITRC 2011a).

4.4.3 Net Environmental Benefits Analysis

NEBA (ORNL 2003) is an analysis methodology developed by DOE at the Oak Ridge National Laboratory (ORNL) and EPA to examine alternatives for remediating ecologically sensitive sites. Of particular interest are sites that have been contaminated by petroleum products. The analysis, per the framework document, is as follows: "Net environmental benefits are the gains in environmental services or other ecological properties attained by remediation or ecological restoration, minus the environmental injuries caused by those actions" (ORNL 2003). The framework lays out a method for comparing and ranking the net environmental benefit associated with multiple alternatives.

Per the framework document, when conducting a NEBA, the primary alternatives examined are "(1) leaving contamination in place; (2) physically, chemically, or biologically remediating the site through traditional means; (3) improving ecological value through onsite and offsite restoration alternatives that do not directly focus on removal of chemical contamination or (4) a combination of those alternatives" (ORNL 2003).

Limitations of the analysis include establishing like units of analysis across multiple alternatives. The authors note that failure to do so might lead land managers may make their decisions more subjectively. Similar concerns are expressed about stakeholder support, and they recommend establishing relative ranking units early in the process, as early as the planning steps, to help gain stakeholder support.

Overall, the self-assessment by the developers of the framework describes the tool as "a high-level framework for NEBA" with more detail when it comes to the "subframeworks for natural attenuation (the contaminated reference state), remediation, and ecological restoration alternatives" (ORNL 2003). Details about NEBA and the links to the framework document can be found on the ORNL web site (ORNL 2003).

4.4.4 Life-Cycle Assessment Tools

LCA is a rigorous approach to footprint analysis. LCA can be used for projects that are more complex; projects that use a large number of materials, chemicals, or other resources; or projects with a large number of metrics. In other words, sites with more "inputs and outputs" may benefit from LCA analysis.

LCA considers energy and resource inputs and waste outputs associated with the life cycle of a project, product, or service. Like footprint analyses, LCA is a quantitative approach. LCA can be used to comprehensively analyze carbon footprint and other impacts. The International Organization for Standardization (ISO) 14040 series defined LCA as a "compilation and evaluation of the inputs, outputs, and potential environmental impacts of a system throughout its life cycle" (ISO 2006). It should be noted that the ISO definition of "product" also includes "services" and is hence applicable to remediation projects. More details on LCA are summarized in a paper recently published by the Sustainable Remediation Forum (Favara et al. 2011). As outlined in the SURF paper, LCA analyses should follow nine steps, which approximately correspond to the steps of the ITRC GSR framework as described in Section 2 of this document. Table 4-1 shows how the ITRC GSR Framework correlates with the SURF LCA process.

Table 4-1. ITRC GSR framework and SURF LCA process

GSR evaluation process	**LCA steps** (Favara et al. 2011)
Review site setting	N/A
Establish GSR goals	1. Define the study goals and scope 2. Define the functional unit
Involve stakeholders	N/A
Select criteria, metrics and tools	3. Establish the system boundaries 4. Establish the project metrics
Perform a GSR evaluation	5. Compile the project inventory (i.e., inputs and outputs) 6. Assess the impacts 7. Analyze the sensitivity and uncertainty of the impact-assessment results 8. Interpret the inventory analysis and impact-assessment results
Report GSR results	9. Report the study results

To aid in the development of an LCA, a process flow chart should be prepared to identify the scope of the analysis, nature and extent of required data, and system boundaries. Ideally, system boundaries would include all material and energy resources, wastes, and emissions related to the product, process, or service being evaluated. Although LCA can be completed without commercial tools, several tools are available to simplify the process, three of which are discussed later in this section.

LCA has not been used extensively to evaluate remedial action options at contaminated sites, mainly due to complexities involved in LCA, lack of input and output data required for LCA, the significant time requirement, and the lack of training on LCA for environmental remediation professionals.

It is up to the practitioner and the project manager to determine whether the site conditions and decision-making requirements warrant conducting an LCA. Further, project teams must evaluate whether they have the resources to conduct an LCA. As with most tools, an LCA can be simplified or as comprehensive as needed for a project.

LCA is based on a holistic approach that accounts for both direct and indirect impacts. LCA is a decision-making tool to select the best GSR approach based on the evaluation of different remedial alternatives that not only protect public health and safety but also minimize the consumption and maximize reuse of natural resources (e.g., minerals, water, land, fossil fuels); maximize the use of renewable energy sources; minimize the generation of solid and liquid wastes, air pollutants, and GHGs; use the site for useful end use; and restore local habitat and ecosystem. Based on the associated costs and benefits as well as efficiency and effectiveness considerations, LCA helps to select the best GSR strategy to be implemented at a given site.

Even in the case of simple LCA application for GSR, one must require the following input data:

- personnel (e.g., labor, design professionals)
- consumable supplies (e.g., process feedstock, reagents or chemical compounds)
- natural resources (e.g., water, minerals, land)
- renewable and nonrenewable sources of energy, including all energy requirements for the implementation and operation of a remediation system as well as the energy required for associated operations, such as transport of personnel, materials, remediation by-products, etc.

Following are descriptions of three LCA tools.

- SimaPro was developed by Product Ecology (Pré) Consultants. Users must purchase a software license to get access to it. SimaPro can be used to calculate carbon footprint and other environmental impacts and identify key areas needing improvement. This LCA software uses several underlying emissions inventory databases, including ecoinvent v.2, US Life Cycle Inventory, European Reference Life Cycle Database, US Input Output, European Union and Danish Input Output, Dutch Input Output, and LCA Food (Pré 2011). SimaPro software also offers a variety of 17 different impact assessment methods for grouping impacts into different categories (e.g., grouping eutrophication and aquatic ecotoxicity into overall ecosystem quality impacts). These include ReCiPe, Eco-indicator 99, USEtox, IPCC 2007, EPD, Impact 2002+, CML-IA, Traci 2, BEES, Ecological Footprint EDIP 2003, Ecological Scarcity 2006, EPS 2000, Greenhouse Gas Protocol, and more (Pré 2011).

- GaBi Software® (PE International 2011) is an LCA software package developed by PE International. A free version of GaBi (GaBi Education) is available to undergraduates. GaBi offers functionality similar to SimaPro and can also be used for conducting an LCA evaluation of GSR.

- Economic Input-Output Life Cycle Assessment (EIO-LCA, www.eiolca.net) is an online tool designed by researchers at the Green Design Institute of Carnegie Mellon University. EIO-LCA estimates the materials and energy resources required for and the environmental emissions resulting from activities in our economy. The EIO-LCA tool can be used to quickly and easily evaluate a commodity or service, as well as its supply chain. EIO-LCA provides guidance on the relative impacts of different types of products, materials, services, or industries with respect to resource use and emissions throughout the supply chain. This method has been used extensively for product development, but its application to assess sustainability parameters of site remediation has received attention only recently.

4.5 Weighting and Normalizing Results

Regardless of the tool being used, any GSR evaluation (Level 2 or 3) requires some method of comparing the multiple impacts of each alternative. For example, excavation may restore a parcel of land for community redevelopment faster than in situ bioremediation but generate more waste. The decision of which remedial approach is considered greener or more sustainable may depend on the decisions made for weighting and normalizing.

4.5.1 Weighting

Weighting is used to denote the relative importance of the various GSR impacts. In the above example, for example, all else being equal, water use may be given more weight at a site where water is scarce. The default assumption in a GSR evaluation is to assign equal weight to each GSR impact. The process of assigning unequal weights is typically subjective and may involve complexities such as evaluating the relative importance of GSR impacts to different groups. For example, some GSR impacts affect an individual, such as the site owner, while others may affect a small group (e.g., site neighbors) or society at large. If unequal weights for GSR metrics are considered, they should be identified early in the GSR process, during the planning stage, with input from all stakeholders. A sensitivity analysis should also be conducted to illustrate how different weighting factors can impact results, as discussed in Section 4.6.

4.5.2 Normalization

A GSR evaluation may require the comparison of kilowatt-hours, tons, gallons, acres, cubic yards, dollars, and unitless ranks. Normalizing is a process to convert various units to a common unit so that they can be summed together. The resulting score can be directly compared to the scores of other alternatives. There are several different methods for normalizing GSR criteria (Ung et al. 2010). Examples include the following:

- Conversion to dollars—Converting all units to a common currency such as dollar value (e.g., cost per pound of CO_2 emissions based on carbon markets) allows various impacts to be summed together. Natural resource damage assessment and other environmental economics principles may be useful for this type of normalization.

- Linear scale transformation—Using this method, the range of values for each criterion is mapped to a common unitless scale, such as 0 to 1, with the maximum value mapped to 1 and the minimum value mapped to 0. This method is a proportional transformation method, achieved by either dividing each value by the maximum value so that scores range from 0 to 1 ("maximum score procedure") or dividing the difference between each value and the maximum value by the score range ("score range procedure"). This process increases the impact of small variations.

- Standard scores or Z scores—This method is used to map each range of values to a common mean (0) and standard deviation (1). Standard scores are derived by dividing the difference between each value and the average value by the standard deviation. The result yields data that typically range from –3 to +3. This process is typically used for data that are normally distributed. The process provides an intuitive interpretation of deviations away from the mean but does not maintain the original "shape" of the data.

After GSR results have been normalized to a common scale and relative weights have been determined, the normalized (or weighted normalized) results can be summed together to develop an overall "score" for each alternative. This process therefore provides a result that is directly comparable.

4.5.3 Tools to Facilitate Weighting and Normalization

Several tools have built-in methods to take information about relative weights and the selected normalization method and develop scores for each GSR alternative. For example, the SRT has a Stakeholder Round Table feature where each stakeholder's weighting values for GSR impacts can be entered. The Round Table calculates the average weighting value to help stakeholders arrive at a consensus.

Other methods for developing weighting values include the analytical hierarchy process, where a weighting is assigned to each alternative after ranking their preference/priority (Ung et al. 2010). Tools for simple (Level 2) GSR evaluations typically assume equal weights for all GSR impacts. Tools may also have built-in methods for normalizing results to a single score or may offer the user several options for normalizing GSR impacts and developing a single score for each alternative. Using multiple normalization methods can be another way of evaluating the sensitivity of results.

4.6 Best Practices for GSR Evaluations

There are several best practices to keep in mind during any GSR evaluation, including the following:

- *Use the simplest level of GSR evaluation that is needed to meet GSR goals.* Advanced tools (Level 3) require additional data, time, and cost compared with simple tools (Level 2) or BMPs only (Level 1). Choose the level of analysis needed to meet site goals. For example, if a remedial technology has already been selected and implemented at a small UST site and the primary GSR goal is to make the remedy implementation process greener, BMPs would likely be appropriate. To improve awareness and conceptually evaluate remedial tradeoffs from a GSR perspective, a simple tool (Level 2) would be appropriate. Finally, if a detailed quantitative assessment is needed for various GSR metrics, an advanced tool (Level 3) is needed. GSR is more likely to be frequently implemented if the process is scalable and the appropriate level of detail is selected.

- *Keep the GSR process transparent.* GSR evaluations are very site specific and require a number of different assumptions. Value judgments are inherent in the process of selecting GSR goals, metrics, and the relative importance of different metrics (i.e., the weighting process). In addition, the quantification of different GSR impacts varies based on the boundaries selected and the assumptions used. Combined with the relative newness of the practice, these aspects make it very important to keep the GSR process transparent.

- *Conduct an uncertainty analysis of GSR results.* The goal of an uncertainty analysis is to indicate how sensitive the GSR results are to changes in key assumptions. This may be as simple as evaluating how a change in relative weights used for GSR metrics could affect GSR results. For advanced Level 3 GSR evaluations, an uncertainty analysis can be conducted by changing key assumptions. Some tools (e.g., The BalancE3™ Tool) have built-in methods to take a range of input estimates and generate a range of probable outcomes (Ung et al. 2010). The uncertainty analysis might reveal that two alternatives have very similar GSR impacts but a third alternative is consistently better or worse than the other two.

As described in this document, the GSR process is adaptive and site specific rather than prescriptive. The level of analysis is highly scalable. GSR has been implemented at a variety of sites ranging from small sites to large, complex sites, as illustrated by case studies (Appendix C). Finally the GSR process outlined in this document provides an opportunity to integrate diverse stakeholder values and ideals into the overall remedy. Following the GSR process will improve stakeholder support for GSR, encourage GSR evaluations, and facilitate the implementation of greener and more sustainable practices during site remediation.

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Appendix A

GSR State Survey Results

GSR STATE SURVEY RESULTS

A.1 OVERVIEW

To gain an understanding of states' interest in and knowledge of the topic of GSR to aid in discussion with outside parties, the ITRC GSR Team surveyed ITRC member states through the ITRC State Points of Contact (POC) network. This survey was conducted between July 2010 and October 2010 (the survey questionnaire is provided in Appendix B). The results of this survey aided the team in the development of the GSR overview document (GSR-1, ITRC 2011a) and this technical and regulatory guidance document. Although some of the issues raised in this survey may not appear to apply to every specific state program, topics related to GSR processes are highlighted by survey responders. The goal of this survey is to capture the current status of how GSR issues are being addressed.

A.2 SUMMARY OF SURVEY RESULTS

The following table contains the respondents' comments.

What should be included in the guidance document?

1) Good, clear examples, best management practices (e.g., what's been tried, what worked, what didn't work) 2) General guidelines to improve the impact and sustainability of the remedy
Should be considered as a remediation method, not pushed to encourage natural attenuation as a solution to all things.
Discuss what "unsustainable remediation" is. There may be no answer, but this would be helpful in framing the national discussion/debate.
Please include a review by someone with technical editing skills.
1) Total energy use and renewable energy use 2) Air pollutants and greenhouse gas emissions 3) Water use and impacts to water resources 4) Materials management and waste reduction 5) Land management and ecosystems protection
Provide specific examples of available technology and the names and contact information of individuals and companies that can provide this technology so that the available resources can be considered during the work plan review and approval. For example, we can consider our ability to reduce greenhouse gas emissions by using drilling rigs and other heavy equipment equipped with the latest green diesel technology only if we know the equipment is available and whom to contact to get information on availability and costs. Can I contract with a trucking company that has clean diesel engines? If necessary develop and promote specific trade shows that promote the development and marketing of clean power technologies that can be used to power soil vapor extraction systems, groundwater extraction and treatment systems, and heavy equipment for the excavation, transportation, treatment and/or disposal of contaminated soils. Many large landfills generate methane gas; can the heavy equipment be reconfigured to utilize the methane gas as a source of fuel for the heavy equipment that is used to compact and cover the trash?

1) List of possible social and economic factors as they pertain to sustainability 2) Flow chart listing possible considerations in each step of process 3) Recommend possible collaborations in order to seriously consider social and economic factors 4) List of references (organizations) with expertise in identification of economic and social considerations 5) Costs and benefits of various remedies
1) Cross-programmatic language/structure/framework and case studies 2) A process that can overlay existing guidance in multiple program areas
A two-tiered approach: a simple way to address the majority of sites that are small and have minimal community involvement and a more in-depth approach for large sites with greater social impact and community involvement
1) How to use it 2) Ideas for GSR, methods, resources
Assistance for determining the footprint of specific technologies; trying to weigh energy use, air pollution, water use, and waste management for given technologies is very complex
1) The perspective that when we say, "protection of human health and the environment," that is not necessarily limited to on/near site. Offer perspective on "protection of the environment" such that the larger environment is considered along with the local environment 2) The understanding that much of GSR can be done within existing laws/regulations/guidance 3) That we have historically been able to implement many of the GSR techniques and have implemented some over the years, but we now should do this while conscious of the larger environmental issues such as climate change, sprawl, etc. 4) Clearly address when a life-cycle analysis is/is not needed 5) An iterative process: for techniques/remedies that can be easily differentiated as greener than others, an exit strategy from the process prior to life-cycle analysis 6) Communicate that everyone involved should proactively select greener techniques/remedies 7) Common conversions and metrics to normalize impacts 8) Relative scales of impacts of various common techniques/remedies based upon others' work in life-cycle analysis (e.g., if enhanced bio is generally greener than excavation, etc.) 9) Examples of the thought processes (e.g., generally in situ thermal desorption may be perceived to be less green due to the energy required, but if green power can be utilized, does the remedy now become more attractive because it solves significant environmental problems and the impact was reduced via the purchase of green power?) 10) An understanding of how social and economic issues can weigh into decision making 11) Integration of cleanup with reuse of the site
1) A list of "off-the-shelf" best management practices 2) A specific methodology for evaluating sustainable practices and/or for remedy selection—lists of metrics are of limited usefulness when people don't know what to do with them 3) Include case studies
An explanation of how states are supposed to evaluate social and economic impacts beyond what's contained in the CERCLA and RCRA regulations. Sustainability is problematic for most of the cleanup programs, particularly VCPs. It's not mandated, and project managers don't have the authority, time, or expertise to review/approve the social or economic aspects of a cleanup.
A description of how to use GSR within the existing regulatory structures of RCRA and CERCLA
Guidance on what would constitute good practices and what level of usage (for example, energy) would be considered "green"

The Tech Reg should include the GSR processes that best suit individual constituents and specific remediation environments

What should be avoided in the guidance document?

Rehash of other guidance documents and publications on the subject
Too much information or details that branch out into historical or already existing guidance
Be very specific Provide examples Do not get lost in vague, esoteric discussions of general concepts You need to reach the project managers in the government, industry, and consulting fields
Presenting GSR as a separate process (outside the scope of established program protocols)
Giving the impression of one size fits all
My program addressed leaking underground and aboveground storage tank sites. Quite often these sites are small and the impacts are below ground and (following assessment) well-defined. Other than from a long-term stewardship perspective on risk-based closures, it is difficult to incorporate social/economic factors into our cleanup actions. For example, a site that has been a gas station for 10 years and will continue to operate as a gas station following cleanup is not a good candidate for social/economic considerations in a broad sense (i.e., not in a "future use" sense). I feel, to make the guide applicable to all sites, the sustainability sections should not be prescriptive. I also would find it useful for the guide to take into account GSR application at smaller "in use" sites rather than focusing only on big RCRA, industrial, or brownfield applications. Although big sites such as these give you "the most bang for your buck per site," in terms of net environmental benefits for applying GSR, the sheer number of tank sites still undergoing cleanup could result in significant benefits via GSR as well.
Overly intensive or highly complex GSR case studies; a scalable process will be directly proportional to the success of ITRC GSR Tech Reg concurrence/reliance
Policy benefits that are not scientifically based
1) Do not include worker safety as part of the analysis. This is not green remediation! We fully expect that we can implement a remedy without killing or injuring workers or the public, regardless of the remedy chosen. We plan for safe remedies through the OSHA/health and safety plan process. Using statistics on this issue is not productive since we strive for zero accidents. (On a related note, some were considering dust as a green remediation issue. It is not, for the same reason as worker safety. We fully expect to control dust as needed.) 2) Prescriptive life-cycle analysis. 3) Rigid processes: There are tradeoffs, but the first priority is protection of human health and the environment.
You may wish to identify policy issues in order to frame the GSR approach, but I would recommend avoiding any lengthy policy discussion. Focus on the technical/methodology. This is where we need ITRC support.
A consideration of worker safety as advocated by SURF-US and AFCEE, first, because worker safety is already taken into account under CERCLA and RCRA, and second, because it puts worker safety on par with community risk. Voluntary risk shouldn't be treated the same as involuntary risk.
Being too broad

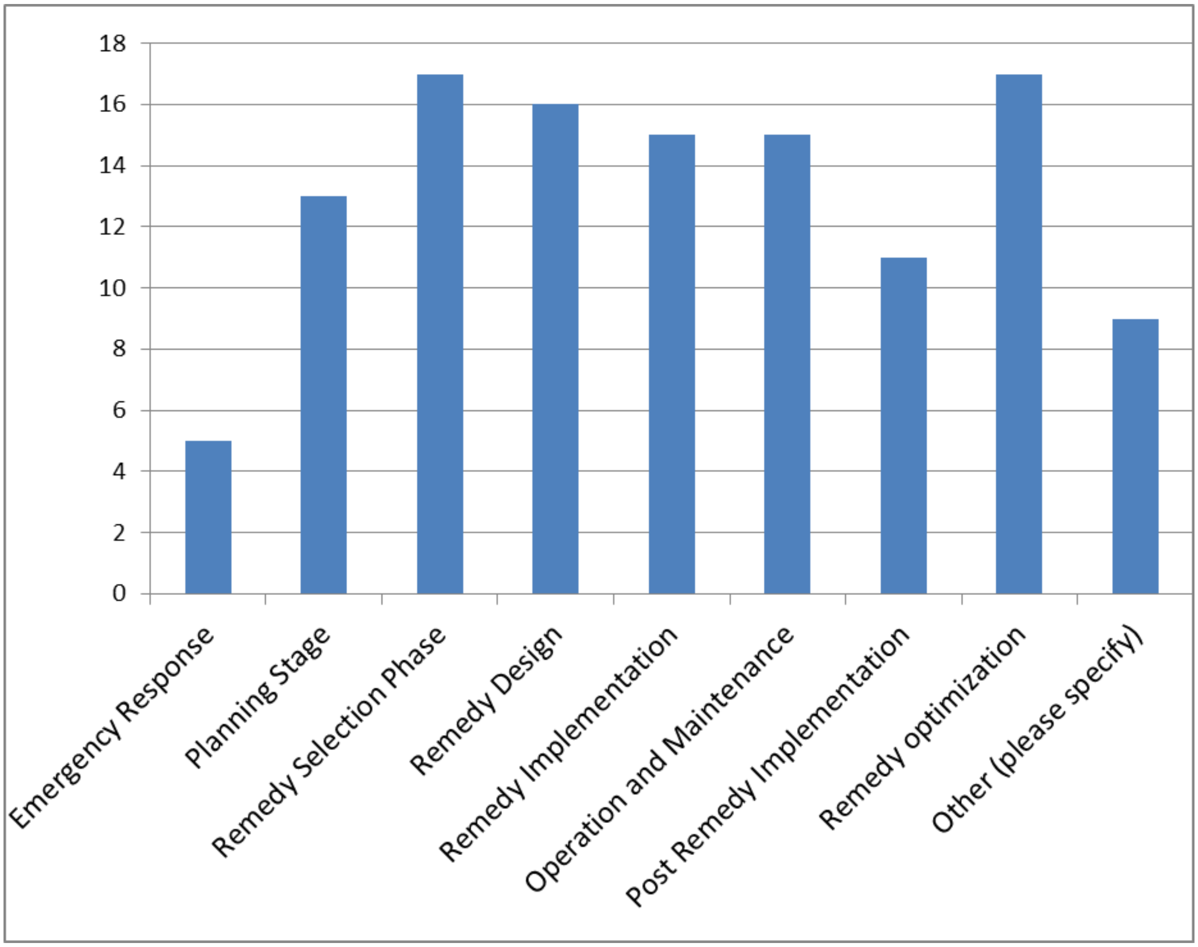
The following paragraphs are presented to summarize responses to specific questions in the survey.

For example, as response to “During which phase of the remediation life cycle does your state/ program believe it is important to apply GSR principles for remediation?”, most respondents provided that GSR is best applied during remedy selection and remedy optimization, with remedy design, remedy implementation, and operations and management phases being close behind them. Applying GSR during emergency response got the least desirable phase for applying GSR process by the state regulatory respondents.

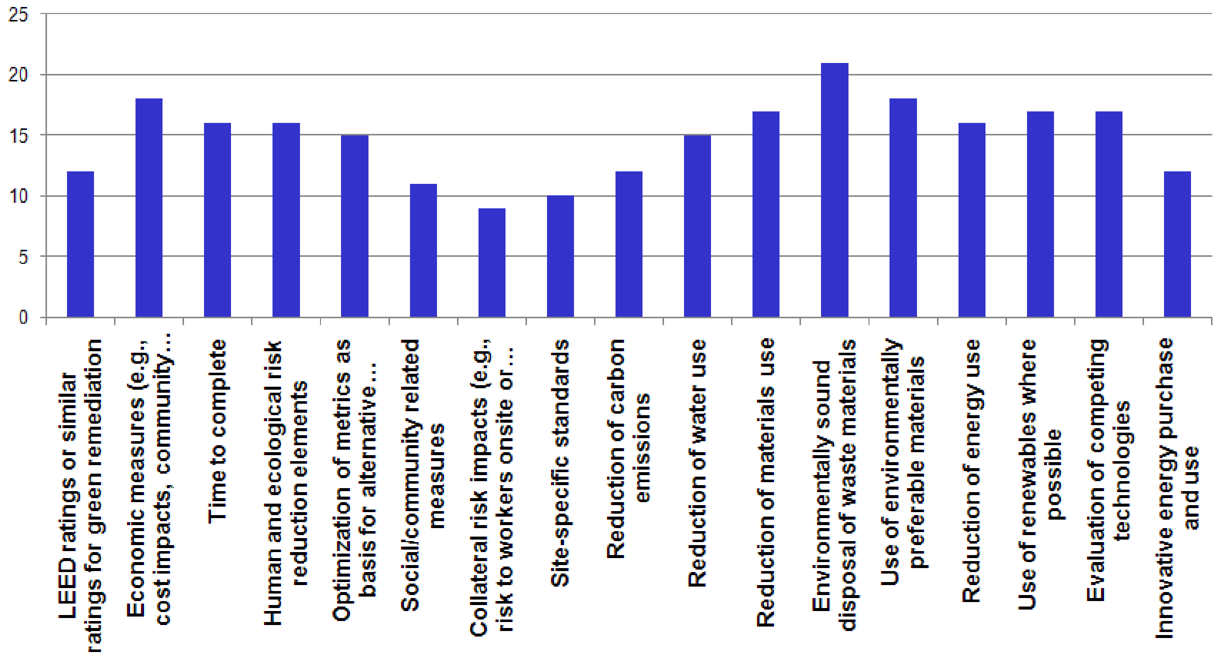
In response to the survey question “What metrics you would like to be included in the evaluation for a GSR approach to remediation?”, environmentally sound disposal of waste materials was ranked the highest. Economic measures (e.g., cost impacts, community impacts), reduction of materials used, use of environmentally preferable materials, use of renewables where possible, and evaluation of competing technologies, all ranked high. Collateral risk impacts and establishing site-specific GSR standards were lowest rated metrics in the survey.

When asked whether additional cost would be a barrier in implementing GSR, an overwhelming state respondents replied “Yes,” indicating that the implementation of GSR is more expensive. As can be seen in the case studies in Appendix C, the actual implementation of a GSR process in the long run will not only be beneficial to environment; it may be cost-neutral or save money.

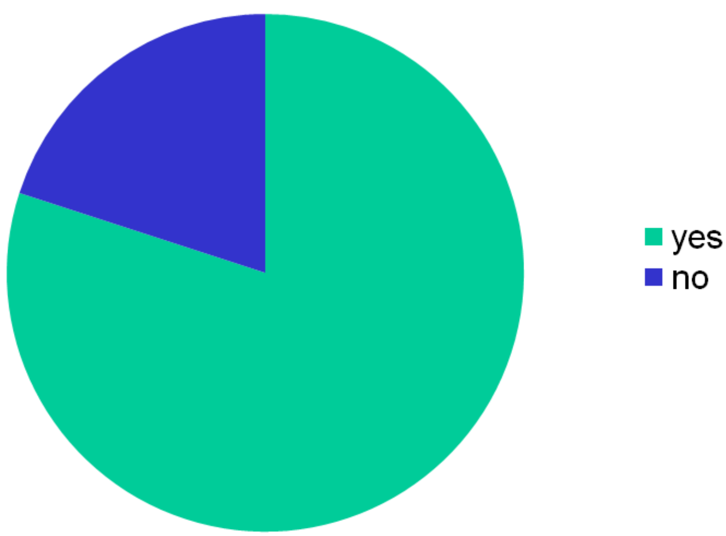
During which phase of the remediation life cycle does your state/program area believe it is important to apply GSR principles for remediation?



What metrics you would like to be included in the evaluation for a GSR approach to remediation? (select all applicable options)



Would additional cost be a barrier to implementing GSR concepts?



Appendix B

GSR State Survey Questionnaire

GSR STATE SURVEY QUESTIONNAIRE

B.1 INTRODUCTION TO GSR TEAM SURVEY OF STATES

The ITRC GSR Team is undertaking this survey in order to determine interest in and knowledge of the topic of Green and Sustainable Remediation (GSR). The results of this survey will aid the team in the development of a Technical Regulatory (Tech Reg) Guidance Document and other ITRC GSR Team products. The ITRC GSR team for this document defines:

> Green and Sustainable Remediation (GSR) is a spectrum standard for site-specific employment of products, processes, technologies, and procedures that mitigate contaminant risk to receptors and reduce carbon foot print and resource use while cognizant of community goals, economic impacts, and net environmental effects.

A collective awareness of the potential adverse impacts of energy- and resource-intensive site assessment techniques and remediation systems has resulted in the investigation of greener and more sustainable remediation approaches. The development of GSR concepts is in its infancy, and application is highly variable across the United States. Green and sustainable standards are being developed at all levels of government. It is our team's belief that practitioners of GSR will employ the ITRC Tech Reg document to varying degrees. States with an existing GSR framework and measurement tools may defer to the ITRC document for comparison only, while other states that are developing GSR may rely exclusively on the ITRC document in defining, framing, measuring, and formatting GSR guidance within their respective programs. Practitioners of GSR currently utilize in-house products to guide the valuation of particular "green" practices and technologies. While some practitioners rely on third-party performance verification processes for a given technology, e.g., the EPA's Environmental Technology Verification Program, they are also tasked with assigning an independent value to any one method, technology, or metric. That value judgment will be enhanced through the identification of metrics and tools during the development of the ITRC GSR document.

As we coordinate our efforts with other entities working on GSR-related topics, we certainly want to complement the efforts of organizations, such as ASTM, USEPA, ASTSWMO, SURF, etc., complementing their efforts while avoiding any duplication as much as possible.

ITRC GSR Team Survey will be focusing on the perspectives and priorities of the states and their regulatory programs. Our aim is to collect the information specific to state needs and capture them in order to benefit the regulatory approval process for greener and more sustainable remediation options.

All the input you provide will help us build the GSR Technical Regulatory Guidance document in the best possible manner reflecting the state perspectives. If there are several program areas where GSR approaches are applicable in your agency, please provide input from as many areas as possible.

Thanks for your cooperation and response to this survey.

B.2 RESPONDENT INFORMATION

Please note: Only state identifiers will be used in writing up the results of this survey. Contact information is requested so we may follow up with you should we have further questions about the data.

1. Please provide your information

Name	
Title	
Program Area	
State	
Zip Code	
Email Address	
Phone Number	

B.3 BASIC INFORMATION

Here are some basic questions to understand your perspective of the Green and Sustainable Remediation Process:

1. What is green remediation in your opinion?

2. What is Sustainable Remediation in your opinion?

3. What is your understanding of overall GSR process?

4. In your opinion, what should be included in the GSR technical regulatory guidance document to help your program with a better understanding and implementation of GSR?

5. What should we avoid in the GSR technical regulatory guidance document that would not be useful to your program from the GSR perspective?

6. Based on the GSR definition above, how does your state/program area address GSR issues in its cleanup efforts?

- ☐ Formal process
- ☐ Informal process
- ☐ Not really addressed
- ☐ Under development

7. In which program areas is GSR formally applicable or has potential to be applicable in your state? (Please check all that apply).

- ☐ Underground Storage Tanks
- ☐ CERCLA
- ☐ RCRA
- ☐ Voluntary Cleanup Program
- ☐ Brownfields
- ☐ Drycleaning
- ☐ Other (please specify)

B.4 GREEN AND SUSTAINABLE REMEDIATION ACTION OPTIONS

Here are some questions specific to GSR Remediations:

1. Which of the following GSR issues below would you identify with GSR in your state/program area? (Please check all that apply).

- ☐ Overall remediation management (includes site assessment and cleanups)
- ☐ Emissions management
- ☐ Energy management
- ☐ Resource management
- ☐ Greenhouse gas reduction strategies
- ☐ Social impact assessment
- ☐ Economic impact assessment
- ☐ Worker/human safety issues
- ☐ Other (please specify)

2. During which phase of the remediation life-cycle does your state/program area believe it is important to apply GSR principles for remediation?

- [ ] Emergency response
- [ ] Planning stage
- [ ] Remedy selection phase
- [ ] Remedy design
- [ ] Remedy implementation
- [ ] Operation and maintenance
- [ ] Post-remedy implementation
- [ ] Remedy optimization
- [ ] Other (please specify)

3. What metrics you would like to be included in the evaluation for a GSR approach to remediation? (select all applicable options)

- [ ] LEED ratings or similar ratings for green remediation
- [ ] Economic measures (e.g., cost impacts, community benefit of property)
- [ ] Time to complete
- [ ] Human and ecological risk reduction elements
- [ ] Optimization of metrics as basis for alternative selection of design basis (provided minimum regulatory requirements are met)
- [ ] Social/community related measures
- [ ] Collateral risk impacts (e.g., risk to workers onsite or offsite population)
- [ ] Site-specific standards
- [ ] Reduction of carbon emissions
- [ ] Reduction of water use
- [ ] Reduction of materials use
- [ ] Environmentally sound disposal of waste materials
- [ ] Use of environmentally preferable materials
- [ ] Reduction of energy use
- [ ] Use of renewables where possible

- [ ] Evaluation of competing technologies
- [ ] Innovative energy purchase and use
- [ ] Other (please specify)

4. Is GSR encouraged in your state/program area?

- Yes
- No

If "No," why?

5. Is GSR implementation in your state/program area:

- Completely voluntary?
- Somewhat voluntary and some required?
- Completely required?
- Other (please specify)

6. Would you believe your state/program area would be willing to modify an existing remedy to include GSR approaches?

- No
- Consider minor changes
- Consider moderate changes
- Consider major changes
- Consider all that is needed to make it effective from GSR perspective

7. Would additional cost be a barrier to implementing GSR concepts?

- No
- Yes

If yes, what percentage increase is not acceptable?

8. Would your state/program area accommodate making changes to decision documents, such as Permits or Orders or Records of Decision to include GSR practices, if needed?

- None
- Minor changes through memo/letter
- Moderate changes that require explanation of significant differences or equivalent
- Major changes that would require amendments to decision document or modifications to permit
- Whatever it takes including changes in program policies

9. In addition to the nine CERCLA and ten RCRA criteria (and similar criteria in other program areas), does your state/program area envision additional criteria added to accommodate any specific GSR issues?

- No need for such additions – current RCRA/CERCLA criteria are comprehensive and encompass all the GSR criteria
- Maybe sometime in the distant future when GSR standards become part of policy requirements
- Definitely sometime in the near future when evaluating and implementing GSR practices become routine
- We currently have enough understanding to include additional criteria to cover the GSR issues
- Other (please specify)

10. What proportion of cleanup sites in your state/program area consider GSR approaches?

- More than 25%
- Between 10% and 25%
- Less than 10%
- None

11. Do you have any GSR case studies you would like to share with the GSR Team?

- No
- Yes

If "Yes," please provide contact information:

12. Does your state/program area have a protocol or policy guidance document on GSR strategies?

☐ Yes

☐ No

13. If your state/program area does not have a GSR protocol or policy guidance document, is one expected in the near future (1-2 years)?

☐ Yes

☐ No

14. Would it be helpful to your state/program area to have GSR Tech-Reg document be developed by the GSR team available for use in developing protocol or policy?

☐ Yes

☐ No

B.5 STATE OR PROGRAM AREA TRAINING NEEDS AND PRIORITIES

Please respond to the following questions that are specific to your state or program area training needs. What are your priorities?

1. Has your state identified a technical coordinator/program area specialist for GSR issues?

☐ No

☐ Yes

If "Yes," please give contact information ________

2. If there are more than one GSR points of contact, please provide their contact information

Contact #2 ________

Contact #3 ________

3. How extensive are the GSR training needs in your agency?

☐ Extensive

☐ Moderately extensive

☐ Not very extensive

4. How many persons might benefit or be interested in such a training?

Provide an approximate number

5. Does your agency generally prefer classroom or Internet-based training?

- ☐ Internet-based
- ☐ Classroom
- ☐ First a general, Internet-based training and then a detailed classroom training

Appendix C

Case Studies

CASE STUDIES

C.1 LEVEL 1: BEST MANAGEMENT PRACTICES (BMPS)

C.1.1 Former Refinery Site

Site Name	Former Refinery Site
Site Location	Wellsville, New York
Contact Name	Stephanie Fiorenza, Ph.D., BP, Stephanie.Fiorenza@bp.com
Regulatory Program	RCRA Superfund, New York State Department of Environmental Conservation
Affected Media	Groundwater, soil
Contaminants of Concern	Petroleum hydrocarbons
Time to Completion	10 years
Estimated Cost	Not available

Site Description

The site has a groundwater extraction system using a constructed wetland as the treatment system.

GSR Metrics Considered

Initial consideration of GSR metrics was not provided; however, treatment effectiveness, energy consumption, and cost are recorded and monitored.

GSR Recommendation(s)

Not applicable.

GSR Practices or BMPs Implemented

Phytoremediation technology has been implemented.

Challenges

Electricity costs increased due to change in metering location.

Lessons Learned

Use of an explanation of significant difference allowed a change in the remedy without changing the ROD. Community involvement was a key contributor to the success of the change in remedy.

Benefits from GSR remedy implemented at site include the following:

- reduced energy consumption by 56,000 kwh/year
- eliminated 105,000 pounds of treatment chemicals, including granular activated carbon

The remediation system was optimized by changing from conventional chemical treatment of extracted groundwater to constructed wetland treatment.

Habitat and biodiversity were improved by changing conventional grass covering of landfill to native grasses.

Stakeholder involvement, including communication and outreach efforts, improved, and the community benefited from trails installed on new cap cover to river and educational opportunities and collaboration with local college. See www.bpwellsville.com for more information.

Overall cost savings were realized from the elimination of chemical consumption.

C.1.2 Travis Air Force Base

Site Name	Travis Air Force Base (AFB)
Site Location	Oil Spill Area, SS016
Contact Name	Lonnie Duke, U.S. Air Force, lonnie.duke@travis.af.mil
Regulatory Program	U.S. Environmental Protection Agency Superfund Program
Affected Media	Groundwater, soil
Contaminants of Concern	Volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs)
Time to Completion	Not available
Estimated Cost	Not available

Site Description

Travis AFB has constructed an in situ bioreactor to treat the source of the largest and most challenging groundwater site on base. Known as the “Oil Spill Area,” its large solvent plume originates near an industrial building that cleaned metal parts, and most of the plume lies beneath a large portion of the aircraft parking ramp.

The contamination was treated by a thermal oxidation unit that used a vacuum to draw the solvents out of the soil and burned contaminated vapor with natural gas. Although successful in treating the contaminants, the unit did not achieve any measureable amount of cleanup. Contaminant concentrations in groundwater remained very high, and the unit used significant quantities of natural gas and generated significant GHG emissions.

The bioreactor which replaced the thermal oxidation system uses solar power to run an extraction pump that recirculates nutrient-rich treated water around the contaminated area. The bioreactor is not connected to the base’s electrical system and is not expected to generate GHG emissions.

GSR Metrics Considered

Time to completion, cost to complete, energy savings, and GHG emissions were considered.

GSR Recommendation(s)

Elimination and replacement of thermal oxidation units and energy-intense vacuum systems were recommended.

GSR Practices or BMPs Implemented

The bioreactor creates the groundwater conditions that allow microbes to reductively dechlorinate solvents into harmless compounds. Microbes attach themselves to gravel particles in the reactor and subsist from carbon in the mulch. Emulsified vegetable oil sprayed into the mulch during construction kick-starts the biological activity. The bottom of the bioreactor is lined with iron pyrite, which promotes the chemical treatment of solvents and their intermediate breakdown products. This system ensures a complete conversion of solvents into harmless compounds.

The system operates entirely on solar-generated electricity and is not connected to the base electrical system. Solar panels power an extraction pump that recirculates nutrient-rich treated water around the contaminated area. Groundwater recirculation increases the effective range of the treatment zone.

Challenges

The construction of the bioreactor involved the excavation of a large volume of solvent-contaminated soil from the source area, speeding up the cleanup process. Although any excavation project can be expensive and generate large amounts of waste that must be sent to a landfill for disposal, it is still relatively inexpensive compared to the long-term cost of operating an extraction system for years to remove the same amount of contaminant mass.

Lessons Learned

The bioreactor has the potential to complete the remediation decades before the site's original estimated cleanup time and will avoid significant energy use and GHG emissions. Finally, there was a reduction in life-cycle costs to run the overall remediation system.

C.2 LEVEL 2: BEST MANAGEMENT PRACTICES (BMPS) + SIMPLE EVALUATION

C.2.1 Rhode Island

Site Name	"Policy for Considering Environmental Justice in the Review of Investigation and Remediation of Contaminated Properties"
Site Location	State of Rhode Island
Contact Name	Terrence Gray, P.E., Assistant Director of Air, Water and Compliance, Rhode Island Department of Environmental Management (RI DEM), terry.gray@dem.ri.gov
Regulatory Program	State of Rhode Island and Providence Plantations Department of Environmental Management Rules and Regulations for the Investigation and Remediation of Hazardous Material Releases
Affected Media	Not applicable
Contaminants of Concern	Not applicable
Time to Completion	Not applicable
Estimated Cost	Not applicable

Site Description

The "Policy for Considering Environmental Justice in the Review of Investigation and Remediation of Contaminated Properties" (Policy) was drafted in July 2007 as a means to consider environmental justice in the review of investigation and remediation of contaminated properties. The goals of the Policy are as follows:

- to help RI DEM make more informed decisions, improve work quality through collaborative efforts, and build mutual understanding and trust between the department and the public it serves
- to ensure that RI DEM staff understand the characteristics of the communities surrounding the sites that they are assigned to regulate
- to increase awareness in the urban centers about RI DEM, the site remediation program, and the opportunities for assistance offered by RI DEM to residents living in these neighborhoods
- to provide a clear process for residents to identify potentially contaminated sites to RI DEM, monitor the initial consideration of those sites, and understand the results of the evaluation
- to encourage investment and development in environmental justice areas that balance the needs of residents, municipalities, and the redevelopment community
- to provide a clear and effective process for ongoing two-way communication and understanding as a site is investigated and cleaned up
- to help RI DEM staff engage residents within their own community and neighborhoods in order to help build capacity of residents and community groups within urban areas to support progress towards the goals of this Policy
- to provide an opportunity to raise concerns about environmental justice and ensure they are considered by RI DEM

The policy can be found at www.dem.ri.gov/envequity/pdf/ejfinal.pdf.

Policy development history

The stakeholder group discussed herein was convened via a court agreement in response to a lawsuit filed by residents in Providence, R.I. over the construction of the Springfield Street School complex on a former city landfill (Hartford Parks Tenants Association v. RI Department of Environmental Management/City of Providence).

The Policy has been incorporated into all programs governed by the RI DEM's "Rules and Regulations for the Investigation and Remediation of Hazardous Materials Releases." These rules were amended, integrating the Policy. The programs affected by the Policy incorporate specific aspects of the Policy into existing program guidance language. Although the effective date of the Policy is June 26, 2009, elements called out in the policy were implemented under draft policy as of July 31, 2007 for new sites entering their respective program(s). Additionally, the Policy is not retroactive for existing sites or those entering prior to July 31, 2007.

The process

RI DEM's "Policy for Considering Environmental Justice in the Review of Investigation and Remediation of Contaminated Properties" is an example of one state agency's attempt to include social or sustainable practices in the existing regulatory cleanup structure. The Policy provides avenues or "action items" for the regulator to perform throughout the cleanup investigation planning and scoping phases, as well as after the site findings/reporting, and post-closure phases of the project. These items include engaging the public through informational outreach in multiple formats, listening and education meetings, mailings, and online resources.

RI DEM project staff may undertake the outreach efforts themselves, directed to the responsible party or its consultant. The degree to which the outreach effort is attempted varies and is dependent on the site size and may depend on the intensity of site interest from the surrounding community. The full array of communication tools described herein has not been tested to date on a singular project/site.

The outreach efforts are specifically targeted to inform those communities identified as "Environmental Justice Focus Areas" as follows:

> The United States Environmental Protection Agency (EPA) uses data from the census to develop population maps in Geographic Information Systems (GIS). In establishing their mapping criteria, EPA calculated (on a regional basis) the percent of the census block group that is minority *and* the percent of the block group that is low-income (under 2x Federal Poverty Level). Areas mapped by EPA are both (% minority & % low-income) high enough to rank in the top 15% of block groups. RI DEM adopted similar criteria; however, it compared the block groups on a state-wide basis instead of a regional basis. In addition, DEM mapped areas where the percent of the block group that is minority *or* the percent of the block group that is low-income (under 2x Federal Poverty Level) are high enough to rank in the top 15% of block groups state-wide. For purposes of implementing

the policy, the census blocks meeting these criteria shall be designated Environmental Justice Focus Areas.

GSR Metrics Considered

When in compliance with this policy, a site may include the following metrics in site evaluations:

- number of outreach meetings, mailings, and responses
- online access attempts
- staff training sessions completed

GSR Recommendation(s)

Site cleanup decisions are likely to be heightened with improved community understanding and acceptance when cognition of community impacts and concerns become part of the holistic evaluation of cleanup remedies. This form of environmental justice policy is a primary example of how the sustainable components of cleanup can be attained through specific action items for regulatory staff. These items have the potential to become an extension of the investigative work guidance requirements.

GSR Practices or BMPs Implemented

RI DEM provided numerous action items for regulators to use in their effort to engage community stakeholders. A sample of the action items is provided below:

Site discovery and public petitioning action items

- Establish multilingual complaint hotline and website (currently under development).
- Accept all public petitions for suspected contaminated sites and investigate the suspicions promptly.
- Communicate, in writing, the results of the initial investigation and anticipated next steps back to the complainant in their native language whenever possible.

Identifying communities of concern

- Maintain GIS mapping site showing Environmental Justice Focus Areas.
- Compare all sites reported to RI DEM with the Environmental Justice Focus Area overlay map to determine whether the site is in such areas.

Challenges

None provided.

Lessons Learned

Use of this type of policy may result in community benefits through knowledge base, engagement, sense of community ownership, and overall participation in the cleanup process. From the regulator's perspective, these action items can be tracked and reported. Finally, benefits may be realized in overall site management decisions that result in more efficient site closures.

C.2.2 Resource Conservation and Recovery Act Corrective Action Interim Remedial Measure, Ohio

Site Name	Confidential
Site Location	Confidential, Ohio
Contact Name	Nick M. Petruzzi, P.E., Cox-Colvin & Associates, Inc., 614-526-2040, nick_petruzzi@coxcolvin.com
Regulatory Program	RCRA, Ohio Environmental Protection Agency (Ohio EPA)
Affected Media	Soil, groundwater
Contaminants of Concern	39 contaminants of concern (COCs) consisting of VOCs and SVOCs
Time to Completion	6 months
Estimated Cost	$4,000,000

Site Description

The facility is located in a highly prolific buried valley aquifer system which serves as a sole source aquifer in the area. Highly permeable sand and gravel outwash deposits are the predominant material within the buried valley system, with near-surface deposits consisting of less-permeable glacial till. A localized perched unit of groundwater consisting of sand and gravel exists at the facility's primary operations area, with the regional aquifer water table at a depth of approximately 45 feet below ground surface (bgs).

The site is a commercial treatment, storage, and disposal facility. The facility maintains a Hazardous Waste Renewal Permit regulated through the Ohio EPA. Implementation of RCRA Corrective Action is a condition of the facility's permit.

In 2009, an explosion and fire destroyed much of the operations area of the facility and resulted in the release of various liquid materials, which impacted (often through preferential pathways) subsurface soil, perched groundwater, and the regional aquifer. Given that contaminants in subsurface soil and perched groundwater would act as a continuing source of contamination to the regional aquifer and may result in unacceptable risk to a site worker and possibly off-site receptors if not addressed, the facility elected to conduct the cleanup as an interim measure through the RCRA Corrective Action program.

Excavation and disposal of subsurface soil and perched groundwater was selected as the preferred remedial alternative. The extent of excavation, approximately 70,000 tons, was guided by site-specific remedial goals that were protective of a site worker and would prevent leaching to the regional aquifer above unacceptable concentrations.

GSR BMPs were identified and employed to the extent possible during the investigation and remedy design/implementation phases of the cleanup. As part of the remedial evaluation phase, GSR concepts were identified and evaluated against the potential remedial alternatives and played a role in the selection of a preferred remedial alternative.

GSR Metrics Considered

The evaluation of potential remedial alternatives relied on RCRA's threshold and balancing criteria for remedy selection. Therefore, a GSR evaluation of potential remedial alternatives was integrated into this regulatory framework. GSR concepts that were considered inherent in the seven existing balancing criteria were identified. Additional and relevant GSR concepts were then used to develop an eighth new balancing criterion. The eighth criterion consisted of five GSR categories, including consumption of resources and materials, CO_2 emissions, waste minimization and reuse, community benefit, and corporate image and corporate sustainability. A weighting factor was used in the CO_2 emissions category. The resulting evaluation scores for the GSR criterion were incorporated into the scores of the other balancing criteria to select a preferred remedial alternative.

Depending on the GSR category, some evaluations were qualitative while others were quantitative. Professional judgment was required in the development of the GSR criterion and the evaluation approach for the GSR categories as limited guidance was available. A brief description of the metrics associated with each GSR criterion category is provided below:

- consumption of resources and materials—quantitative and qualitative consideration of water, clean soil, construction materials, and other consumables
- CO_2 emissions—quantitative consideration of direct CO_2 emissions from fuel used for transportation, construction equipment (on and off site), and on-site treatment; indirect CO_2 emissions from power plans for the generation of on-site electricity
- waste minimization and reuse—quantitative consideration of the volume of soil disposed off site and the volume of treated soil used as backfill
- community benefit—quantitative and qualitative consideration of the effects of increased traffic with respect to noise pollution, the eyesore factor, travel delays, and "wear and tear" on roadways
- corporate image and corporate sustainability—quantitative consideration of stakeholder perception and the avoidance of potential future liability in terms of regulatory enforcement and human health–related risk

Three potential remedial alternatives (RAs) satisfied all of the threshold criteria requirements and were carried through to the balancing criteria and GSR evaluation. These potential remedial alternatives included excavation, off-site disposal, and backfill with clean material from an off-site source (RA-1); excavation with on-site ex situ thermal desorption mobile unit and backfill with the treated material (RA-2); and in situ electrical resistance heating, hotspot excavation and off-site disposal, and hotspot backfill with clean material from an off-site source (RA-3). RA-1 and RA-2 tied as the most green and sustainable remedial alternatives.

GSR Recommendation(s)

Incorporation of GSR into the cleanup project allowed for various benefits to be realized, including slight improvement in the time to completion, reduction in fuel use and CO_2 emissions, and positive perception among stakeholders (including nearby neighbors, the general public, and Ohio EPA). Costs throughout the cleanup project were impacted only slightly (some higher, some lower). One example of an increase in cost related to GSR is the possible purchase of carbon offset credits. The facility is currently evaluating the purchase of a sufficient number of credits to claim a carbon-neutral cleanup.

GSR Practices or BMPs Implemented

A formal evaluation was not necessary for GSR BMPs. Based on professional judgment various GSR BMPs were recommended to the facility to be performed as part of the investigation and remedy design/implementation phases. GSR BMPs recommended during the investigation phase included the Triad approach, direct-push soil sampling, limiting/compressing off-site sample shipments, and a mobile wastewater treatment system. GSR BMPs recommended during the remedy design/implementation phase included exhaust particulate filters/oxidation catalysts for construction equipment, low-sulfur diesel or biodiesel blend for trucks and construction equipment, routine maintenance on construction equipment, anti-idling policy, recycling concrete and demolition debris, transportation of backfill during return trips from the landfill, identifying preferred truck routes with local officials, green concrete, promoting public awareness/education/involvement, and purchase of carbon offset credits.

Challenges

Various GSR barriers and uncertainties were encountered due to the lack of consensus, the constantly evolving nature, and limited guidance associated with the GSR initiative. In an effort to overcome some of these barriers and uncertainties, professional judgment was heavily relied on. Uncertainties and barriers related to the following:

- identification of inherent GSR similarities in existing balancing criteria
- development of the GSR criterion categories
- evaluation weighting
- GSR BMP implementation
- facility benefits, incentives, and recognition

Lessons Learned

In general, this case study provides a successful demonstration with respect to GSR evaluation and implementation, given guidance limitations, permit-required constraints, complexities associated with site-specific conditions (e.g., time frame, COCs, and hydrogeology), and a situation where the most feasible options were not considered the most green and sustainable.

Based on research and conversations with U.S. EPA and Ohio EPA, this case study appears to represent the first documented RCRA Corrective Action cleanup project within EPA Region 5 (and possibly further) which devoted a significant level of effort to incorporate GSR into all applicable phases of the project and included a qualitative/quantitative GSR evaluation of potential remedial alternatives.

C.2.3 Florida Department of Environmental Protection Resource Conservation and Recovery Act

Site Name	Kennedy Space Center
Site Location	Cape Canaveral, Florida
Contact Name	Rebecca Daprato, Ph.D., P.E., GeoSyntec, RDaprato@GeoSyntec.com
Regulatory Program	RCRA Superfund, Florida Department of Environmental Protection (FDEP)
Affected Media	Groundwater, soil
Contaminants of Concern	Trichloroethylene (TCE)
Time to Completion	4 years
Estimated Cost	Not available

Site Description

The site is a launch pad surrounded by wetlands and the Merritt Island National Wildlife Refuge. The remedy included recirculating enhanced anaerobic bioremediation system using biostimulation and bioaugmentation. Initially, potassium lactate was used as the electron donor, but later Emulsified Oil Substrate (EOS™) was used as the substrate. KB-1 was the microbial culture, and sodium bicarbonate was added as the buffer. Two injection wells were used for recirculation, and two extraction wells with 12 volt (V) centrifugal pumps running 2–4 gallons per minute (gpm), 24 hours per day, 7 days per week were powered by a mobile solar unit. The sun-hours averaged 4.5 per day; the two batteries had a 2-day reserve. The batteries were 12 V, 265 amp-hours each. A charge controller was used to prevent the batteries from overheating. The four photovoltaic (PV) modules were Sharp 123 watt, 17.2 V, 7.16 amps.

GSR Metrics Considered

CO_2 equivalents were considered.

GSR Recommendation(s)

None provided.

GSR Practices or BMPs Implemented

A corrective measures study compared the carbon footprints of bioremediation, pump and treat, air sparge, and multiphase extraction. The CO_2 equivalents in metric tons were 5–15, 40, 30–60, and 50–100, respectively.

The selected remedy minimized impacts to habitat and reduced risks to surface water receptors.

Challenges

The remediation substrate needed to be optimized to improve remediation performance.

Lessons Learned

The mobile solar unit was easy to install, mobilize, and demobilize and can be reused at other sites.

C.2.4 New Jersey Terminal

Site Name	Former Terminal
Site Location	Paulsboro, New Jersey
Contact Name	Stephanie Fiorenza, BP, Stephanie.Fiorenza@bp.com
Regulatory Program	NJDEP
Affected Media	Groundwater, soil
Contaminants of Concern	Petroleum hydrocarbons, chlorinated solvents
Time to Completion	5 years
Estimated Cost	$5–$10 million

Site Description

A former terminal included 16 remedial management units (RMUs) on site. This case-study focuses on site-wide groundwater and remediation of hot spots in two RMUs.

The uppermost saturated zone is 5–10 feet bgs and 60–100 feet thick. It overlies a clay unit above an intermediate aquifer and another clay unit. The lower aquifer, beneath the lower clay unit, is used as a drinking water aquifer by the borough.

GSR Metrics Considered

The metrics considered were as follows:

- GHG and criteria pollutant emissions
- performance efficiency—emissions per pound of COC removed
- energy consumption
- solid waste consumption
- occupational and transportation risk
- remediation life-cycle cost
- return on investment for sustainability enhancements (direct and indirect)
- community outreach/participation

GSR Recommendation(s)

A solar plant eliminates 570,000 pounds of CO_2, 1600 pounds of SO_2, and 1100 pounds of NO_x annually and saves $40,000–$150,000.

GSR Practices or BMPs Implemented

A post-selection assessment is being conducted using a proprietary private tool.

Environmental: Renewable energy supplies part of the power required by the groundwater extraction system. Waste is minimized through careful planning and reuse. Air emissions are reduced by use of renewable energy. The ozone remediation system was redesigned to require less power. Trip management reduces mileage.

Social/community involvement: Local and state civic leaders proposed the location for the new port facility and issued bonds for port construction. The city has 99-year lease, and the county has issued bonds for redevelopment of the site as a port facility.

Economic: It is anticipated that the marine terminal will create 2,500 full-time direct and indirect jobs as well as 500 construction jobs. Power reduction has led to a cost savings for this remediation project.

Challenges

The redevelopment of the site defined remedial options and dictated the course of remediation construction.

Lessons Learned

Combining site remediation with redevelopment requires commitment and frequent communication among all parties so that construction and remediation efforts can be coordinated to the advantage of all.

C.3 LEVEL 3: BEST MANAGEMENT PRACTICES (BMPS) + ADVANCED EVALUATION

C.3.1 Tucson Air National Guard

Site Name	162nd Fighter Wing, Arizona Air National Guard (AANG)
Site Location	Tucson, Arizona
Contact Name	James D. Colmer, P.E., BB&E, 248-489-9636 x309, jcolmer@bbande.com Richard McCoy, NGB/A7OR, 240-612-8541, Richard.mccoy@ang.af.mil
Regulatory Program	EPA Superfund Program, Arizona Department of Environmental Quality (ADEQ)
Affected Media	Groundwater
Contaminants of Concern	VOCs, mainly TCE
Time to Completion	Not available
Estimated Cost	Not available

<u>Site Description</u>

In 1987, EPA designated the 162nd Fighter Wing installation as a principal responsible party for the Area B contamination beneath the AFB property. As part of the RI and other investigations, more than 70 groundwater monitoring wells have been installed on the base. EPA prepared a ROD for the Tucson International Airport Area (TIAA) Superfund site specifying a groundwater extraction, treatment, and recharge system (GWETRS) remedy. In May 1997, the GWETRS was installed and began operation.

The current COCs in groundwater include VOCs (mainly TCE). On-site historical TCE concentrations have ranged from nondetect to 46 parts per billion (ppb). Currently, TCE concentrations range from nondetect to about 8.4 ppb. The EPA maximum contaminant level (MCL) for TCE in drinking water is 5 µg/L.

The GWETRS currently consists of 10 operating extraction wells, including 8 extraction wells screened in the upper subunit and 2 in the lower subunit. Extracted groundwater is treated via air stripping prior to reinjection into an infiltration gallery consisting of 5 reinjection wells screened in the vadose zone. The reinjection gallery is located in the northeast portion of the base, distant from the extraction wells. Air-stripping off-gases are treated with vapor-phase carbon prior to discharge to the atmosphere.

Site hydrogeology

The vadose zone at the AANG project area extends from the surface to a depth of approximately 88 feet bgs and is composed of silty sands, caliche deposits, and gravelly sands. The upper zone of the regional aquifer in the AANG project area consists of two subunits and a middle aquitard. All of the known groundwater contamination at the AANG project area is found in these subunits. The upper subunit consists of well-graded, gravelly, course sand and is found at a depth of approximately 88–103 feet bgs. Near Site 5 the upper subunit is generally silt free. The middle aquitard separates the upper and lower subunits and is composed of tight sandy silt with scattered pebbles. At Site 5, the middle aquitard lies at a depth of about 103–128 feet bgs. The lower subunit is found at a depth of approximately 128–138 feet bgs and is composed primarily of course-grained sand. There is also a northwest-southeast trending sand channel in the lower subunit along the south-central portion of the AANG base. The groundwater flow direction in the upper and lower subunits is toward the northwest, and the depth to groundwater is approximately 90 feet bgs.

GSR process

The scope of this sustainable remediation evaluation is the operation, maintenance, and monitoring of the existing GWETRS located at the base. As part of its RPO program, AANG conducted a sustainable remediation evaluation (SRE) of the existing remediation system located at the 162nd Fighter Wing. A simplified SRE process was developed by AANG based on EPA's green remediation primer (EPA 2008) to identify opportunities for optimizing the sustainability of existing remedies. The primer provided focused core elements that framed the SRE. In addition, AANG's targeted scope was critical in the efficient and cost-effective completion of the evaluation. Within the bounds of the evaluation, a sustainable aspect inventory was completed for each core element and associated impacts noted. Alternatives to mitigate the impacts identified by the sustainable aspect inventory were developed for consideration and potential implementation.

<u>GSR Metrics Considered</u>

The following metric were considered for this site:

- gallons of water pumped
- pounds of contaminant removed
- kilowatt-hours of energy consumed
- metric tons of CO_2 equivalents generated
- metric tons of CO_2 generated

<u>GSR Findings</u>

The following were key findings of the SRE:

- Significant amounts of water had been pumped (708 million gallons) with little removal of TCE (approximately 37 pounds).
- Considerable energy was expended in operating systems (265,184 kwh annually, or 2.34% of the base's electrical consumption).
- Approximately 250 metric tons of CO_2 equivalents was created annually, based on energy usage.
- An opportunity for solar power use existed if the energy demand was reduced.

- Significant tailpipe emissions (approximately 14 metric tons of CO_2 per year) were generated from sampling events, nonregional suppliers, etc.
- Large amounts of sampling materials (approximately 9 miles of polyethylene tubing per year) and associated disposal of the used sampling materials, were needed.
- Some sustainable principles had already been applied, such as RPO processes, passive cooling, groundwater recharge, etc.

GSR Recommendation(s)

The following recommendations were generated during the GSR evaluation:

- Evaluate and discontinue the use of noncontributing extraction wells (wells pumping water with TCE concentrations below the MCL) based on current groundwater treatment needs.
- Evaluate elimination of the air stripper, the associated 15 hp blower, and the off-gas heater, as well as use of the current influent tank to strip VOCs by the action of falling water.
- Conduct a validation study using passive diffusion sampling bags for groundwater monitoring, with regulatory approval.
- Review the sampling schedule for potential sampling reduction opportunities, with regulatory approval.
- If the GWETRS must continue operating, continue to recharge treated groundwater to the aquifer and not divert treated water for irrigation or other purposes, since the aquifer is a shared community resource.
- Evaluate the use of local/regional vendors and suppliers that can meet cost and quality objectives.

It should be noted that to implement many of these recommendations, the ROD may require modification.

One of the recommendations that has been implemented is an ISCO pilot test without the GWETRS. This test was successful, and there do not appear to be additional health risks by using ISCO versus continuing operation of the GWETRS.

Another recommendation that has been implemented to some degree is the installation of PV units to provide solar power. While the return on investment and limited space were not favorable for a specific PV array for the GWETRS, it was more economically feasible to address GWETRS power needs as part of a broader base effort. To some extent this is being accomplished as the Base is installing some PV arrays where feasible.

GSR Practices or BMPs Implemented

One of the recommendations that has been implemented is an ISCO pilot test without the GWETRS. This test was successful, and there do not appear to be additional health risks by using ISCO versus continuing operation of the GWETRS.

Another recommendation that has been implemented to some degree is the installation of PV units to provide solar power. While the return on investment and limited space were not favorable for a specific PV array for the GWETRS, it was more economically feasible to address GWETRS power needs as part of a broader base effort. To some extent this is being accomplished, as the base is installing some PV arrays where feasible.

The projected benefits from the proposed recommendations include the following:

- annual reduction in energy use of over 50%
- nearly 75% reduction in tailpipe emissions
- significant reduction in material use (e.g., 9 miles of polyethylene tubing per year)
- retention of water in the aquifer
- potential reduction or elimination of the need for NaHx (sodium hexametaphosphate, aka SHMP).

Challenges

Various GSR barriers and uncertainties were encountered due to the lack of consensus, the constantly evolving nature, and limited guidance associated with the GSR initiative. In an effort to overcome some of these barriers and uncertainties, professional judgment was heavily relied on. Uncertainties and barriers related to the following:

- identification of inherent GSR similarities in existing balancing criteria
- development of the GSR criterion categories
- evaluation weighting
- GSR BMP implementation
- facility benefits, incentives, and recognition

Lessons Learned

There has been interest from AANG for some time to discontinue the use of the GWETRS and move to a more passive remedy due to the limited amount of TCE removed and high annual cost of operation. However, with a ROD in place, regulators seemed reluctant in replacing the active treatment with a more passive remedy.

In April 2008 (and since amended), EPA's green remediation primer was published, signaling a potential shift in thinking by considering how to achieve cleanup goals in a more sustainable fashion. Acting on the information presented in the primer, AANG embarked on creating a streamlined GSR evaluation approach that could frame remedial system performance in terms of sustainability. In August 2009, the results of the 162nd Fighter Wing GSR evaluation were shared with EPA and ADEQ.

The GSR findings presentation did not result in an immediate position change by the regulators. However, in September 2009, EPA Region 9 issued a green remediation policy letter, and the policy message began moving through the organization. With policy in place, the GSR findings presented contributed to the collaborative project team effort to improve the sustainability parameters of the GWETRS. In early 2010, at a project team meeting, EPA presented the possibility of discontinuing active treatment in favor of ISCO with MNA. In March 2011, at a

ROD amendment working group meeting, AANG presented a proposed ISCO plan that was well received and will likely be included in a ROD amendment, tentatively scheduled for late 2011.

C.3.2 Air Force Sustainable Remediation Tool

Site Name	TCE Site, Confidential
Site Location	Air Force Base
Contact Name	Doug Downey, CH2M Hill, 303-674-6547, Doug.downey@ch2m.com
Regulatory Program	CERCLA, state agency
Affected Media	Groundwater, soil
Contaminants of Concern	TCE
Time to Completion	40 years
Estimated Cost	$2–$3 million

Site Description

In general, the site geology consists of silt/clay underlain by sands and then bedrock at the bottom. The groundwater is approximately at 60 feet bgs. TCE was found at concentrations up to 2000 ppb in groundwater. The source was located above the water table. The FS for the site was in progress. The FS compared an in situ oxidation to in situ bioreactor approach and evaluated sustainability impacts using the AFCEE SRT.

GSR Metrics Considered

A GSR study was conducted as part of the FS for the site. All SRT metrics were considered with the exception of natural resources. These metrics include the following:

- GHG
- NO_x
- SO_x
- PM production
- energy use
- public and worker risk

GSR Recommendation(s)

The GSR evaluation showed that the in situ bioreactor provided a more sustainable remediation over the 40-year life cycle. For example, GHG production for the bioreactor was less than half the GHG production estimated for in situ oxidation. Worker and public risk potential was also higher for in situ oxidation.

GSR Practices or BMPs Implemented

A GSR assessment was conducted using the AFCEE SRT.

Challenges

None provided.

Lessons Learned

The GSR evaluation added a new dimension to the FS evaluation and confirmed that in situ bioremediation provides a safer and environmentally friendly remediation alternative. The FS recommendation for an in situ bioreactor was supported by the regulatory agency.

The GSR evaluation was easily rolled into the short-term effectiveness criteria of the FS document. The approach used was to provide a separate paragraph for each alternative describing SRT results. SRT information was visible but did not change the standard FS report format. The GSR evaluation was completed in less than a day once all the FS conceptual design information was available.

C.3.3 New Jersey Department of Environmental Protection Brownfields Site

Site Name	NJDEP Brownfields Site
Site Location	New Jersey
Contact Name	Maria D. Watt, P.E., CDM, 732-590-4659, wattmd@cdm.com Michael Burlingame, NJDEP, 609-292-1424, Michael.burlingame@DEP.state.nj.us
Regulatory Program	NJDEP
Affected Media	VOCs and chlorinated organic compounds
Contaminants of Concern	Groundwater, soil
Time to Completion	Not available
Estimated Cost	Not available

Site Description

An 85-acre municipal landfill is located within a 200-acre brownfield development area (BDA). The BDA consists of eight abandoned brownfield sites along 2 miles of the New Jersey shoreline along the Delaware River, overlooking the Philadelphia skyline and within a highly urbanized area of New Jersey. The municipality has received significant brownfields funding to stimulate redevelopment and revitalization. Redevelopment plans for this landfill include a state-of-the-art, 132,000-square-foot community center that will feature an atrium-style town plaza, a family service center, indoor and outdoor recreational facilities, an aquatic center, and a child care center, as well as community enrichment, job-training, and antipoverty programs. To meet the aggressive construction and redevelopment schedule, an expedited Triad approach was used to comprehensively delineate a contaminated industrial source area within this site.

The unlined landfill operated 1952–1971, when it was closed with a vegetative soil cover. The preliminary investigations revealed it contained mainly municipal solid waste. An area of industrial chemical waste material saturated with chlorobenzene (CB) and dichlorobenzenes

(DCB) was identified in the southeast portion of the landfill. This material is approximately 20–30 feet bgs and acts as a continuing source of groundwater contamination and localized soil vapor contamination.

Although operations at the landfill ceased in 1971, illegal dumping activities continued at the site through the 2000s. While evaluating the property for redevelopment in 2006, a source area of VOC contamination was identified in the southeast quadrant of the landfill.

Investigations at the site identified concentrations of benzene, CB, isomers of DCB (1,2-, 1,3-, 1,4-), and 1,2,4-trichlorobenzene above the state cleanup standards in both soil and groundwater. More specifically, it was identified that a grey-black clay layer situated below the waste fill was highly contaminated and was likely acting as the source of groundwater contamination in this area of the parcel.

An interim remedial measure (IRM) was performed to excavate the majority of the unsaturated source area from the landfill to expedite the redevelopment of the site and leverage grant funding currently available within a specified time frame. A Triad investigation was performed to expedite the comprehensive delineation of any residual source material remaining within the saturated zone. Additional IRMs were considered that included ISCO, in situ thermal remediation (ISTR), and MNA.

Site hydrology

The site is located in the New Jersey Coastal Plain and is underlain by the Potomac-Raritan-Magothy (PRM) aquifer system. The PRM aquifer system consists of three principal layers of fine to coarse sand and gravel separated by stiff clay layers 20–50 feet thick. The three sand/gravel layers are referred to as the lower, middle, and upper aquifers of the PRM system. At the site, only the middle and lower aquifers of the PRM are present, and in the hot spot area, only the middle aquifer of the PRM is contaminated. Depth to groundwater in the middle aquifer of the PRM in the source area ranges approximately 27–29 feet bgs, and groundwater flow is to the east-southeast.

The waste fill is 15–20 feet thick and consists of fine tan sand, black silt, lenses of clay, gravel, rocks, concrete, wood, roots, construction and demolition (C&D) debris, and municipal solid waste. The C&D debris includes pieces of brick, asphalt, cement, plastic, glass, paper, tires, drums, metal scraps, wood, and cinders. The municipal solid waste includes plastics (e.g., bags, bottles), glass bottles, cans, cardboard and paper, clothing, fabrics and rags, ceramic fragments, car metal fragments, wires, large rubber belts, and Styrofoam. The waste fill is underlain by 6–12 feet of dark grey to black medium plasticity clay/silty-clay. The clay has a hydraulic conductivity ranging from 2.0×10^{-6} to 7.7×10^{-8} cm/sec. Clay surface contouring suggests that the topography of the clay forms a “U” shape to the east of the excavated area, with highs to the northwest and southeast and an undulating trough running southwest to northeast.

The clay layer is underlain by the middle aquifer of the PRM, a light brown to gray fine to medium sand to silty-sand, with trace to some gravel. This unit is approximately 25 feet thick.

Beneath the middle aquifer of the PRM is a red fat clay layer with a very low hydraulic conductivity of 2.2×10^{-8} cm/sec extending about 55–97 feet bgs. The clay is underlain by the lower aquifer of the PRM, a light brown to gray fine to coarse sand with gravel, which extends to bedrock.

GSR Metrics Considered

Metrics included the following:

- pounds of contaminant removed
- kilowatt-hours of energy consumed
- metric tons of CO_2 equivalents generated
- metric tons of CO_2, NO_x, SO_x, and PM10 generated
- gallons of water consumed
- accident risk

An extensive community engagement process was developed to ensure that local community needs were met. An extensive waterfront master plan was developed that preserved bald eagle foraging areas, design spaces, and recreation amenities and provided safe gathering spaces, civic services, and employment opportunities as well as leveraged local investment.

A Triad investigation expedited the delineation of the residual source area and ensured that redevelopment could be initiated in a safe and sustainable manner. Three-dimensional visualization and modeling provided real-time graphic representation of data, optimizing the placement of sampling locations. All heavy equipment used biofuels to reduce GHG emissions during the characterization phase. Based on source investigations, redevelopment plans were revised to ensure exposure to the source area was mitigated by altering area-specific uses.

Remedial alternatives including excavation, ISTR, ISCO, and MNA were evaluated, and the carbon footprint of each alternative was calculated. To provide a comprehensive assessment of the tools used, a comparison of the two leading publically available tools (SRT and SiteWise) was developed for the ISTR alternative and is presented in the table on the next page.

GSR Recommendation(s)

Site cleanup decisions are likely to be heightened with improved community understanding and acceptance when cognition of community impacts and concerns become part of the holistic evaluation of cleanup remedies. This form of environmental justice policy is a primary example of how the sustainable components of cleanup can be attained through specific action items for regulatory staff. These items have the potential to become an extension of the investigative work guidance requirements.

SiteWise output for in situ thermal remediation

Activities	GHG emissions (metric tons)	Total energy used (millions BTUs)	Water con-sumption (gallons)	NO_x emissions (metric tons)	SO_x emissions (metric tons)	PM10 emissions (metric tons)	Accident risk fatality	Accident risk injury
Consumables	108.18	1.00E+03	NA	NA	NA	NA	NA	NA
Transportation-personnel	19.35	2.20E+02	NA	3.30E+01	6.90E+00	1.60E+00	1.20E-04	8.30E-03
Transportation-equipment	0	0.00E+00	NA	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Equipment use and miscellaneous	2856.43	5.70E+04	2.80E+06	4.10E+00	1.90E+01	9.90E-04	1.60E-05	7.00E-03
Residual handling	0.71	1.70E+01	NA	7.60E-04	1.80E-04	1.10E-04	1.90E-06	3.90E-04
Totals	2984.67	5.81E+04	2.80E+06	3.69E+01	2.63E+01	1.57E+00	1.38E-04	1.56E-02

GSR Practices or BMPs Implemented

A GSR assessment was performed and integrated in to all phases of this project, originating from the planning and redevelopment, through site characterization and remedy selection, design, and construction. The green and sustainable elements that were considered during this project include the following:

- significant community outreach and planning for site redevelopment
- Triad investigation to expedite source delineation
- biofuel usage for all on-site heavy equipment
- environmental footprint analysis to compare remedial alternatives
- environmental footprint tool comparison analysis between SiteWise and SRT

There were numerous benefits from holistically considering the social, economic and environmental factors of the "triple bottom line" in the remediation of an impacted site.

From a social perspective, the following benefits were achieved:

- Redevelopment and reuse of an otherwise impacted and stagnant property, which is consistent with smart growth principals developed to reduce urban sprawl.
- Strengthened community institutions and catalyzed neighborhood revitalization.
- A state-of-the-art, 132,000-square-foot community center is currently under construction.
- A family service center, indoor and outdoor recreational facilities, an aquatic center, and a child care center will provide the needed civic services to spur community enrichment.
- Redevelopment plans were modified based on the expedited source area delineation to prevent potential exposure.

From an economic perspective, the following benefits were achieved:

- Redevelopment within this urban blighted area will generate local jobs and increase the prosperity of the local community.
- Reduction in poverty, building of assets, and contribution to the local economy by providing a stable source of jobs and income.
- An increase in local wages and the tax base will support the growth of the local government and governmental services and may leverage local investment in future economic development and prosperity.

From an environmental perspective, the following benefits were achieved:

- Triad expedited the complete delineation optimizing the design of the integrated remedial strategy and reducing project uncertainty and provided comprehensive site data on an expedited basis to accurately evaluate remedial alternatives in a cost-effective manner.
- Generation of waste was significantly reduced by implementing GSR principles.
- The remedial approach was dovetailed into the redevelopment plans to ensure that source areas were addressed in a timely fashion. To expedite redevelopment and treatment, objectives were aligned with future uses of each area within the redevelopment plans.
- A greater than 50% reduction in project carbon footprint was realized through an integrated remedial approach.
- A greater than 30% reduction was realized in characterization and remediation project schedules.
- The impacts to ecological habitat and wetland areas were minimized and areas were restored.

Challenges

None provided.

Lessons Learned

The following lessons were recognized on completion of this GSR evaluation:

- Upfront community engagement and involvement are critical in determining local community needs and desires and facilitate support for redevelopment project.

- Concurrent remedial and redevelopment activities allow synergies in redevelopment planning and remedial strategy development to provide a cost-effective remedial solution that not only is protective of human health and the environment but meets the social and economic needs of the local community.

- The Triad approach reduced project uncertainty and expedited the characterization of the source area facilitating the execution of the remedial approach and redevelopment of the property.

- The following factors significantly impacted the carbon footprint of a remedial alternative:
  - ISCO: Supply chain considerations in manufacturing of oxidant can have a significant impact on carbon footprint. The use of green oxidants would significantly reduce the carbon footprint.
  - ISTR: Direct on-site emissions from fuel usage were the significant driver in the overall carbon footprint. Thus, renewable energy or renewable energy credits would assist in reduction of the overall carbon footprint.
  - Excavation: Indirect off-site transportation was the significant contributor to the carbon footprint. Thus, location of disposal site is a major consideration in lowering the carbon footprint.
  - MNA: Even though this alternative has the lowest carbon footprint, monitoring well sampling was the major contributor to carbon footprint. Using passive sampling techniques would further reduce the carbon footprint of this alternative

- The SRT and SiteWise results were comparable. SRT did not require extensive design information for input parameters and is better used prior to the development of detailed alternatives. However, as a technology-based model, SRT does not allow for significant flexibility in modeling an integrated remedial approach or site-specific complexities. As an activity-based model, SiteWise allows the accurate assessment of an integrated remedial approach that may include several different technologies. Even though more design data are necessary for SiteWise, it better assesses a complex integrated remedial strategy. Also, SiteWise output tables and graphs allow the user to readily determine the significant drivers in the carbon footprint, which facilitates the optimization of the remedial approach with respect to minimizing sustainable impacts.

C.3.4 U.S. Environmental Protection Agency Superfund Region 4

Site Name	Cabot Carbon/Koppers Superfund Site
Site Location	Gainesville, Florida
Contact Name	Jessica Gattenby, ARCADIS, U.S., 267-685-1851, Jessica.Gattenby@arcadis-us.com Alexis Troschinetz, ARCADIS, U.S., 612-373-0245, Alexis.Troschinetz@arcadis-us.com
Regulatory Program	RCRA Superfund, EPA Region 4
Affected Media	Groundwater, soil
Contaminants of Concern	Phenols, polyaromatic hydrocarbons, arsenic, chromium, dioxins, furans
Time to Completion	Not applicable
Estimated Cost	Not applicable

Site Description

The site has operated as a wood-treating facility for more than 90 years and is still in operation. The Cabot Carbon/Koppers site was proposed for the NPL in September 1983 and listed as final in September 1984. Several remedial technologies were evaluated as components of the final remedial alternatives, including the following:

- no action
- hydraulic containment
- passive dense, nonaqueous-phase liquid (DNAPL) extraction
- excavation
- slurry wall
- cover
- in situ solidification/stabilization (ISS/S)
- ISCO

The following remedial alternatives were compiled and evaluated in terms of GSR impact. For each remedial alternative, the estimated time frame for O&M and projected costs were compiled, as described below.

Site remediation system	Proposed lifetime (years)	Projected cost ($ millions)
1. No action	---	---
2. Continue current actions • Hydraulic containment • Passive DNAPL extraction	>30	7.31
3A. Surficial aquifer excavation • Excavation to 25 feet • Slurry wall to 65 feet • Cover	5 (3 for active remedy)	66.10
3B. Excavation to the Hawthorn Group middle clay unit • Excavation to 65 feet • Slurry wall to 65 feet • Cover	5	172.55
4A. ISS/S to the Hawthorn Group middle clay unit • ISS/S to 65 feet • Cover • Storm-water monitoring	5	96.95
4B. ISS/S to the Hawthorn Group upper clay unit and in situ biogeochemical stabilization (ISBS) in the Upper Hawthorn • ISS/S to 25 feet • ISCO to 65 feet • Cover	5 (2 for active remedy)	57.60
5A. Vertical flow barrier • Slurry wall to 65 feet • Cover • Hydraulic containment • Passive DNAPL extraction	30 (3 for slurry wall and cover)	19.30

Site remediation system	Proposed lifetime (years)	Projected cost ($ millions)
5B. Vertical flow barrier with ISBS in the Upper Hawthorn • Slurry wall to 65 feet • ISCO 35–65 feet • Covers • Hydraulic containment	30 (3 for active remedy, 30 for hydraulic containment)	36.82
5C. Vertical flow barrier with ISBS in the surficial aquifer • Slurry wall to 65 feet • ISCO 0–25 feet • Covers • Hydraulic containment • Passive DNAPL extraction	30 (3 for active remedy, (30 for passive DNAPL extraction)	25.20
5D. Vertical flow barrier with ISS/S in the surficial aquifer • Slurry wall to 65 feet • ISS/S 0–25 feet • Covers • Hydraulic containment • Passive DNAPL extraction	30 (3 for active remedy, 30 for passive DNAPL extraction)	46.42

<u>GSR Metrics Considered</u>

Several green remediation metrics were evaluated:

- energy use
- air emissions
- water use and impacts
- land and ecosystem impacts
- material consumption
- waste generation

Other balancing criteria were also evaluated, including the following:

- health and safety considerations
- an assessment of the community impacts
- other social and economic implications of the remedial alternatives

Life-cycle costs were incorporated into the proprietary GSR tool but were not used as a metric for this site.

GSR Recommendation(s)

The GSR evaluation predicted the following metrics for each remedial alternative:

Alternative number	Energy (millions kilowatt-hours)	GHG emissions (metric tons CO_2 equivalent)	Water (millions gallons)	Land impacts (acres)	Materials and waste generation (millions cubic feet)	Health and safety (1–10 scale)	Stewardship (1–10 scale)
1	--	--	--	--	--	--	--
2	2.05	3.9	647	1	87	4.3	2
3A	3.26	1,414	136	31	124	2.6	1.4
3B	6.41	4,038	175	49	36	5.5	2.7
4A	5.23	1,246	133	31	23	3.2	1.4
4B	3.61	851	112	31	8	3	1.3
5A	2.28	1,554	35	39	108	2	2.7
5B	2.75	1,665	38	39	109	2.5	2.6
5C	2.38	1,577	36	39	108	2	2.6
5D	3.61	1,926	37	39	108	2	2.7

Health and safety of site workers evaluates the inherent risks associated with site location, working conditions, and remediation activities. Risks associated with site location include geography-dependent hazards, such as those associated with weather, flora, and fauna. Working condition risks consider the site layout and the dangers of doing the work (e.g., work at high heights or near water bodies). There are inherent risks associated with any remediation activity. Some of these risks are similar among varying remedial approaches for a given site (e.g., potential injuries during construction activities and exposure to COCs), and some risks differ greatly depending on the remedial approach (e.g., reagent storage and handling for chemical oxidation in situ remediation versus decalcification maintenance of an air stripper in a pump-and-treat system).

Stewardship is the reflection of project impacts on the short- and long-term sustainability of a surrounding community, the ecosystem, and the local economy. The social element of sustainability includes involving the local community as a stakeholder in the decision making and considering quality-of-life issues, such as noise, lighting, and traffic impacts on the community. Hiring a local workforce and purchasing from local businesses provides economic stimulus to the local community. Stewardship incorporates the environmental element by considering emissions of gases with global climate change potential and use of renewable forms of energy.

GSR results were reviewed by EPA Region 4 and taken into consideration when selecting the final remedy. A remedy that was most similar to RA #4B was selected for implementation. The selected remedy also included a vertical flow barrier wall (an element of Alternatives 3A and the 5 series), a low-permeability cap (not included in any of the original alternatives), and chemical oxidation injection wells (included as a contingency in all of the original alternatives and therefore not included in the GSR comparison of alternatives assessment).

GSR Practices or BMPs Implemented

A formal GSR assessment was performed to estimate the relative impact of each remedial alternative on GSR metrics. The GSR assessment considered GSR impacts of materials used on site as well as GSR impacts associated with transporting materials to the site. The GSR analysis was conducted using a proprietary GSR tool which is a quantitative, web-based tool used to evaluate different GSR approaches and incorporate them in remedy evaluation, selection, and design on a site-specific or portfolio-wide basis.

Challenges

Many of the stewardship considerations are decided on a project basis, not necessarily on a remedy alternative basis. Therefore, it was challenging to see stark differences among remedy alternatives for stewardship.

Lessons Learned

The GSR analysis results also indicate that the selected remedy was a relatively safer remedy for site workers when compared to the other alternatives. The GSR analysis also demonstrated that the project as a whole scored well for stewardship (all alternatives have low values on its scale of 1–10). Remedial selection for this site included participation from an array of stakeholders, and therefore the project coordinators' attention to stewardship topics were heightened.

Appendix D

GSR Resources and Contacts

GSR RESOURCES AND CONTACTS

GSR RESOURCE DIRECTORY

This directory is a compilation of resources identified by the ITRC GSR Team, including state contacts, private organizations, standards-setting organizations, and federal agencies. The team has attempted to locate useful and current information for a broad range of GSR contacts. Not all of these organizations have the same views or philosophies regarding GSR. ITRC provides these resource links as a research resource and does not endorse the positions of any of these organizations. Please send any additions, corrections, or updates to Tom O'Neill, tom.o'neill@dep.state.nj.us, and Rebecca Bourdon, rebecca.bourdon@state.mn.us, Co-Leaders of the ITRC GSR Team.

The directory is organized as follows:

- tribal nations
- states and territories
- federal agencies
- other organizations

Tribal Nations

Institute for Tribal Environmental Professionals (ITEP)
P.O. Box 15004, Flagstaff, AZ 86011-5004
Phone: 928-523-9555, Fax: 928-523-1266, itep@nau.edu
www4.nau.edu/itep/index.asp

The following link includes information on green remediation:
http://www4.nau.edu/itep/waste/docs/2010TWRAP_Booklet.pdf

National Pollution Prevention Roundtable—Tribal Workgroup: www.tribalp2.org/nppr/index.php

States and Territories

State contacts and resources are located in a variety of program areas, from brownfields to the Superfund. The reader should take care to contact each agency directly for the most up-to-date contact information. Nongovernmental resources with single state or regional ties are also found here. See www.itrcweb.org and the ITRC GSR Team contacts later in this appendix for more state contact information.

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California
Department of Toxic Substance Control, www.dtsc.ca.gov/OMF/Grn_Remediation.cfm

Illinois
Illinois Environmental Protection Agency, www.epa.state.il.us/land/greener-cleanups

Illinois Environmental Regulatory Group, www.ierg.org
215 East Adams St., Springfield, IL 62701
Phone: 217-522-5512, Fax: 217-522-5518, iergstaff@ierg.org

Indiana
Indiana Finance Authority–Brownfields Program, www.in.gov/ifa/brownfields/2351.htm

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New York
New York Dept. of Environmental Conservation's Green Remediation Policy, www.dec.ny.gov/docs/remediation_hudson_pdf/der31.pdf

Oregon
Oregon Dept. of Environmental Quality, www.deq.state.or.us/lq/cu/greenremediation.htm

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Wyoming
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307-675-5678, sforis@wyo.gov
The following document has a brief discussion of GSR concepts:
http://deq.state.wy.us/shwd/stp/STPDownloads/Guidance/Guidance_14.pdf

Federal Agencies

U.S. Environmental Protection Agency
The most comprehensive portal to GSR information and links can be found at www.cluin.org/greenremediation.

Carlos Pachon, U.S. Environmental Protection Agency, OSRTI
1200 Pennsylvania Avenue, NW, 5203P, Washington, DC 20460
Phone: 703-603-9904, Fax: 703-603-9135, pachon.carlos@epa.gov

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Region 10
Sean Sheldrake, U.S. EPA
1200 Sixth Ave., Suite 900, Seattle, WA 98101
206-553-1220, sheldrake.sean@epa.gov

Department of Defense

Air Force

Air Force Center for Engineering and the Environment (AFCEE) has a number of GSR-related web pages, including the following:

- GSR—A link to the Sustainable Remediation Tool (SRT) can be found at www.afcee.af.mil/resources/technologytransfer/programsandinitiatives/sustainableremediation/greenandsustainableremed/index.asp
- Sustainability: www.afcee.af.mil/resources/sustainability
- Sustainable Communities: www.afcee.af.mil/resources/sustainability/communities/index.asp

Army

Army Corps of Engineers—Decision Framework for Incorporating Green and Sustainable Practices www.environmental.usace.army.mil/interim_guidance.htm

Army Environmental Command—A search here will turn up several case studies and the following strategic plan document that references green remediation under "future directions": http://aec.army.mil/usaec/cleanup/10stratplan.pdf.

Navy

GSR Portal—Numerous GSR resources found here, including a link to the SiteWise tool: www.ert2.org/t2gsrportal

Department of Energy

DOE Main Page:, www.energy.gov/index.htm

DOE Office of Environmental Management (EM) Page: www.em.doe.gov/Pages/EMHome.aspx (No reference or policy found as green or sustainable remediation on either page—green remediation information coming soon.)

Other Organizations

Association of State and Territorial Solid Waste Management Officials (ASTSWMO): www.astswmo.org/programs_sustainability.htm

Greener Cleanups Task Force

Heather Nifong, Chair, 217-785-4729, heather.nifong@illinois.gov

Sustainable Remediation Forum (SURF): www.sustainableremediation.org

Sustainable Remediation Forum—UK:

www.claire.co.uk/index.php?option=com_content&view=article&id=182&Itemid=78

www.nicole.org/sustainableremediation

ConSoil 2010 Conference: www.consoil.olanis.de

ASTM International
Committee E50 on Environmental Assessment, Risk Management and Corrective Action:
www.astm.org/COMMIT/COMMITTEE/E50.htm
www.astm.org/SNEWS/MA_2010/bassettgreen_ma10.html
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Appendix E

Acronyms

ACRONYMS

AANG	Arizona Air National Guard
ADEQ	Arizona Department of Environmental Quality
AEC	Army Environmental Command
AFB	Air Force Base
AFCEE	Air Force Center for Engineering and the Environment
ANG	Air National Guard
ASTM	ASTM International (formerly American Society for Testing and Materials)
ASTSWMO	Association of State and Territorial Solid Waste Management Officials
BDA	brownfield development area
BEES	Building for Environmental and Economic Sustainability
bgs	below ground surface
BMP	best management practice
CASI	Center for Advancement of Sustainability Innovation
CB	chlorobenzene
C&D	construction and demolition
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CleanSWEEP	Clean Solar and Wind Energy in Environmental Programs
CLU-IN	Contaminated Site Clean-Up Information
CMI	corrective measures implementation
COC	contaminant of concern
CSM	conceptual site model
CVOC	chlorinated volatile organic compound
DCB	dichlorobenzene
DNAPL	dense, nonaqueous-phase liquid
DOE	(U.S). Department of Energy
DOI	(U.S.) Department of the Interior
DSIRE	Database of State Incentives for Renewables and Efficiency
DTSC	(California) Department of Toxic Substances Control
ECOS	Environmental Council of States
EDIP	environmental design of industrial products
EIO-LCA	Economic Input-Output Life Cycle Analysis
EM CX	Environmental and Munitions Center of Expertise
EOS™	Emulsified Oil Substrate
EPA	(U.S.) Environmental Protection Agency
EPD	environmental product declaration
EPS	environmental priority strategy
ERIS	Environmental Research Institute of States
ERP	Environmental Restoration Program
FDEP	Florida Department of Environmental Protection
FS	feasibility study
FUDS	Formerly Used Defense Sites
GHG	greenhouse gas
GIS	geographic information system

gpm	gallons per minute
GREM	Green Remediation Evaluation Matrix
GSR	green and sustainable remediation
GWETRS	groundwater extraction, treatment, and recharge system
hp	horsepower
IDW	investigation-derived waste
IPCC	Intergovernmental Panel on Climate Change
IRM	interim remedial measure
ISBS	in situ biogeochemical stabilization
ISCO	in situ chemical oxidation
ISO	International Organization for Standardization
ISS/S	in situ solidification/stabilization
ISTR	in situ thermal remediation
ITRC	Interstate Technology & Regulatory Council
IUCN	International Union for Conservation of Nature
kwh	kilowatt-hour(s)
LCA	life-cycle assessment
LEED	Leadership in Energy and Environmental Design
LTM	long-term monitoring
MCL	maximum contaminant level
MNA	monitored natural attenuation
MPCA	Minnesota Pollution Control Agency
NaHx	sodium hexametaphosphate (aka SHMP)
NARPM	National Association of Remedial Project Managers
NAVFAC	Naval Facilities Engineering Command
NEBA	net environmental benefit analysis
NICOLE	Network for Industrially Contaminated Land in Europe
NJDEP	New Jersey Department of Environmental Protection
NO_x	nitrogen oxides
NPL	National Priorities List
NRC	National Research Council
OACSIM	Office of the Assistant Chief of Staff for Installation Management
O&M	operations and maintenance
ORNL	Oak Ridge National Laboratory
OSRTI	Office of Superfund Remediation and Technology Innovation
OSWER	Office of Solid Waste and Emergency Response
PBEM	performance-based environmental management
PBR	performance-based remediation
PM	particulate matter
PM10	particulate matter less than 10 μm in aerodynamic diameter
ppb	parts per billion
PRM	Potomac-Raritan-Magothy
PTT	Performance Tracking Tool
PV	photovoltaic
RA	remedial alternative
RAC	remedial action contract

RACER™	Remedial Action Cost Engineering and Requirements
RA-O	remedial action operation(s)
RCRA	Resource Conservation and Recovery Act
RI	remedial investigation
RI DEM	Rhode Island Department of Environmental Management
RMU	remedial management unit
ROD	record of decision
RPM	remedial project manager
RPO	remediation process optimization
RRM	remediation risk management
RSE	remediation system evaluation
SMART	specific, measurable, actionable, relevant, and timely
SO_x	sulfur oxides
SRE	site remediation evaluation
SRT™	Sustainable Remediation Tool™
SSPP	Strategic Sustainability Performance Plan
SURF	Sustainable Remediation Forum
SuRF-UK	Sustainable Remediation Forum—United Kingdom
SVOC	semivolatile organic compound
TCE	trichloroethylene
TIAA	Tucson International Airport Area
TRACI2	Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts 2
USACE	U.S. Army Corps of Engineers
USAF	U.S. Air Force
USGBC	U.S. Green Building Council
UST	underground storage tank
V	volt
VOC	volatile organic compound
WARM	Waste Reduction Model