Framework for Integrating Sustainability Into Remediation Projects

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The US Sustainable Remediation Forum (SURF) created this Framework to enable sustainability parameters to be integrated and balanced throughout the remediation project life cycle, while ensuring long-term protection of human health and the environment and achieving public and regulatory acceptance. Parameters are considerations, impacts, or stressors of environmental, social, and economic importance. Because remediation project phases are not stand-alone entities but interconnected components of the wider remediation system, the Framework provides a systematic, process-based approach in which sustainability is integrated holistically and iteratively within the wider remediation system. By focusing stakeholders on the preferred end use or future use of a site at the beginning of a remediation project, the Framework helps stakeholders form a disciplined planning strategy. Specifically, the Framework is designed to help remediation practitioners (1) perform a tiered sustainability evaluation, (2) update the conceptual site model based on the results of the sustainability evaluation, (3) identify and implement sustainability impact measures, and (4) balance sustainability and other considerations during the remediation decision-making process. The result is a process that encourages communication among different stakeholders and allows remediation practitioners to achieve regulatory goals and maximize the integration of sustainability parameters during the remediation process. © 2011 Wiley Periodicals, Inc.

INTRODUCTION

Sustainable remediation can be defined as a remedy or combination of remedies whose net benefit on human health and the environment is maximized through the judicious use of limited resources (US Sustainable Remediation Forum [SURF], 2009). Organizations sometimes refer to *green remediation*, which can be defined as the practice of considering all environmental effects of remedy implementation and incorporating options to maximize the net environmental benefit of cleanup actions (US Environmental Protection Agency, 2008). In this article, the term *sustainable remediation* reflects a more holistic approach aimed at balancing the impacts and influences of the triple bottom line of sustainability (i.e., environmental, societal, and economic) while protecting human health and the environment. For example, negative impacts, such as those resulting from greenhouse gas emissions, can be reduced without sacrificing the protection of human health and the environment, significantly increasing cost, and reducing productivity. Likewise, positive impacts (e.g., stimulating the local economy surrounding the site by using local resources) can be maximized without sacrificing quality, schedule, or cost.

Significant breakthroughs have occurred in the sustainable remediation field during the last few years, specifically through the publication of guidance, strategies, and policies by government agencies, remediation practitioners, and industry associations. The availability of this information has resulted in remediation practitioners incorporating sustainability parameters (i.e., considerations, impacts, or stressors of environmental, social, and economic importance) more frequently during remedy selection and implementation. However, the methodologies employed when integrating sustainability parameters have generally been inconsistent, caused in part by the lack of a broad-ranging, widely applicable sustainable remediation framework. As a result, remediation project teams evaluating the sustainability of projects may find it difficult to compare sustainability parameters between diverse remediation sites. Additionally, regulatory agency personnel have not been provided a consistent approach to include, validate, and incorporate sustainability into their decision making. By developing this framework, SURF is providing stakeholders, including remediation practitioners and regulatory personnel, a consistent process to consider and balance sustainability parameters throughout the remediation project life cycle.

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SURF was formed in 2006 by a group of remediation professionals passionate about sustainability and with a desire to extend sustainability to remediation. Following the inception of SURF, SuRF-United Kingdom (SuRF-UK) and SURF Australia were founded to pursue similar goals. In June 2009, SURF published a sustainable remediation White Paper that evaluated the current status of sustainable remediation practices (SURF, 2009). The White Paper recognized that there was a need for a well-defined framework for incorporating sustainability parameters into the remediation decision-making process. One of SURF's missions, therefore, as stated in the White Paper, was to establish a framework that incorporates sustainability parameters within and throughout the remediation process while protecting human health and the environment and achieving public and regulatory acceptance.

The resulting Sustainable Remediation Framework (herein referred to as the "Framework") is designed to be accessible and helpful to all stakeholders involved in remediation projects, applicable to different phases of a remediation project, and applicable to different regulatory programs in the United States. Because of its inherent flexibility, the Framework can also be applied to remediation projects outside of the United States. Specifically, the Framework provides a systematic, process-based, holistic approach for (1) performing a tiered sustainability evaluation, (2) updating the conceptual site model (CSM) based on the results of the sustainability evaluation, (3) identifying and implementing sustainability impact measures, and (4) balancing sustainability and other considerations during the remediation decision-making process. When using the Framework, stakeholders must take the approach of *beginning with the end in mind*. As such, determining the preferred end use(s) or future use(s) of a site early in the planning stages of a remediation project is critical and helps stakeholders form a disciplined planning strategy aimed at streamlining the project toward the preferred end use or future use and avoiding unnecessary processes and activities. The resulting collaborative and iterative process encourages communication among different stakeholders and allows remediation practitioners to achieve regulatory goals and maximize the integration of sustainability parameters during the remediation process.

FRAMEWORK OVERVIEW

The 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 upon 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 Framework provides step-by-step guidance to assist practitioners in identifying the data sources required for different sustainability analyses, selecting the most appropriate type and level of analysis, documenting sustainability results, and integrating sustainability parameters into the decision-making process.

The Framework is designed to be easy to use and includes each phase of a traditional remediation project: investigation, remedy selection, remedial design and construction, operation and maintenance (O&M), and closure. Each phase is described in Exhibit 1. The implementation of each of the remediation project phases is traditionally represented in a linear manner as illustrated in the left portion of Exhibit 2. This linear approach suggests that each project phase is a stand-alone entity and that a certain project phase needs to be completed before remediation practitioners can proceed to the next phase. For example, remedy selection can only commence following the completion of the investigation phase. Consistent with this linear approach and as shown in Exhibit 2, sustainability parameters have historically been integrated into existing remediation projects in a phase-by-phase approach.

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Yet remediation project phases are not stand-alone entities, but rather interconnected components of the wider remediation system. These interconnected components interact with each other as the project progresses. Therefore, it would be more beneficial for sustainability parameters to be integrated holistically and iteratively within this wider system, as shown in the right portion of Exhibit 2. Remediation practitioners are encouraged to look backward to previous project phases to integrate sustainable learnings already achieved, as well as forward to future phases to identify and implement opportunities for sustainability improvements as the project progresses. Although it is not necessary to continually return to previous project phases and reassess all of the elements of a project until project completion, revisiting certain elements of previous phases can achieve a more efficient, sustainable remedy.

The Framework is designed to enable remediation professionals to identify sustainable remediation opportunities that may add value to the project while at the same time improve the financial performance of the remedy. Resulting benefits may include fewer impacts to the environment and enhanced relationships with and investments in the local community. The amount of literature demonstrating that sustainability parameters can be adopted successfully into remedies is increasing. Highly successful precedents have been and continue to be established as sustainability parameters are integrated into other industries upstream of the remediation industry (e.g., research and development, manufacturing, distribution). In the same way, many opportunities exist within the remediation industry to integrate sustainability parameters as a way to generate higher value (Exhibit 3).

Exhibit 1. Project phase descriptions

Remediation Phase	Description (in Context of Framework)
Investigation	In this phase, remediation practitioners identify the impacted media, contaminants of concern, and potential risks to human health and the environment. The project objectives and scope are developed, and stakeholder concerns are identified. Stakeholder groups are often contacted during this phase to provide input during decision making. Field activities are performed to gather pertinent information regarding site-related impacts. Effective project planning can help optimize data collection and analysis. Sustainability considerations should be specified in work plans and implemented in the field. A preliminary, site-specific conceptual site model (CSM) should be developed based on the information obtained during this phase.
Remedy Selection	In this phase, remediation practitioners use the information obtained during the investigation phase to evaluate the feasibility of applicable remedial alternatives. Practitioners should focus the evaluation on the preferred end use(s) or future use(s), while always being protective of human health and the environment. The results obtained during this phase should be balanced with project considerations (including sustainability) to determine the most appropriate remedy. The information gained during this phase serves to improve the CSM and define a preferred approach to site management.
Remedial Design and Construction	In this phase, remediation practitioners design the approaches and technologies that will be applied to the site, including the integration of sustainability parameters into the design. Throughout the design process, remediation practitioners should ensure that sustainability parameters are continually improved through optimization and management of the site. Practitioners should consider how sustainability will be implemented and recorded during the construction and operation and maintenance (O&M) phases and should establish triggers within the design for re-evaluation of the remedy where appropriate. In the construction phase, practitioners should have the necessary resources in place to conduct performance monitoring during the O&M phase. The sustainability objectives established during the design and tendering process should be implemented and monitored. If needed, practitioners can identify and implement additional sustainability opportunities during this phase.
Operation and Maintenance	During this phase, remediation practitioners should assess opportunities for continual sustainability improvement of the system as site conditions change and remediation technologies advance.
Closure	During this phase, remediation practitioners should ensure that the preferred end use(s) or future use(s) is achieved and that the site can be reused. Practitioners should determine whether the sustainability objectives have been met and should use this information to improve the sustainability approach for future projects.

Intended Use

Intended users of the framework include all stakeholders involved with or affected by a remediation project, regardless of prior sustainable remediation experience. Individuals who are directly and indirectly affected by the remediation project activities are considered stakeholders. The most obvious stakeholder groups include responsible parties and regulatory entities with jurisdiction over the cleanup. Other stakeholder groups include (but are not limited to) the workers who will participate in the remedy application, the local community and surrounding community(ies), industry service

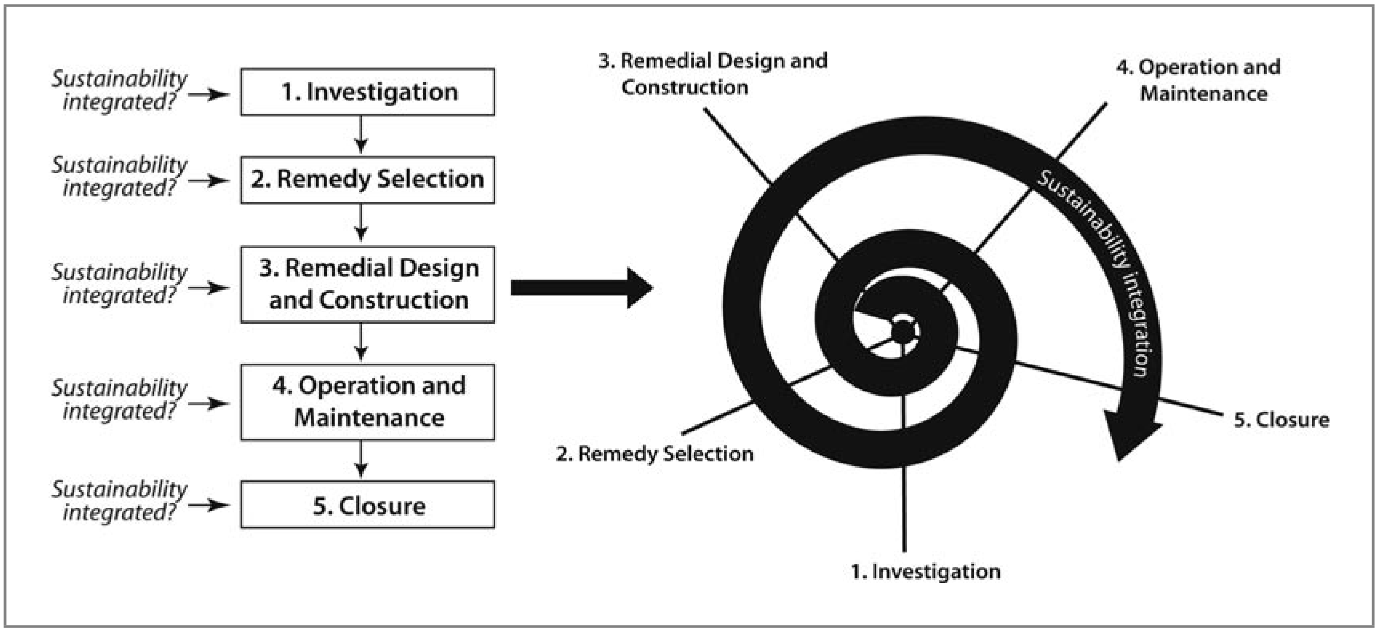

Exhibit 2. Linear phase-by-phase integration of sustainability

providers, and special interest groups. Examples of members within the different stakeholder groups are provided in Exhibit 4.

As illustrated later in this document, the Framework is intended to help remediation practitioners make decisions when applying existing programs (including regulatory frameworks) so that environmental, social, and economic considerations are balanced (or optimized) with regard to the scope of a remediation project. By design, the Framework creates a natural arena for collaborative decision making between stakeholders. As such, the Framework is intended to be used by these stakeholder groups as well.

Process-Based Versus Goal-Based Implementation

Traditional remediation projects often focus on goal-based implementation to achieve a particular outcome or goal, which is often to achieve a regulatory requirement. On the other hand, the Framework provides a process through which information (e.g., data, technologies, interests, resources) is routinely incorporated into the decision-making process that focuses on collaborative dialogue between different stakeholders. As such, the Framework can be described as one that uses process-based implementation. Process-based implementation focuses on understanding how a program works and evaluating the components that can be balanced to achieve the optimal, most sustainable solution (or remediation strategy). A process-based implementation can include several decision points that are necessary before the final outcome is achieved. In the Framework, these decision points do not act to slow down the remediation project; instead, they form part of a disciplined planning strategy aimed at streamlining the project by avoiding unnecessary processes and activities. In this way, process-based implementation is adaptable over long periods of time and can provide flexibility in the face of changing conditions or requirements. This type of implementation is collaborative in structure and requires heightened attention to communication.

Exhibit 3. Examples of value generated by integrating sustainability concepts into the remediation project life cycle

Remediation Project Phase	Example	Relative Impact on Sustainability
Investigation	Perform effective project planning to (1) reduce the number of field mobilizations required, (2) use resources local to the site, and (3) collect the most optimal selection of data necessary for decision making.	Incremental
Remedy Selection	Consider sustainability parameters when evaluating multiple remedial alternatives to select a remedy optimally balanced for achieving the remedial objectives of the project and site.	High
Remedial Design and Construction	Balance detailed operational considerations to optimize sustainability within the selected remedy or modify the remedy design based on new information.	Incremental High (if design modified)
Operation and Maintenance	Adjust or change processes to match site conditions that may have altered during remediation.	Incremental Generally moderate, occasionally high (if process modified substantially)
Closure	Balance the impacts of continuing remediation activities (assuming the protection of human health and the environment) with the value it provides. (For example, O&M can be discontinued in an area that has no adverse effect on human health or the environment so that resources can be reallocated to generate higher value at other sites.)	Incremental Moderate (if project accelerated to closure phase in lieu of ongoing O&M) High (if remediation activities stopped and human health and the environment protected)

Goal-based implementation relies on goals (for example, regulatory requirements) as outcome metrics for the project, with the advantage that these requirements are easily measured and quantifiable. By evaluating only how to reach the required cleanup goals, these remediation projects can prove inflexible during implementation. In addition, the structure of goal-based implementation can make it difficult for each stakeholder group to participate in decision making or stakeholders may believe that their input is not valued within the goals of the structure. Although the Framework requires achievement of the regulatory requirements as outcome metrics as well, interim metrics and assessment points can be included to ensure that collaborative decision making and stakeholder involvement occur throughout the remediation life cycle. In this manner, the sustainability of a remediation implementation is continually evaluated and optimized for the benefit of all stakeholders. By using the Framework, remediation practitioners can achieve regulatory goals, and stakeholders can benefit from the collaborative and iterative process.

FRAMEWORK APPLICATION

The Framework allows remediation practitioners to incorporate sustainability parameters during any remediation project phase. As shown in Exhibit 3, the point at which

Exhibit 4. Stakeholder groups and example members

Stakeholder Group	Example Stakeholder Members
Responsible Parties	Property owner
	Operator
	Organization that accepts responsibility for the property
	Organization representing the responsible party
Regulatory Entities	Federal agencies
	State agencies
	Local agencies
	Tribal organizations
Local and Surrounding Communities	Residents
	Regular visitors
	Elected officials
	Local businesses
	Nongovernmental organizations
	Municipal managers
Industry Service Providers	Environmental consulting firms
	Specialized remediation companies
	Technology contractors and related service providers
	Treatment and disposal facilities
	Soil, aggregate, and vegetation vendors
Workers	Workers operating remediation equipment
	Waste haulers
Special Interest Groups	Academics
	Financers and insurers

sustainability parameters are incorporated into a project life cycle affects the amount of value that can be generated. For example, in the remedy-selection phase, a large number of high-level parameters are evaluated against multiple remedial alternatives. Sustainability parameters can also be incorporated at the end of the remedial design and construction phase. At this phase, however, it is likely that less value will be generated because the point of incorporation is closer to the end of the remediation life cycle. Incorporation at the end of the life cycle (versus during the remedy-selection phase) results in less opportunity to affect downstream phases and decisions. Although fewer opportunities exist for generating value from incorporating sustainability parameters later in the remediation life cycle, value can still be derived from integrating sustainability parameters at any phase.

Future-Use Planning

Although the preferred end use(s) or future use(s) of a site serves as the end of the remediation life cycle, it also serves as the beginning of the site's next life cycle. The US EPA's Brownfields Program recognizes the relationship between the remediation and

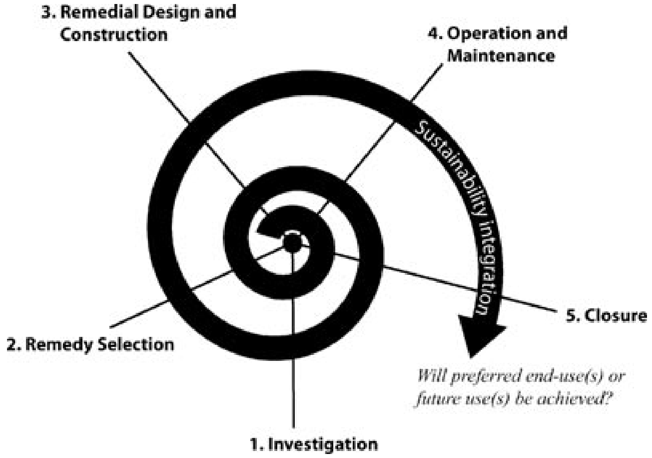

Exhibit 5. Incorporation of preferred end-use or future use planning into the remediation project life cycle

future use and, therefore, manages site cleanup with the preferred end use or future use in mind, be it site expansion, redevelopment, or reuse. A transition strategy is intrinsically linked to the preferred end use(s) or future use(s) of the site and moves the project from the remediation process to the next appropriate long-term use after remedial objectives (including regulatory objectives) are achieved.

Preferred End Use or Future Use

The types of preferred end use or future use are broad ranging and may include residential use, recreational use, or simply continued operation of an industrial or manufacturing site (for example, in the case of an accidental spill at a facility). In all cases, however, preferred end-use or future-use considerations are critical to the Framework under the premise of beginning with the end in mind. Under this premise, all planning, activities, and resources dedicated to remediating a site should align and add value to the preferred end use(s) or future use(s) from the inception of the project. This is analogous to building a home and being conscientious to incorporate the future owners' interests into the building plans, as well as periodically checking with the future owners to ensure continued alignment with their interests as construction proceeds. At a very basic level for remediation, "beginning with the end in mind" means determining if the remediation goals will allow or restrict future residential use.

With this in mind, a successful sustainable remediation includes property end-use care requirements that can be implemented to ensure long-term protection of human health and the environment. Because sustainable remediation is typically performed by containing as much of the corrective action on-site as feasible (e.g., reducing off-site discharge, reducing off-site hauling or disposal, increasing on-site treatment), considering preferred end-use or future use options is crucial in achieving a more sustainable remediation. Thus, the Framework includes the preferred end use(s) or future use(s) of a site as part of the conceptual representation of the project life cycle (Exhibit 5). As seen in this exhibit, remediation practitioners should continually address and re-evaluate the preferred end use(s) or future use(s) of a site as the project progresses and new information becomes available.

Sustainable remediation programs are conducive to generating ancillary environmental end-use benefits (e.g., open space and wildlife habitats) or socioeconomic benefits for the community (e.g., alternative land use, housing). In this way, properly planning for the most beneficial preferred end-use or future-use options will ultimately serve the community by providing environmental and socioeconomic assets while protecting human health and the environment. Planning for preferred end use(s) or future use(s) of a site is a site-specific process that considers, among other things:

- local laws, rules, and ordinances as they relate to the site, deed restrictions, and the likely pattern and nature of future development around the site;
- the ability to implement and maintain appropriate institutional controls, where applicable;
- long-term technical, geotechnical, environmental, ecological, and land-use issues that may include stormwater management and surface-water quality preservation;
- potential liabilities, regulatory requirements, and community needs;
- the end use of the site that would be the most acceptable and/or provide the greatest value to stakeholders; and
- opportunities to incorporate sustainable parameters into the redevelopment process.

It is important to determine the end use or future use of a site early in the planning stages of a remediation project to maximize the flexibility available to meet the needs of the key stakeholders (e.g., site neighbors, local community) involved. For some stakeholders, the end use or future use of the site is equally important as or even more important than the remediation process implemented to obtain the end use. For example, remediation practitioners can employ covenants, deed restrictions, or other land-use control mechanisms to ensure that the land is used only as intended. Although deed restrictions can limit the financial value and the breadth of end-use opportunities available, they are an important component of community planning and supplement potential beneficial future land-use options. Therefore, collaborating with stakeholders to ensure that their views and concerns are integrated into the end-use strategy is essential.

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Transition Strategy

As mentioned earlier, a transition strategy moves the project from the remediation process to the next appropriate long-term use after remedial objectives are achieved. Within the iterative nature of the Framework, the transition strategy serves as a checkpoint for ensuring that the remedial goals remain aligned with the preferred end use(s) or future use(s) and the sustainability goals of the project. In fact, using a transition strategy in a way that considers the preferred end use(s) and future occupants of the site follows the principle of sustainable land use. In this principle, land can be made available for beneficial purposes while providing economic benefits to stakeholders. With this in mind, remediation practitioners should develop a transition strategy that supports project closure once it is demonstrated that residual contaminants will not potentially cause adverse impact to human health or the environment.

Exhibit 6. Example considerations when developing a transition strategy

It is not uncommon for a remediation site to remain unoccupied and unproductive due to the disassociation of the following items: (1) residual contamination target levels, (2) selected remedy and technology implemented, and (3) preferred end-use and associated future uses of the site. Remediation practitioners should perform careful, iterative evaluation of these three items in combination to avoid the unnecessary risk, cost, and lost opportunity associated with this type of site.

Remediation practitioners should develop and apply a transition strategy early in the remediation process to ensure that the following is achieved: (1) the residual contamination target levels are appropriately protective of the preferred end use and future uses of the site, (2) the remedy selected and technology implemented are appropriate for achieving the residual contamination target levels, and (3) the remedy implementation is conducted in a way that facilitates the preferred end use of the site.

Ideally, remediation practitioners should develop a transition strategy during the remedy-selection phase and then iteratively refine it as new information is obtained during subsequent remediation phases. Obtaining input, feedback, and continued buy-in from stakeholders helps align remedial goals with the future site use. The primary points considered when developing a transition strategy include (1) whether all aspects of future use have been considered (e.g., people using the site), (2) whether remedial goals can be achieved so the site can be transitioned, and (3) whether the sustainability of the remediation life cycle is optimally balanced to achieve the remedial goals and lead into future-use goals. Examples of the types of items that should be considered when developing a transition strategy are provided in Exhibit 6.

The transition strategy can also include provisions for implementing intermediate steps (e.g., switching from active to passive remediation, reducing the number of wells that require monitoring after risks are reduced to an acceptable level), where applicable. These intermediate steps help optimize the use of resources (e.g., the raw materials required for monitoring, skilled labor to implement monitoring requirements). In addition, these intermediate steps assist the remediation practitioner in balancing related sustainability impacts, such as the fuel consumption and atmospheric emissions associated with the soil vapor extraction system operation described in Exhibit 7. Again, the intermediate steps are supported by the sustainable human health and environmental impact assessments, as well as the tiered sustainability evaluation and the sustainable CSM described in the next sections.

Tiered Sustainability Evaluation

Many approaches exist for performing sustainability evaluations at remediation sites. The approach proposed in this document is aligned with the tiered approach for Risk-Based Corrective Action (RBCA), a process enabling decisions to be made based on the risks posed to human health and the environment (ASTM International, 2010). This approach is also similar to the tiers discussed in the SuRF-UK framework (2010). As seen in Exhibit 8, the Framework allows users to perform a tiered sustainability evaluation that informs the CSM and enables remediation practitioners to identify and implement sustainability impact measures. The selection of the appropriate tier of evaluation is based on a review of

Exhibit 7. Case study demonstrating disproportionate environmental impacts

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A former service station caused the release of fuel to the subsurface, creating a large plume that was impacting a drinking-water aquifer. An off-site groundwater pump, treat, and reinjection system was capturing the off-site dissolved plume, and a soil vapor extraction (SVE) system was reducing the source of vadose-zone contaminants leaching to groundwater. The CSM was well defined for the site and showed that the residual soil contamination present after remediation would not migrate to underlying groundwater. Although the site obtained closure for groundwater impacts, the responsible party was required by the local regulatory agency to operate the SVE system to remove residual contamination present in soil.

A carbon footprint analysis was performed to determine the greenhouse gas emissions associated with SVE system operation. This evaluation was conservative because it did not consider the fuel required to power the equipment used to extract the contaminant. Results indicated that, over the last year of operation, the SVE system expended 25 gallons of fuel for every 1 gallon of fuel extracted from the soil. As SVE efficiency decreased over the last year, the system expended 32 gallons of fuel for every 1 gallon of fuel extracted from the soil. Overall, the annual carbon footprint of the SVE system was equivalent to the annual greenhouse gas emissions generated by 13 passenger vehicles. This case study demonstrates the value of evaluating whole-system environmental considerations so that remediation activities do not create disproportionate environmental impacts.

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a number of project considerations, including (but not limited to) the project objectives, scope, complexity, budget and resources, and concerns of stakeholders (Exhibit 8). A more detailed description of these project considerations is provided in Exhibit 9.

In the tiered sustainability evaluation, Tier 1 comprises a standardized, non-project-specific, qualitative evaluation. Tier 2 relies both on project-specific and non-project-specific information and follows a semiquantitative approach. Tier 3 is the most detailed tier, is project-specific, and includes a quantitative evaluation. The objective of the sustainability evaluation, regardless of the evaluation tier selected, is to balance parameters in a manner that increases the positive sustainability impacts of the project while reducing the negative sustainability impacts. A more detailed description of each tier is as follows:

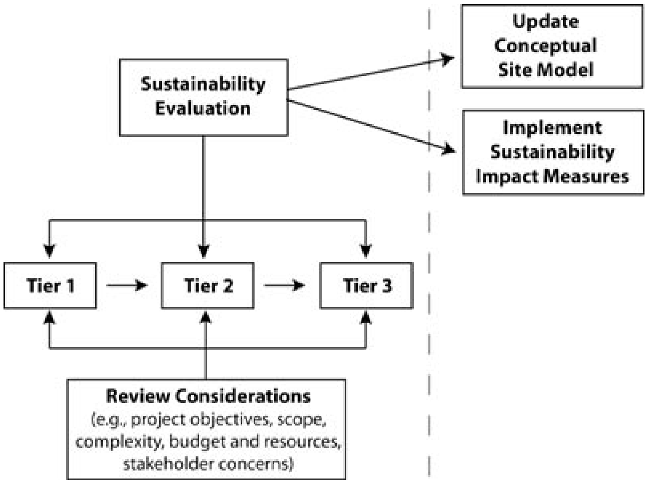


Exhibit 8. Tiered sustainability evaluation

Exhibit 9. Considerations for selecting the appropriate tiered sustainability evaluation for a project

Objectives: Project objectives can include project life-cycle objectives and phase-specific objectives. Remediation practitioners should consider both of these objectives when selecting which tiered sustainability evaluation to perform. An example of a project life-cycle objective is to begin a remediation project with the preferred end use(s) or future use(s) in mind. Examples of phase-specific objectives are to complete the phase in a timely manner and to optimize resource utilization.

Scope: The project scope is defined by the physical extent of the project in terms of both space and time. The scope may be influenced by impacted media, the types of contaminants requiring remediation, the extent of contamination, and cleanup goals. Spatially, the scope is not necessarily defined by the project boundary. Instead, remediation practitioners should adopt a more holistic approach that considers the boundary of the impacted area (which can extend beyond the project boundary). For example, resource inputs (e.g., raw materials) and outputs (e.g., solid and/or liquid wastes) often travel beyond the physical boundary of the site. When evaluating factors that affect timing, remediation practitioners should consider the complexity of the project, the stakeholder expectations, and the remediation approaches and technologies.

Complexity: The complexity of the project is usually dependent on the project scope. Generally, the project complexity drives the complexity of the sustainability evaluation and, therefore, usually influences the selection of the applicable sustainability evaluation tier. As a general rule of thumb, the sustainability analysis tier is proportionate to the level of complexity of the project. Project complexity can be influenced by the following: (1) type and extent of contamination; (2) technical difficulties of remediation; (3) availability of data, including sustainability data; (4) number of stakeholders involved; (5) level of analysis required; and (6) number of technologies employed.

Budget and Resources: Many remediation projects are constrained by budget and resources. Remediation practitioners should balance the level of sustainability analysis in accordance with the budget and available resources. The budget typically determines what resources may be accessed and allocated to complete a remediation project. Resources can include the following: remediation technologies implemented, manufactured goods and raw materials used, energy and equipment applied, and man-hours spent. Results from a sustainability evaluation can impact the budget positively by identifying opportunities to create tangible value through more sustainable practices, processes, or technologies. For example, cost reductions can be achieved by reusing materials that would be otherwise classified as waste or by reusing treated water instead of buying clean water. Remediation practitioners should recognize that, in certain circumstances, it is beneficial to implement a sustainable remediation strategy that exchanges increased capital costs in the short term for increased remediation efficiency and significant cost savings in the long term.

Stakeholder Concerns: A key objective during the sustainability evaluation is to encourage collaborative participation with stakeholders to ensure that their views and concerns are taken into account during the remediation process. Remediation practitioners should present the sustainability evaluation openly in layman's terms so that the process and results can be easily understood by all stakeholders.

- *Tier 1*: Tier 1 is the simplest tier and comprises a qualitative, standardized sustainability evaluation. In a Tier 1 evaluation, checklists, lookup tables, guidelines, rules of thumb, and matrices are just some examples of the information that can be used to identify best management practices for different activities, processes, and technologies for maximizing positive sustainability impacts. The Tier 1 evaluation considers only the most significant sustainable aspects of the project. For example, a Tier 1 evaluation would welcome involvement by stakeholders; however, the involvement would be limited. The standardized approach in this tier sustainability evaluation reduces the cost and resources necessary to perform the evaluation and interpret the results. Exhibit 10 provides an example of a Tier 1 sustainability evaluation. Descriptions of

Exhibit 10. Tier 1 sustainability evaluation example

A value-engineering evaluation was conducted for a remedial design involving the excavation and disposal of 4,000 cubic yards of lead-impacted soil. Inherent in the design was the disposal of the soil at the closest hazardous waste disposal facility, which was located 400 miles from the site. A Tier 1 sustainability evaluation was prepared as part of the value-engineering evaluation. A matrix was developed listing the major remediation activity tasks, and the tasks were ranked as requiring low, moderate, or high equipment usage and transportation demand. Soil transportation was ranked as high in the areas of transportation and disposal demand and costs, local truck traffic, atmospheric emissions, and fuel usage. Results indicated that *in situ* soil stabilization was the preferred approach because it allowed disposal of the treated soil at a local, nonhazardous landfill. The on-site approach was implemented and led to a reduction of approximately 150,000 miles of truck travel.

Exhibit 11. Data needs, applicability, and available tools for performing tiered sustainability evaluations

Evaluation Type	Type of Analysis	Applicability	Available Approaches
Tier 1	Qualitative evaluation based on the most significant sustainability elements of the project (e.g., energy consumption, extent of stakeholder participation)	Smaller-scale sites that have time, budget, and resource constraints; demonstrate low risk or reduced complexity; *and* would not likely benefit significantly from a higher tiered evaluation	– Checklists – Best management practices – Industry guidelines – Rules of thumb – Matrices – Rating system
Tier 2	Semiquantitative analysis that focuses on a few site-specific information areas to supplement Tier 1 evaluation results	Sites that are moderately complex *or* that necessitate a greater consideration of and involvement by stakeholders	– Spreadsheet-based – Scoring and weighting systems – Site-specific characterization – Monitoring data assessment – Risk projections – Exposure simulations – Emission calculations – Simple cost-benefit analysis
Tier 3	Site-specific, in-depth, quantitative analysis of practices, processes, and technologies	Sites that are significantly complex, may necessitate significant consideration of and involvement by stakeholders, *and* have availability of data	– Life-cycle assessment – Detailed cost-benefit analysis – Spatial and temporal boundary evaluation – Energy analysis models – Social return on investment analysis – Social accounting and auditing – Net benefit models

different approaches for performing a Tier 1 sustainability evaluation are provided in Exhibit 11.

- *Tier 2:* In Tier 2 evaluations, remediation practitioners use project-specific information to perform more detailed, semiquantitative evaluations than Tier 1 evaluations. Tier 2 evaluations have greater stakeholder involvement than Tier 1 evaluations because

Exhibit 12. Tier 2 sustainability evaluation example

A remedial optimization evaluation was performed for a petroleum-contaminated site being remediated via a pump-and-treat system. Although the pump-and-treat system has removed a substantial quantity of mass during its five years of operation, contaminant concentrations are currently asymptotic at levels just above cleanup target values. The following four optimization scenarios of the current system were created:

- ***Scenario 1:*** Maintain status quo and continue system operation.
- ***Scenario 2:*** Discontinue system operation, inject chemical oxidant in the source area, and allow the dilute plume to naturally attenuate.
- ***Scenario 3:*** Discontinue system operation, inject an oxygen source in the source area to stimulate aerobic bioremediation, and allow the dilute plume to naturally attenuate.
- ***Scenario 4:*** Discontinue system operation and allow the entire site to naturally attenuate.

A Tier 2 sustainability evaluation was performed and the remaining time to reach the remedial objectives was calculated for each scenario. The greenhouse gas emissions associated with each scenario were also estimated and ranked. The results are summarized in the table below.

Scenario Number	Additional Time to Reach Remedial Objectives (years)	Greenhouse Gas Emissions Ranking*
1	10	1
2	3	2
3	8	4
4	20	3

*The scenario with the largest greenhouse gas emissions was ranked as 1.

Scenario 1 resulted in the largest greenhouse gas emissions because of the electricity production during the ten-year life cycle of the scenario. Scenario 2 was ranked second due to the elevated greenhouse gas emissions during oxidant production. Scenario 4 was ranked third in greenhouse gas emissions because of the intense transportation requirements associated with monitoring natural attenuation over a ten-year period. Scenario 3 was ranked lowest in greenhouse gas emissions because low quantities of the oxygen source were required to facilitate aerobic bioremediation. The Tier 2 sustainability evaluation results were compared to the effectiveness, cost, and ease of implementation of the remedy in each scenario. Scenario 3 was selected based on a relatively short life cycle, low cost, low greenhouse gas emissions, and ease of implementation (i.e., via the current monitoring network).

stakeholders are encouraged to provide input during the sustainability evaluation. The use of a more project-specific approach in this tier requires more resources to perform the evaluation and interpret the results, which results in increased costs. Exhibit 12 provides an example of a Tier 2 sustainability evaluation. Descriptions of different approaches for performing a Tier 2 sustainability evaluation are provided in Exhibit 11.

- *Tier 3:* Tier 3, the most detailed sustainability evaluation tier, requires a large quantity of project-specific data. Sophisticated mathematical tools (e.g., life-cycle analysis [LCA] methodologies) would likely be of great value in conducting the sustainability evaluation. In Tier 3 evaluations, stakeholders are very involved and have a more

Exhibit 13. Tier 3 sustainability evaluation example

At a former manufacturing facility planned for redevelopment, cleaning solvents were historically used and disposed of in drains leading to a field. Subsequent groundwater investigations delineated a four-acre groundwater plume of trichloroethene and 1,4-dioxane in a shallow superficial aquifer and a deeper semiconfined aquifer. The shallow plume was also discharging into a neighboring bay and impacting the bay sediments. Commercial fishermen and community organizations are very active in public participation meetings, as the impacts are potentially detrimental to their livelihoods and the local economy. A draft feasibility study was prepared, suggesting remedial alternatives for groundwater and sediment treatment. Groundwater remedial alternatives included pump and treat, *in situ* anaerobic bioremediation, and permeable reactive barriers. Remedial alternatives proposed for sediment included dredging, sediment capping, and land-use controls. Following a review of the draft feasibility study, state regulators requested that an in-depth life-cycle assessment (LCA) be performed of greenhouse gases, criteria pollutants, energy demand, and marine ecotoxicity to help with the decision-making process. Local organizations and commercial fishermen requested that the social and economic impacts of the various remedies also be evaluated.

A Tier 3 sustainability evaluation was performed due to the complexity of the environmental conditions, presence of human health and environmental risk, stakeholder interests, future land redevelopment concerns, and recognition of the overall cost and economic impact of the proposed remedies. LCA results were integrated into a cost-benefit analysis and were presented to the community and regulators to support the remedy selection. Permeable reactive barriers were selected as the preferred groundwater remedy based on its low impact on future development; protectiveness of surface water, groundwater, and ecological resources; and use of locally available construction forces, lower life-cycle emissions, and reduced energy demands. Thin-layer sediment placement was selected as a sediment capping technology based on the availability of local, clean dredged sediment and its minimal invasiveness during implementation. Dredged sediments were stored within a facility only three miles from the site, reducing the truck traffic impacts to the nearby community.

defined role in the decision-making process. Although Tier 3 evaluations generally cost more, this approach provides a more robust sustainability evaluation than the other tiered approaches. Exhibit 13 provides an example Tier 3 sustainability evaluation. Descriptions of different approaches for performing a Tier 3 sustainability evaluation are provided in Exhibit 11.

At a minimum, it is recommended that remediation practitioners perform a Tier 1 sustainability evaluation at the beginning of the remediation project. Practitioners may then shift to a more detailed tier within a specific project phase or during subsequent project phases. Regardless of the tier applied and the project phase, remediation practitioners can use the Framework to continually improve the sustainability evaluation by refining the sustainable inputs with more accurate and complete information. This perpetual refinement can lead to performing a higher, more detailed, project-specific tiered sustainable evaluation as the project progresses.

For example, a remediation project team who opts for a Tier 1 sustainability evaluation during the investigation phase and a Tier 2 sustainability evaluation during the remedy-selection phase is not locked into these decisions during subsequent phases. If altered site conditions are encountered during remedial design and construction, the remediation project team can change to a Tier 3 sustainability evaluation for the remainder of this project phase. As presented in Exhibit 9, the selected tier is dependent on many considerations. Therefore, the project team can return to a Tier 2 sustainability evaluation during O&M and closure. Although the Tier 2 evaluation is not as detailed as the Tier 3

Exhibit 14. Environmental, social, and economic indicators developed by SuRF-UK

Environmental	Social	Economic
– Impacts on air (including climate change)	– Impacts on human health and safety	– Direct economic costs and benefits
– Impacts on soil	– Ethical and equity considerations	– Indirect economic costs and benefits
– Impacts on water	– Impacts on neighborhoods or regions	– Employment and capital gain
– Impacts on ecology	– Community involvement and satisfaction	– Gearing*
– Use of natural resources and generation of wastes	– Compliance with policy objectives and strategies	– Life span and “project risks”
– Intrusiveness	– Uncertainty and evidence	– Project flexibility

*Gearing is the process of bringing economic resources to a region or a project that may increase its attractiveness (SuRF-UK, 2009).

evaluation, sustainability observations made during previous project phases inform subsequent evaluations. In this example, the result is a more robust Tier 2 sustainability evaluation because of the knowledge of sustainability improvements from previous phases.

Metrics

Metrics form an integral part of the tiered sustainability evaluation. Metrics are the measurable values that correlate to a parameter being evaluated, such as carbon dioxide emissions, groundwater or energy use, local laborers trained, or local suppliers utilized. While any number of metrics *may* be applied to assess the sustainability of a particular remediation project, the use of more metrics *does not* necessarily translate to a site being better assessed. Metrics should be selected for a remedy according to the specific sustainability considerations being applied and in accordance with those influences in which key stakeholders express specific interest. In short, the Framework assists in the selection of appropriate metrics.

The list of parameters and metrics is growing, particularly as the number of stakeholders interested in the remediation project life cycle continues to increase and stakeholder interests continue to expand. To provide an initial point of reference, SURF created a table of standard parameters, associated metrics, and example sustainable activities common to elements of each phase of remediation. A summary of the table is published within this issue of *Remediation* (Butler et al., 2011), and a more detailed table will be available online at www.sustainableremediation.org. Both tables serve as a guide for determining which metrics are the most appropriate for assessing the sustainability parameters applied for a particular remedy. The table also provides guidance on what typically comprises each particular metric, how each metric can be implemented, and the anticipated challenges for applying each metric.

SuRF-UK also addressed the issue of metrics in its point-in-time compilation of sustainability guidance for remediation projects (SuRF-UK, 2009). The document provides comprehensive lists of sustainability “indicators” (which are analogous to metrics) organized by sustainability indicator category. Exhibit 14 illustrates the overarching categories of indicators identified in the SuRF-UK document.

Tools

Various public and proprietary tools and methodologies have been developed specifically to help remediation practitioners perform sustainability evaluations. These tools and methodologies provide varying levels of scope, complexity, and analysis. A listing of tools will be available on the SURF website (www.sustainableremediation.org) as a supplement to this document. It is important to note that the list is not exhaustive; other tools may be available to assist remediation practitioners perform tiered sustainability evaluations. Although SURF does not endorse a specific tool, it recognizes the value of each tool in performing different types of evaluations.

Similar to its goal of promoting a consistent framework for sustainable remediation, SURF recognizes the value of a consistent, holistic approach when performing sustainable remediation evaluations. Therefore, SURF has developed a flexible nine-step process that is transparent and reproducible for conducting and documenting footprint analysis and LCA during remediation sustainability evaluations (Favara et al., 2011). This process can be applied to Tier 2 and 3 evaluations where quantitation is used. The guidance is published within this issue of *Remediation* and will also be available on the SURF website (www.sustainableremediation.org). It is designed to assist remediation practitioners in evaluating the impacts resulting from potential remediation activities so that preventable impacts can be mitigated.

Sustainable Conceptual Site Model Development

A sustainable CSM can be used as a platform for illustrating how humans and the environment may be affected not only by impacts at a site but also by sustainability impacts caused by remediation activities. The CSM is a fundamental tool that can be used during decision making to address difficult questions, for example:

- Is the site adequately characterized?
- What is the concentration and total mass of contamination present at the site?
- Can treated or untreated groundwater be used beneficially at the site?
- Is closure possible based on the remediation approach implemented at the site?
- How will reaching the remediation goal change the risk at the site?

> Similar to its goal of promoting a consistent framework for sustainable remediation, SURF recognizes the value of a consistent, holistic approach when performing sustainable remediation evaluations.

Traditionally, a CSM concentrates on elements, such as exposure routes and pathways, contaminants of concern and their sources, current and future land use, impacted media, and receptors. Whole-system sustainability, which considers how different sustainability parameters interconnect with each other to affect the remediation system as a whole, is often not afforded as much importance. However, in the Framework and as illustrated in Exhibit 15, traditional CSM elements and sustainable CSM elements are complementary and form a sustainable CSM. Sustainability becomes a driving principle within each CSM element (including both traditional and more sustainable elements). The list of sustainable elements in Exhibit 15 is not exhaustive; remediation practitioners can identify additional sustainability elements to incorporate into the CSM.

Exhibit 16 illustrates the shift of moving from a traditional CSM to a sustainable CSM by incorporating value-adding sustainable data alongside traditional data. The level of data (e.g., generic versus site-specific, qualitative versus quantitative) included in the

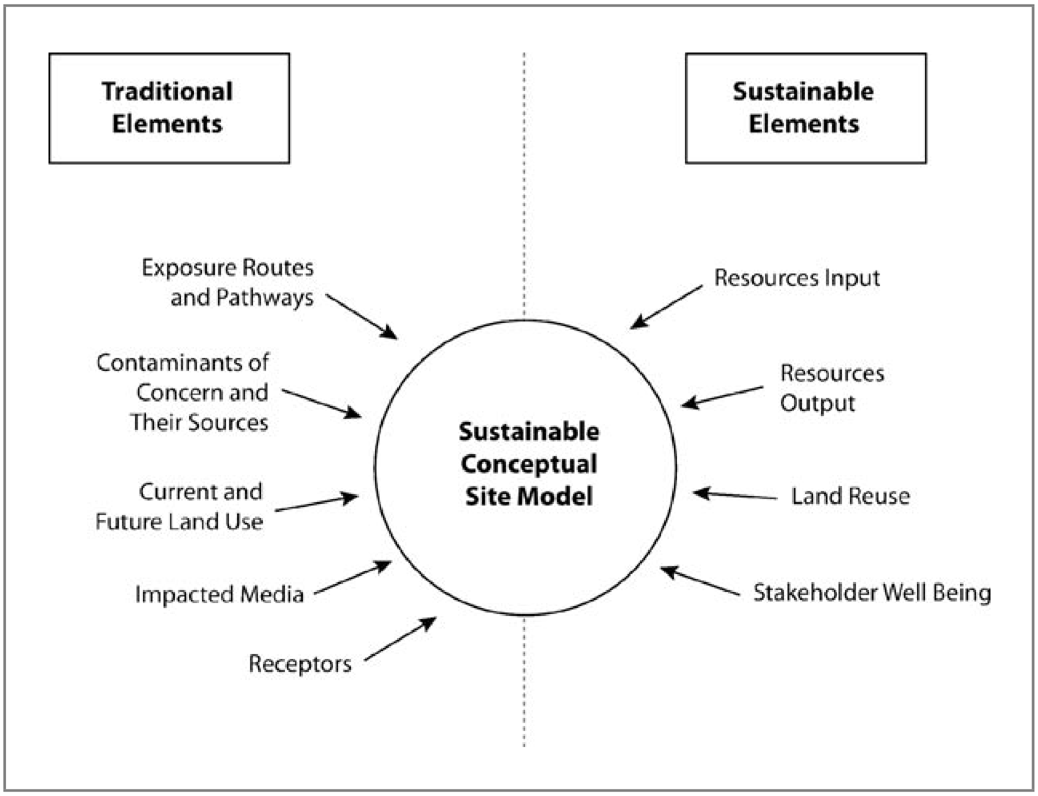
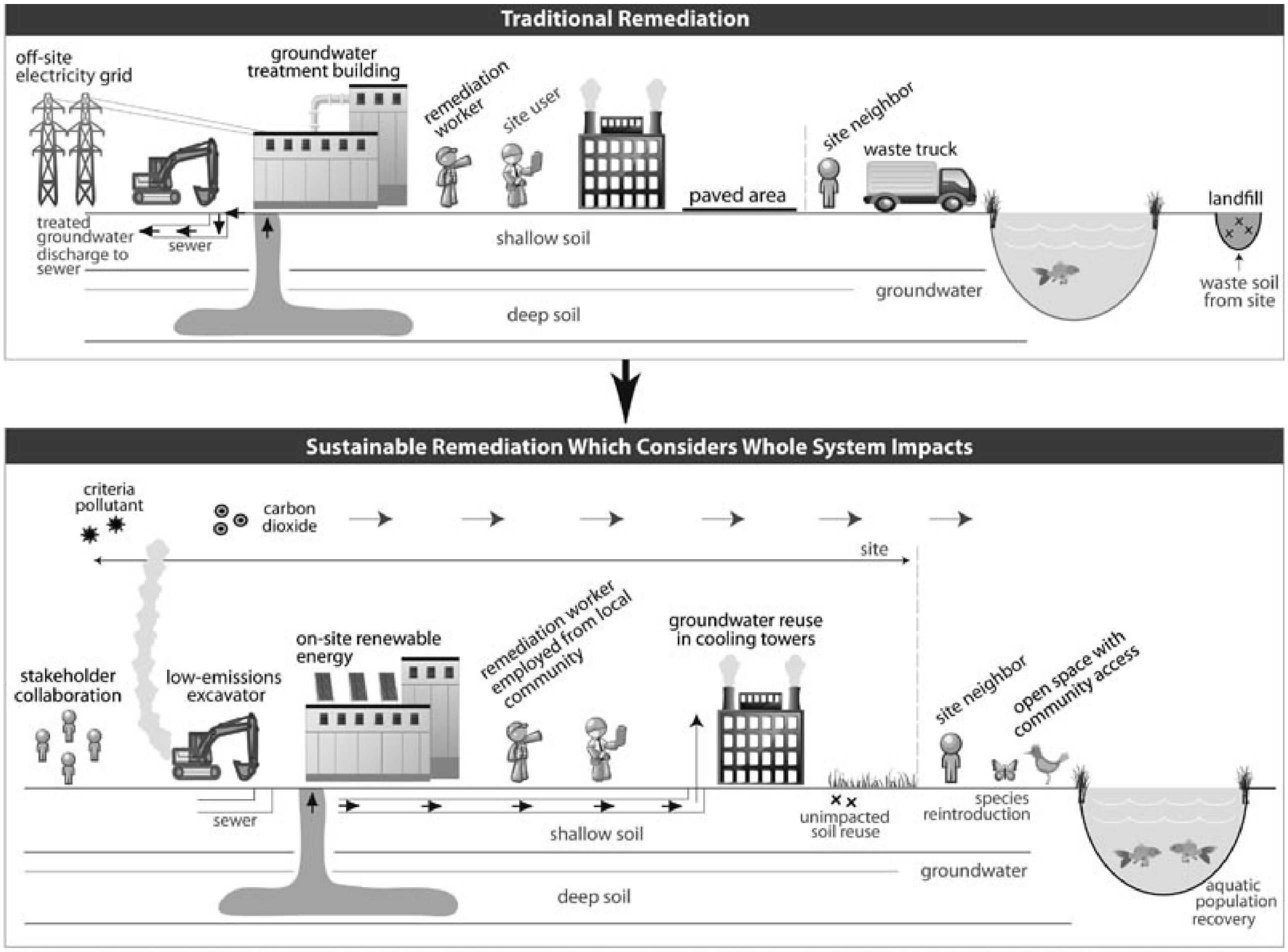


Exhibit 15. Sustainable conceptual site model

sustainable CSM is proportionate to the sustainability tier (i.e., Tier 1, Tier 2, or Tier 3) being applied to the site and/or phase of the project.

Because both site impacts and sustainability impacts can change as the project progresses, remediation practitioners should strive both to incorporate sustainability parameters into the CSM at the beginning of the remediation project and to continually update the sustainable CSM as more information is collected (Exhibit 17). For example, when additional site data (including sustainability data) are collected, the sustainable CSM should be updated with the results. As the sustainable CSM is updated, data gaps may emerge. Remediation practitioners should assess whether additional data, including data needed to support sustainability parameters, are necessary. If deemed necessary, additional data should be collected to fulfill the project objectives and sustainable collection methods should be considered. After data collection and analysis, the sustainable CSM should be updated with this information. As a more holistic picture of site conditions emerges, fewer data gaps are likely, thereby reducing the need for additional data collection. Integrating whole-system sustainable considerations into the CSM as soon as possible allows remediation practitioners to identify ways to streamline the project and allows the project to be implemented in a more cost-effective and efficient manner. Through these considerations, the most optimal decisions can be made for each CSM element; each phase; and, ultimately, the site overall.



Note: In this example, both the traditional and sustainable CSMs assume that the selected remedy for groundwater treatment is a pump and treat system for ease of comparison. Optimally, a more sustainable strategy would be to select an *in situ* technology that would likely use less energy, be more protective of the aquifer, be less expensive and be more effective in achieving remediation goals.

Exhibit 16. Shift to a sustainable conceptual site model

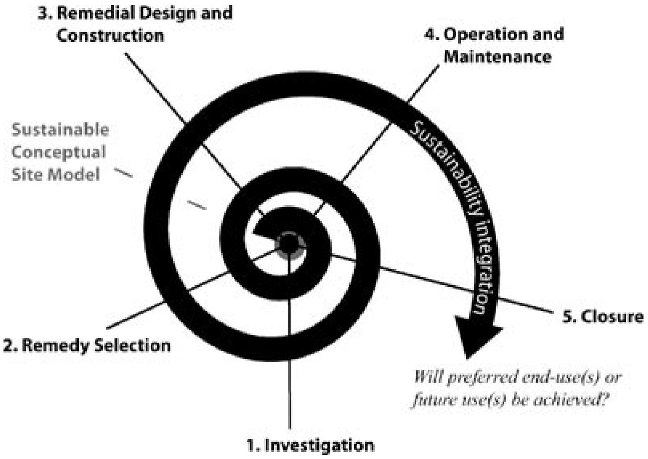


Exhibit 17. Continual improvement of sustainable conceptual site model

Sustainability Impact Measures Implementation

The sustainability evaluation and the sustainable CSM enable remediation practitioners to identify activities at a site that are associated with pertinent sustainability impacts. Then, measures that reduce negative and enhance positive sustainability impacts can be implemented throughout the project life cycle. Numerous impact measures can influence the sustainability of a remediation project, including the following:

- implementing *in situ* technologies where feasible,
- recycling or reusing unimpacted soil or demolition materials,
- using renewable energy for remedial system operation,
- reducing transportation needs,
- providing training to local workers, and
- conducting collaborative community events.

In line with the iterative nature of the Framework, new or enhanced sustainability impact measures are identified as the sustainability evaluation and the CSM are refined. These measures should be implemented to maximize the sustainability improvements to the remediation project throughout the project life cycle.

> Sustainable human health risk assessments and environmental impact assessments consider and seek to balance the potential risks to humans and the environment caused by site impacts, as well as those associated with remediation activities throughout the remediation life cycle.

Integration of Sustainability Elements Into Traditional Assessments

Remediation projects are generally implemented for many reasons, including the identification of potential risks to human health and/or the environment. However, remediation activities are also associated with various negative environmental and social (including human health) risks and impacts, as discussed later. These risks and impacts are often associated with financial implications. The ITRC recognizes the inherent risks associated with performing remediation projects and, therefore, has established a Remediation Risk Management team to address this issue. Sustainable human health risk assessments and environmental impact assessments consider and seek to balance the potential risks to humans and the environment caused by site impacts, as well as those associated with remediation activities throughout the remediation life cycle.

Sustainable Human Health Risk Assessment

Remediation projects often include a human health risk assessment to identify the potential risks that contaminants pose to current and future site users. Traditionally, less attention has been afforded to other receptors, such as on- and off-site workers who perform remediation activities or local community members who become implicated in accidents involving trucks hauling site waste. By using the Framework, remediation practitioners can apply these nontraditional receptors to human health risk assessments.

As the sustainable remediation movement has evolved, remediation practitioners have begun evaluating occupational risks to remediation workers in addition to the risks typically included in human health risk assessments prescribed by different regulatory regimes (e.g., cancer risks). Evaluation results suggest that, in many cases, the occupational and transportation risks to workers retained for a remediation project can be significant. As illustrated in a case study (Exhibit 18), a direct comparison of occupational

Exhibit 18. The challenges of comparing occupational risk to workers and cancer risk to receptors

The release of polychlorinated biphenyls (PCBs) and other chemicals during manufacturing operations at a facility caused sediment impacts in a nearby river and some of the surrounding floodplain soil. A variety of remedial alternatives were evaluated to remove and/or cap the PCB-impacted sediments. As part of the evaluation, an occupational risk analysis and human health risk assessment were performed for each alternative. Worker fatality potential during on-site construction and remediation activities and when transporting materials to and from the site were considered in the analysis. The estimated numbers of worker fatalities for the sediment remediation alternatives ranged from 2.6×10^{-1} to 3.0×10^{-1}. In other words, the highest potential for worker fatalities was 26 percent (approximately one in four). Multiple exposure pathways and scenarios, both direct and indirect, were evaluated in the human health risk assessment. A receptor with an elevated risk of exposure was an adult consuming fish with PCB-contaminated tissue. The estimated cancer risk for this receptor was 2×10^{-2}.

Based on these results, both the occupational fatality risk and the human health cancer risk are potentially significant. To complete a sustainability evaluation, it is necessary to directly compare these two different risks. Yet, a quantitative comparison of occupational risk with human health risk is challenging. Occupational fatality risk is calculated as an expected occurrence, whereas the cancer risk is calculated as a probability. For the sustainability evaluation, remediation practitioners need to determine a multiplier of the number of people predicted to be exposed to obtain an expected occurrence comparable to the occupational fatality risk. This multiplier is not information commonly included in risk assessments; instead, the information is more commonly represented as the probability of occurrence of cancer for a single person exposed to the contamination. Additionally, remediation practitioners must recognize that the human health cancer risk represents all expected cancer occurrences (i.e., fatal and nonfatal). Therefore, the impact associated with occupational fatality risk is likely to be more severe than that expected from the cancer risk.

In summary, occupational risk can be calculated, but performing a quantitative comparison with human health risk is challenging. Nevertheless, occupational risk to workers can be an important risk to consider, along with human health risk, during the remedy-selection phase of a remediation project.

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risk and cancer risk is difficult. However, the impact associated with occupational risk may, in certain circumstances, be higher than the theoretical cancer risk threshold for requiring remediation. (This threshold is generally considered to be between 1 chance in 10,000 and 1 chance in 1 million of a human developing cancer due to contaminants at the site.) These results are especially significant because many human health risk assessment results provide conservative estimates of risk; therefore, actual risks may in fact be lower. Additionally, human health risk assessments generally do not address life-cycle human health risks (for example, those risks that arise during the manufacture and transportation of materials). These activities may generate dangerous emissions—for example, carcinogens, smog constituents, and particulate matter to the atmosphere with potential local and regional social impacts (e.g., human health impacts) and resulting economic consequences (e.g., health care costs).

When using the Framework, stakeholders should agree, to the extent possible, on a remediation approach that appropriately balances the risk-reduction benefits of completing the remediation project with the negative sustainability impacts and risks resulting from performing remediation activities. Stakeholders should work together to develop risk thresholds for remediation workers and other stakeholders who may be directly or indirectly at risk of injury or fatality as a result of remediation project activities. This will ensure that both risks associated with site contaminants *and* with remedial activities are considered as part of the remediation strategy.

Sustainable Environmental Impact Assessment

With the additional focus on advanced science and technology, it is more important than ever for remediation practitioners to present the technical aspects of remediation projects in a nontechnical manner to stakeholders who may not have knowledge of the science or equipment.

Until recently, remediation projects focused on reducing environmental impacts to land and/or water only. Other sustainability impacts, such as greenhouse gas emissions, natural resource use, financial returns to the local community, and occupational risk (as discussed earlier), were not afforded as much importance in the remediation decision-making process and sometimes were not considered at all. The sustainability impacts of the remediation project life cycle were also not considered extensively. Remediation practitioners should consider these sustainability impacts during remediation because such impacts have present and future sustainability implications. For example, the manufacture of granular activated carbon for certain remediation technologies may require coal from mining operations. Currently, these mining operations are associated with elevated human health risks and environmental degradation. Greenhouse gas emissions (e.g., those generated during the combustion of fuel at remediation sites) are also believed to be a significant contributor to climate change (Intergovernmental Panel on Climate Change, 2007). Adverse social outcomes (e.g., displacement of communities caused by sea-level rise) and their associated financial implications (e.g., rehousing displaced communities) are projected in the future as a result of climate change.

Many examples, such as the one provided in Exhibit 7, demonstrate that the environmental impacts caused by a remedial approach may outweigh the environmental impacts caused by subsurface contaminants. Sustainability impacts become particularly prevalent as a remediation project approaches the end of its life cycle when only residual impacts remain. At this stage, the efficiency of a remediation system often decreases exponentially. It is for this reason that stakeholders should consider whole-system sustainability elements during the remediation decision-making process so that remediation activities do not create disproportionate sustainability impacts.

INTEGRATION OF THE FRAMEWORK

Remediation projects are, by nature, complex and often occur over a long period of time—from discovery through investigation into remediation to final closure and prospective reuse or redevelopment. These projects are, however, generally monitored and evaluated from within a regulatory program that has a specific required outcome (i.e., goal) that must be achieved before closure is granted. This Framework presents an opportunity for synergy between a process-based and goal-based implementation to achieve remediation. By focusing primarily on the remedial goal, a long-term project may not be adaptable to changing site conditions, requirements, technologies, or stakeholders' interests. The process-based implementation of the Framework allows for the inclusion and adaptation of these altering conditions while still achieving regulatory requirements.

And yet science and technology developments are changing how sites are evaluated, generating heightened concern around "emergent" contaminants and causing the determination of "clean" to be questioned. With the additional focus on advanced science and technology, it is more important than ever for remediation practitioners to present the technical aspects of remediation projects in a nontechnical manner to stakeholders who may not have knowledge of the science or equipment. Otherwise, some stakeholder groups can be inadvertently excluded from discussions. Social equity forms an important component of sustainability and requires that stakeholder involvement be taken seriously throughout the remediation process. By using the Framework, remediation practitioners can identify opportunities for stakeholder involvement and for including stakeholder groups who may not immediately be apparent during the initial project setup. In this way, the Framework creates a natural arena for collaborative decision making throughout the remediation project life cycle and beyond (i.e., site reuse). It is the recognition that stakeholders may value different elements within a remediation project that allows remediation practitioners to use the Framework to consider and balance differing viewpoints during the decision-making process.

Existing Programs

The Framework is complementary to and builds upon existing sustainable remediation programs developed by government agencies, industry associations, and the regulated community. Exhibit 19 provides a brief overview of some of the programs that support the Framework, including documents developed by the California Department of Toxic Substances Control, SuRF-UK, the US Army Corps of Engineers, the New York State Department of Environmental Conservation (NYSDEC), the Network for Industrially Contaminated Land in Europe (NICOLE), the US EPA, the Illinois EPA, ASTM International, and the ITRC.

Many regulatory programs currently include provisions for sustainable remediation at different remediation phases; however, these provisions often are geared toward the achievement of regulatory-specific goals and objectives. The goal-oriented nature of regulatory programs is beneficial in that clear goals are provided that can be understood by all stakeholders. This approach can also prove to be inflexible, however, when remediation practitioners are trying to decide when to incorporate sustainable parameters into remediation projects. Within existing regulatory programs, prescribed approaches are accepted, and gaining acceptance of alternate approaches can be challenging. The process-based implementation inherent in the Framework allows the goal-based structure of a specific regulatory program to drive the project outcomes while introducing additional opportunities for sustainability parameters to influence the project throughout the remediation life cycle. Thus, the Framework complements existing programs and allows remediation practitioners to achieve a greater understanding of how sustainability impacts are associated with achieving project goals.

The Framework complements existing programs and allows remediation practitioners to achieve a greater understanding of how sustainability impacts are associated with achieving project goals.

Remediation practitioners using the Framework are guided through a system of iterative sustainability evaluations that can be integrated into existing regulatory programs. As an example, when the project scope is defined by an existing program, remediation practitioners using the Framework can extend the physical boundaries of the project (e.g., consider where raw materials travel from and outputs such as waste products are taken), which allows a broader, whole-system understanding of the sustainability impacts of the remediation. It is important to note that remediation practitioners using the Framework must still comply with the regulatory requirements for the remediation project. In this way, the Framework works as a complement to regulatory programs and outcomes and not in opposition to them.

Exhibit 19. Existing sustainable remediation guidance documents and frameworks

Reference	Description
California EPA, Department of Toxic Substances Control (2009)	This advisory was developed for project managers, responsible parties, and environmental consultants performing sustainable remediation assessments at remediation sites. It introduces the concepts of sustainability and life-cycle thinking and shows how these concepts can be incorporated into any remediation project phase. This advisory presents a tool, the Green Remediation Evaluation Matrix (GREM), that may be used to perform qualitative comparisons of treatment alternatives. The framework for sustainability introduced within the advisory includes completing a checklist for each alternative under consideration and combining them into the GREM. At the simplest level, the framework helps users identify key areas for improvement or opportunities for reducing impacts on remedial alternatives.
SuRF-UK (2010)	This document is the first to provide an authoritative framework for assessing the sustainability of soil and groundwater remediation in the United Kingdom. The SuRF-UK framework is intended to be a voluntary initiative but one that has regulatory support. This document does not make recommendations on the sustainability of any specific remediation technologies or approaches, but rather provides a framework for assessors to identify the optimum solution on a site-by-site basis. The SuRF-UK framework recognizes two main stages where sustainable remediation decision making may be applied: the project/plan design stage and the remediation implementation stage. The SuRF-UK framework is flexible so that it can be applied to various remediation decision-making scenarios within a property life cycle and for different site sizes and complexities. It can also be applied to remediation decision making within regulatory systems beyond the United Kingdom. Many concepts introduced in the Framework complement those discussed in the SuRF-UK framework.
US Army Corps of Engineers (2010)	This document provides a road map for incorporating sustainable remediation principles throughout the remediation life cycle at formerly used defense sites (FUDS). The decision framework identifies different ways to incorporate sustainable remediation principles. It also provides template contract language for identifying, considering, and implementing sustainable remediation principles into contracts on FUDS environmental remediation projects. Although applicable specifically to FUDS sites, the decision framework and the references therein can also be used as a guide for projects in the larger Army environmental remediation program.
US EPA (2008, 2010)	In addition to its successful Brownfields program, the US EPA has established a comprehensive sustainable remediation program that focuses on the environmental (green) component of sustainability and is supported by the publications of numerous guidance documents (e.g., US EPA, 2008), strategies (e.g., US EPA, 2010), and policies. The US EPA also maintains a website that provides up-to-date information on the latest green remediation developments (http://www.clu-in.org/greenremediation/). The agency hosts regular webinars on a variety of green remediation topics.
NYSDEC (2010)	This policy details a holistic approach to improve the overall sustainability of remediation projects. It applies to all phases of site investigation and remediation for new sites and to relevant phases for existing sites in various state regulatory programs. This policy requires that concepts and principles of sustainable remediation be considered, implemented to the extent feasible, and documented. It does not specify methods or criteria to quantify the effectiveness

(*Continued*)

Exhibit 19. Continued

Reference	Description
	of the sustainable remediation program. The general procedures prescribed are designed to reduce direct and indirect greenhouse gas and other emissions; conserve water, energy, and resources and materials; and reduce waste through recycling, project optimization, and the reuse of materials. Sustainability aspects are evaluated by maximizing habitat value and fostering green and healthy communities that balance ecological, economic, and social goals with an eye toward an end use that encourages sustainable redevelopment.
NICOLE (2010)	The road map describes NICOLE's views on how to incorporate sustainability principles into remediation projects. It is intended to provide responsible parties and their stakeholders with a single, structured process to begin working together to implement best practices in sustainable remediation across a wide range of regulatory and policy frameworks. The road map is designed as a series of steps to ensure a consistent and collaborative approach to decision making and it can support robust and durable decisions, regardless of project size.
Illinois EPA (2008a, 2008b, 2009a, 2009b, 2009c)	The Illinois EPA is currently refining its remediation program to emphasize more sustainable practices for remediation projects. The agency has created a simple matrix to guide site owners and consultants in choosing sustainable practices that can be applied to site assessment, planning and design, and remediation, as well as an expanded matrix that lists individual actions followed by a qualitative ranking of their level of difficulty and feasibility. The benefits of each action to air, water, land, and energy are also identified. Mind maps have been developed to illustrate more sustainable remediation concepts for different remediation sites. The agency has also created a decision tree for leaking underground storage tanks that identifies 17 additional environmental remediation activities that may be undertaken during different phases of the remediation life cycle. The Illinois EPA sustainability efforts focus only on the environmental (green) component of sustainability.
ASTM International (in development)	ASTM International is currently developing a *Standard Guide for Greener and More Sustainable Cleanups*. The aim of the guide is to support remediation by incorporating a comprehensive and integrated consideration of environmental, economic, and social factors while working within applicable regulatory criteria. The guide is complementary to and does not supersede federal, state, and local regulations.
Interstate Technology & Regulatory Council (ITRC) (in development)	The Green and Sustainable Remediation committee of the ITRC is currently developing a *Technical Regulatory Document* that includes a sustainable remediation framework and available sustainable remediation tools and technologies and covers various topics, such as barriers to sustainable remediation and stakeholders' perspectives. The framework will provide an in-depth "how-to" guide for each remediation phase. SURF's Framework is harmonious with the framework that will be presented by the ITRC. Where SURF's Framework enables a shift in thinking so as to consider the wider sustainability system, the ITRC's document will provide concrete examples of strategies for applying sustainability during remediation.

Stakeholder Involvement

Individuals who are directly and indirectly affected by the remediation project activities are considered stakeholders in the project. The most obvious stakeholder groups include responsible parties and regulatory entities having jurisdiction over the cleanup. Other stakeholder groups may include the workers who will participate in the remedy application, the local community and surrounding community(ies), industry service providers, and special interest groups (Exhibit 4).

Traditional regulatory programs often require some aspect of stakeholder involvement—for example, with the local community and with special interest groups; however, the involvement is usually limited to discrete remediation phases rather than throughout the remediation project life cycle. The Framework is designed to encourage remediation practitioners to form stakeholder groups early in the remediation process and promote stakeholder collaboration at the onset of a project. Preclusion from these early discussions can create conflict and mistrust if the stakeholders believe that they do not have a voice and/or collaborative role in the decision process or that they were not provided an opportunity to learn about site issues in a nontechnical manner from an expert. On the other hand, inclusion in these early discussions and during subsequent discussions may enable constructive stakeholder engagement and promote stakeholder consensus. For example, if community stakeholders have serious and valid concerns about a complicated or politicized site undergoing remediation, the formal structure of goal-based implementation (i.e., the current structure of regulatory programs) may limit the inclusion of these stakeholders in initial decision-making discussions despite best efforts to do so. For this reason, the process-based implementation inherent in the Framework allows whole-system sustainability to be evaluated in an iterative manner throughout the remediation project life cycle and provides a mechanism for stakeholder participation throughout the remediation process.

> The Framework is designed to encourage remediation practitioners to form stakeholder groups early in the remediation process and promote stakeholder collaboration at the onset of a project.

Taken a step further, the more iterative and process-based design of the Framework allows more opportunities for collaboration between the various stakeholder groups throughout the remediation project life cycle. In many cases, stakeholder involvement includes the regulators and responsible parties only. Major decisions are often made with these two groups of stakeholders and their representatives (e.g., consultants, legal representation). For smaller-sized, less complex remediation projects with no off-site contaminant migration, a smaller group of involved stakeholders can be appropriate. In other cases, bringing additional stakeholder groups into discussions earlier in the remediation process ultimately benefits the project and can increase their acceptance, understanding, and support of the project. For example, when public meetings are held *before* a remedy is selected and stakeholders provide input, additional negotiations with stakeholders related to the selected remedy may not be needed. Similarly, if knowledgeable vendors and contractors participate during the remedial design phase to share on-site application or implementation knowledge, redesign requirements to optimize the remedy to real-life conditions may be avoided.

The collaborative decision-making process encouraged by using the Framework differs from the traditional remediation process of goal-based frameworks. For example, during traditional remediation processes, industry service providers who participate in the implementation of the remedy are usually involved during feasibility study preparation, but not during remedy selection. The Framework prompts the remediation practitioner to involve these individuals because of their experience with real-life applications of remediation technologies and remedial system operations. Timely involvement of these stakeholders can provide access to alternative approaches or increase the sustainable efficacy of a particular approach. In the same way, the iterative nature of the Framework enables remediation practitioners to engage with community stakeholders throughout the remediation process (e.g., when updating the sustainable CSM). This involvement can increase access to local resources, such as raw materials, skilled labor, or manufacturing labor. In addition, community stakeholders can provide early input about community interests such as preservation of community culture (e.g., traffic volumes, noise levels). Without this early input and involvement, members of the community may begin to feel disengaged or disenfranchised, which can lead to misunderstandings and mistrust of the regulatory entities and responsible parties. As evidenced by this discussion, different stakeholder groups (knowingly or not) possess crucial information that can impact the remediation process in some way (e.g., remedial approach, resources, schedule).

DOCUMENTATION AND RECORDKEEPING

Maintaining up-to-date records ensures transparency with respect to how the Framework is implemented and how decisions relating to sustainability are made. Documenting sustainability data enables remediation practitioners to track how the Framework is applied. Documentation should occur at the initiation of a remediation project and should be updated as additional data are collected and analyzed during different remediation project phases. The records should document the following:

- the sustainability evaluation tier (i.e., Tier 1, 2, or 3) selected for the project and the results of the evaluation;
- the key considerations that led to the selection of the tier;
- the methodologies selected to perform the sustainability evaluation;
- the metrics selected to support the sustainability evaluation;
- the rationale and the approach implemented to update the sustainable CSM;
- the role of whole-system sustainability and other considerations in the remediation decision-making process;
- the remediation and sustainability performance data collected throughout the remediation project life cycle; and
- additional important information (e.g., successes, lessons learned).

Documenting sustainability data enables remediation practitioners to track how the Framework is applied.

Records should also include instances where less optimal decisions were made due to overarching factors (e.g., stakeholder disagreement, budget and resource constraints, emergency situations). In this instance, the balancing of factors that led to the less-than-optimal decision should be recorded.

To the extent feasible, sustainability considerations should be integrated into remediation documents that are submitted to regulatory entities and/or provided to stakeholders. The level of detail provided should be proportionate to the size and complexity of the remediation project and the audience. For example, sustainability evaluation results can be presented and discussed in relation to traditional remedial alternative criteria (e.g., overall protection of human health and the environment, long-term effectiveness, and permanence) in a remedial action selection report submitted to a regulatory agency. Fact sheets distributed to the local community can be used to communicate the sustainability attributes of a remediation project in layperson's terms. By documenting the integration of sustainability, remediation practitioners can demonstrate the value of using the Framework throughout the project life cycle.

SUMMARY AND RECOMMENDATIONS

SURF developed this Framework to provide a systematic, process-based, holistic approach for remediation practitioners to consider and integrate sustainability parameters throughout the remediation project life cycle. The Framework is designed to be easy to use for all stakeholders regardless of sustainable remediation experience and includes each phase of a traditional remediation project: investigation, remedy selection, remedial design and construction, O&M, and closure. Because these project phases are not stand-alone entities but rather interconnected components of the wider remediation system, sustainability should be integrated holistically and iteratively with this wider system. With this in mind, the Framework describes an approach for the following:

- planning for the preferred end use or future use of a site so that all aspects of the triple bottom line are considered;
- performing a tiered sustainability evaluation that informs the CSM and enables remediation practitioners to identify and implement sustainability measures;
- integrating whole-system sustainable considerations into the CSM based on the results of the sustainability evaluation so that the most optimal decisions can be made for each CSM element, each phase, and, ultimately, the site overall;
- identifying the most relevant sustainability parameters and implementing sustainability impact measures in a way that balances parameters according to the relative sustainability of each element as well as the remediation project as a whole; and
- performing a whole-system sustainability evaluation in a way that allows remediation practitioners to ascertain the most relevant sustainability parameters for a specific remediation project.

Many opportunities exist within the remediation industry to integrate sustainability parameters as a way to generate higher value. Although fewer opportunities exist for generating value from incorporating sustainability parameters later in the remediation life cycle, value can still be derived from integrating sustainability parameters at any phase. Therefore, SURF encourages remediation stakeholders to apply the Framework to new *and* existing remediation projects. Because of its inherent flexibility, the Framework process can be integrated into existing domestic and international programs to achieve greater understanding of how sustainability impacts are associated with achieving project goals. SURF recommends the following activities to help remediation practitioners maximize the sustainability of remediation projects:

- Evaluate environmental, social, and economic aspects of a remediation project collectively, and balance each of these aspects with other considerations (e.g., risks) to optimize decision making throughout the project life cycle.
- Incorporate sustainability parameters at the beginning of a remediation project to maximize sustainability, but remember that sustainability parameters can be incorporated in any project phase.
- Consider whole-system sustainability elements so that learnings from previous remediation phases can be leveraged into synergistic improvements in future phases.

- Engage stakeholders throughout the project so that the unique expertise and perspectives of different stakeholder groups are part of the decision-making process, potentially leading to the achievement of a more sustainable solution.
- Implement a disciplined planning strategy that focuses on the preferred future use or end use of the site to streamline the project, and develop a transition strategy that supports project closure once it is demonstrated that residual contaminants will not potentially cause adverse impact to human health or the environment.
- Select a sustainability analysis tier that is proportionate to the scope and level of complexity of the project.
- Select metrics for the tiered sustainability evaluation for a remedy according to the specific sustainability considerations being applied and in accordance with those impacts and influences in which key stakeholders express specific interest.
- Shift from a traditional CSM to a sustainable CSM by incorporating value-adding sustainable data alongside traditional data, and use the sustainable CSM as a decision-making tool.
- Compile and implement sustainability impact measures throughout the life cycle of the remediation.
- Perform traditional human health and environmental impact assessments in a more sustainable manner and include nontraditional receptors (e.g., on- and off-site workers) and impacts that have present and future sustainability implications (e.g., greenhouse gas emissions).

By way of this publication, SURF is presenting the first version of its sustainable remediation framework. The Framework will be refined and enhanced as remediation practitioners begin using the Framework and documenting successes and lessons learned. To support this effort, SURF is investigating how best to capture sustainable remediation case studies to share and disseminate knowledge about the ways that remediation practitioners can add value by integrating sustainable parameters into remediation projects.

DISCLAIMER

This document was produced by the US Sustainable Remediation Forum (SURF), which is a New Jersey nonprofit corporation with broad membership. The views and opinions expressed in this document are solely those of SURF and do not reflect the policies or positions of any organization with which SURF members are otherwise associated.

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