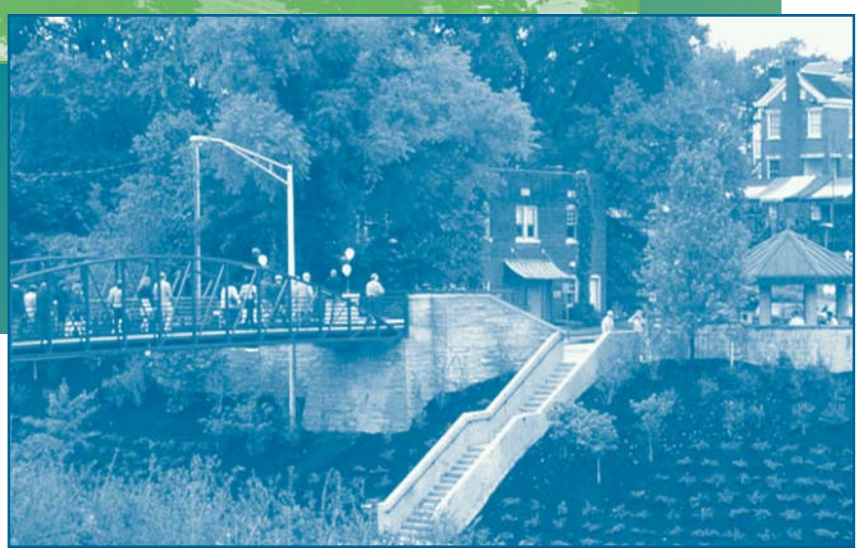
ITRC

Technical and Regulatory Guidance

Planning and Promoting Ecological Land Reuse of Remediated Sites



July 2006

Prepared by
The Interstate Technology & Regulatory Council
Ecological Land Reuse Team

ABOUT ITRC

Established in 1995, the Interstate Technology & Regulatory Council (ITRC) is a state-led, national coalition of personnel from the environmental regulatory agencies of some 40 states and the District of Columbia, three federal agencies, tribes, and public and industry stakeholders. The organization is devoted to reducing barriers to, and speeding interstate deployment of, better, more cost-effective, innovative environmental techniques. ITRC operates as a committee of the Environmental Research Institute of the States (ERIS), a Section 501(c)(3) public charity that supports the Environmental Council of the States (ECOS) through its educational and research activities aimed at improving the environment in the United States and providing a forum for state environmental policy makers. More information about ITRC and its available products and services can be found on the Internet at www.itrcweb.org**.**

DISCLAIMER

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EXECUTIVE SUMMARY

An ecological enhancement is a modification to a site which increases and improves habitat for plants and animals while protecting human health and the environment. Elements of ecological enhancement can include natural or green remediation technologies and/or an end use which restores or otherwise increases the ecological value of the land. Ecological elements may be designed into remediation and closure projects. Considered at the inception of planning a site cleanup, green and natural technologies, in addition to traditional technologies, can cost-effectively cleanup soil and groundwater contamination and restore, create, and/or improve habitat or the ecosystems. Designing an ecological end use as an integrated component of the remediation system can realize more benefits from the remediation process without compromising the selected remediation goals and objectives. Incorporation of ecological enhancements can benefit multiple stakeholders, such as regulatory agencies, the regulated community, local communities, and the general public. The team believes that greater benefits may be gained by integrating ecological land reuse into the initial remediation strategy, but this in no way is meant to preclude incorporation of ecological enhancements into remediation projects which are already underway.

The Interstate Technology and Regulatory Council (ITRC) Ecological Land Reuse Team has developed this guidance document to promote ecological land reuse as an integrated part of site remediation strategies and as an alternative to conventional property development or redevelopment. This reuse may be achieved through a design that considers natural or green technologies or through more traditional cleanup remedies. The decision process presented here helps stakeholders to integrate future land use and stakeholder input into an ecological land end-use-based remediation project. Key to the project success is an understanding of the service capacity (the ability to produce jobs, housing, environmental habitat, mineral resources, agricultural goods, and other societal values) at, near, and surrounding a remediation project. Integrating stakeholders input regarding their desires for community development and needs is critical. This type of an integrated project can gain strong support from the stakeholders and can transform them into strong advocates for projects integrating ecological elements into the future land reuse plans. The ITRC team is experienced in cleanup and ecological and habitat development techniques and in representing various interests (such as community stakeholders, consultants, the regulated community, government regulatory agencies, non-governmental organizations, and other government agencies). The team has incorporated various perspectives into this guidance to improve its applicability, usability, and value.

This document describes key decision points in a flow diagram format and defines the practicality of applying natural or green technologies to traditional remediation processes. Ecological benefits have not traditionally been designed into, nor credited to, the value of the reusable land until successful remediation was completed. Now, natural and green technologies can improve the ecology of the site as long as they support the intent of the land's use and do not jeopardize the elimination or reduction of the human or environmental risk. Consideration of ecological benefits, as well as the end use of an environmentally impacted site, is an integral component of the remediation process.

Ecological land reuse may have multiple advantages, and a single ecological element may have multiple benefits such as environmental, economic, or public. This guidance document categorizes several ecological reuses, without limiting their benefits, in order to offer a presentation of possible advantages. The potential advantages are shown below:

Environmental	Economic	Public
• attracts wildlife • hydraulically controls landfill leachate • biodegrades environmental contaminants • controls dust • reduces sediment transport and controls erosion • stabilizes stream banks • uses atmospheric carbon dioxide • improves groundwater recharge • minimizes human and environmental exposures • provides a harvestable resource • improves aesthetics • provides educational opportunities • provides recreational areas • provides migratory pathways • improves plant diversity	• is cost competitive • provides use for waste material • enables more efficient use of limited resources • provides institutional control • can potentially generate revenue • provides marketing and competitive advantages • increases property value • provides source of recoverable resources • provides potential for environmental offsets • potential for enhanced environmental stewardship • offers tax advantages • reduces natural resources damage liability	• provides recreational and tourism opportunities • provides educational opportunities • improves corporate reputation • improves goodwill through good neighbor • enhances workforce stability through improved morale • improves aesthetics • improves livability • increases natural resources

These benefits are included in a value system used to estimate the cost of cleanup alternatives at a contaminated site. A project team should consider the complete life cycle of the project, from technology selection to final disposition of the property, for an accurate economic picture of the alternatives. A comparison of the relative economic advantages of two alternative approaches, one having moderate initial costs, high O&M (operation and maintenance) costs, and a short duration and the other having low initial costs, moderate O&M/administrative costs and a long duration can be made through a net present value analysis. These cost elements can be broken down into three general categories: quantifiable values, semiquantifiable values, and qualitative values.

Items in each of the three value categories should be considered for every potential alternative in a project to fully evaluate its value in comparison to other alternatives. When properly done, they present a "story"—an objective and subjective description of the outcome that also explains the indirect benefits, which may not have a clear economic value. This process leads to inclusive decision making. Even if a factor is thrown out for lack of impact on the decision, it should still be considered to make sure all projects are evaluated consistently and completely. A comprehensive financial estimate, using as many of the pertinent factors as possible, will provide more sound decisions, thus offering optimal benefits to the site, the company, the community, and the ecology of the area.

Ecological service as a reuse element is still emerging; however additional information or data is necessary to fully realize the broad benefits of ecological land reuse. New research and reporting needs to accomplish the following:

- Explain and document the service capacity offered by a given area and how that capacity can be fulfilled by man-made systems.
- Track ecological land reuses and evaluate how they may positively impact the surrounding and interconnected systems.
- Better explain the methodologies to create ecological end-use projects that will provide the desired service.
- Document the impact ecological land reuse of remediated, reclaimed, or restored sites has on migratory flyways and corridors.
- Document the integration of environmental remediation technologies into a sustainable ecological end use.
- Integrate information from sites, which have restored or created ecological benefits, into a learning center or database which is readily available to all stakeholders.
- Provide the basis to move remediation away from pumps and pipes and toward more nonmechanical systems capable of the same level of environmental and human health protection, while providing a more wildlife- and human-friendly end use.
- Document ecologically based mechanisms that provide sustainable institutional controls.
- Better explain the mechanisms and institutional controls that can be placed on property to manage any residual threats (e.g. deed restrictions, uniform covenant program, or conservation easement).
- Develop a template that states can use, and adjust to their own use, to track and evaluate the environmental effectiveness of land use controls placed on a site, perhaps through a national organization that represents the states (see Section 4.8.2, ITRC ALT-4 2006).
- Document the improved quality of life of the individual and the livability of the community where green space is incorporated into the urban and suburban environment.

A case study from Chattanooga, Tennessee, most effectively demonstrates the successful application of ecological elements to improve the livability of an area while restoring a site. A working partnership between government, industry, and the community transformed an industrial wasteland into a vibrant, upscale downtown community—resulting in improved livability, increased property values, healthy environments, and controlled growth. Certainly not all future land use may be conducive to ecological elements or enhancements; however, in situations where ecological elements or enhancements may be integrated into the remediation process, whether using conventional or green remediation technologies, they can benefit the owners, operators, community, and ecosystem through the ecological elements used to remediate the site.

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1. INTRODUCTION

Often ecological considerations are incorporated into remediation and closure projects as an afterthought, or worse, following completion of the remediation project. This approach does not take advantage of a fully integrated ecological end use in the remediation design. In 2003, The Wildlife Habitat Council (WHC) and the ITRC (Interstate Technology & Regulatory Council) worked cooperatively to develop a white paper, *Making the Case for Ecological Enhancements* (ITRC ECO-1 2004). The purpose of this white paper was to present natural or ecologically friendly alternatives to traditional remediation processes, thus allowing the incorporation of ecological enhancements as integral components of both the remediation process and the reuse of environmentally impacted sites. The document defined ecological enhancements as modifications to a site that restore, increase, or improve habitat for plants and animals while protecting human health and the environment.

> ***Ecological land use, where appropriate, yields both tangible and intangible benefits for remediated sites.***
>
> *"An ecological enhancement modifies a site to increase/improve habitat for plants and animals while protecting human health and the environment. An ecological element can include natural remediation technologies and/or also represent an end-use which restores/increases the ecological value of the land"*
>
> *-From: Making the Case for Ecological Enhancements*

The white paper included several objectives:

- gaining greater regulatory flexibility and support for use of ecological land reuse
- identifying the strategy for obtaining constructive and meaningful stakeholder involvements
- ensuring sound scientific and technical support for ecological land reuse practices
- defining the value of ecological land reuse and communicate those values

As illustrated in the *Making the Case for Ecological Enhancements*, natural or green technologies can effectively contribute to the success of remediation projects; however, ecological reuse is not universally applicable. Site-specific considerations and engineering evaluation of goals and objectives, regulatory constraints, potential technologies, predicted costs, and likely benefits must be objectively studied at each potential site. This new guidance document, *Planning and Promoting Ecological Reuse of Remediated Sites*, describes a decision-making process that provides for an ecological end use through the planning and design process of remediating a site. The design and construction of the ecological end use as an integrated component of the remediation system will result in more pronounced benefits from the remediation process. In order to help remediation planners and stakeholders implement ecological enhancements at the earliest possible stage, this document includes the following:

- benefits, incentives, and limitations for implementing ecological enhancements at environmentally impacted sites
- a team questionnaire which asked states to provide their rationale for incorporating ecological elements or enhancements into a remediation project
- case studies in which the ecological enhancements are incorporated into the remedial design and/or end use
- recommendations for the successful design of ecological enhancements at environmentally impacted properties
- recommendations for improvements to foster greater acceptance and regulatory flexibility for incorporation of ecological enhancements as components of remedial actions and end use
- areas where additional scientific research is needed

Ecological enhancements considered at the start of planning for environmental remediation at Superfund or Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Resource Conservation and Recovery Act (RCRA), and Brownfield sites[1] can be a cost-effective and efficient way to restore, create, and/or improve wildlife habitat or the ecosystems of the site, while meeting established remediation goals and objectives. Incorporation of ecological enhancements can benefit multiple stakeholders such as regulatory agencies, the regulated community (industry), local communities, and the general public. In the National Contingency Plan (NCP), the U.S. Environmental Protection Agency (EPA) determines on a case-by-case basis whether an activity or feature constitutes an enhancement [40 CFR 300.515(f)]. Although enhancements that do not contribute to the remediation of a site cannot be funded by EPA, they can be included in a remedial action if they are consistent with and do not interfere with the protectiveness of the selected remedy.

Figure 1-1. Decision tree

This guidance describes a process to promote ecological land reuse activities considering natural or green technologies instead of, or in conjunction with, traditional technologies and considers natural or ecological end-uses as alternatives to conventional property development or redevelopment. The decision tree shown in Figure 1-1 contains a potential conceptual process for integrating future land use and stakeholder input into an ecological land end-use-based remediation project. Key to the success of these projects is an understanding of the potential future land uses at, near, or around a remediation site. Integrating stakeholder input regarding community development and needs is critical in helping planners to gain strong support from the stakeholders and to become advocates for projects integrating ecological land reuse.

[1] For the purpose of this document, a site is an area subject to remediation and potential ecological land reuse.

Finally, this guidance document also contains a decision diagram (see Section 5) that illustrates the practicality of applying natural or green technologies to the traditional remediation processes. Natural and green technologies, together with natural/ecological end uses, are referred to as "ecological elements" throughout this guidance. Ecological benefits have not routinely been designed into, nor credited to the value of, the reusable land following successful remediation. Natural and green technologies can improve the ecology of the site as long as they are coincident with the intent of the land's use and do not interfere with the remediation of the site. Ecological benefits should be considered as integral components of the remediation process, as well as in the end use of an environmentally impacted site. Without an early evaluation of the ecological enhancement options, adverse impact to the ecology resulting from the remediation is usually never evaluated and could potentially outweigh the benefit of the remediation.

2. OVERVIEW OF ECOLOGICAL LAND REUSE

The purpose of ecological enhancements to a site is to restore the lost or diminished ecological resources, thereby enhancing the site's value to the owners, operators, and the community while maintaining protection for both human health and the environment. To optimize long-term maintenance, an ecological end use is best served by elements and technologies that are permanent and sustain themselves after remediation is complete. Whether or not the final ecological land use is sustainable will depend on the attitudes, resources, and values of both the current and future site owners, as well as the surrounding community.

The reduction or removal of contamination or the reduction of risk through remediation must not be jeopardized or compromised by the inclusion of ecological elements or the designation of an ecological land reuse.

Transforming a degraded habitat into an ecological asset presents a variety of challenges, thus an ecologically-based remediation project can be more challenging than one using conventional remediation technologies. On the other hand, the initiation of ecological remedial activities at a site represents a unique opportunity to leverage limited resources and achieve an improved outcome. Ecological site remediation presents the opportunity to do much more than treat or remove contamination from impacted water, air, and soil—when a remediation project is completed, the sustainable ecological elements will leave a legacy of ecological assets for the community. The Ecological Land Reuse Team's position is that their organizations support the use of ecological elements in remedial projects to support an ecologically-based end use.

Habitat and the sustainable condition of a resource are seldom elements of the typical remedy in RCRA Subtitle C; however, CERCLA has more effectively attempted to capture ecological land reuse in its remedy selection process (see *CERCLA Coordination with Natural Resource Trustees, OSWER Directive # 9200.4-22A*, 1997; *Issuance of Final Guidance: Ecological Risk Assessment and Risk Management Principles for Superfund Sites*, OSWER Directive 9285.7-28 October, 1999; and *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments*, EPA 540-R-97-006, OSWER, 1997). The use of technologies providing ecological elements as all or part of the remedial alternative may not be familiar to many regulators; however, the use of natural or green technologies, as remediation tools, are gaining greater acceptance. Additionally the likelihood of regulatory acceptance is enhanced by a focused remedial objective, inclusion and leveraging of stakeholder support, and a realistic timeline for achieving a sustainable site end use. States and owners are realizing the value of ecological land reuse and, in some cases, advocating such reuse. This experience indicates that the incorporation of ecological elements into the remedial design will not compromise the effectiveness or acceptability of the cleanup, nor will it necessarily increase the overall cost of the project to the EPA. If costs do increase, however, non-CERCLA funding will be required for the extra cost of the ecological enhancements that do not contribute to the cleanup design (see Section 4).

EPA emphasizes that the ultimate goal of corrective action (cleanup) is to satisfy the "protection of human health and the environment [HH&E]" standard, which can be achieved using engineered and institutional controls. EPA recognizes that, for a number of reasons, establishing remediation goals for ecological receptors is considerably more difficult than establishing goals for the protection of human health. Although the NCP establishes a protective risk range for human health, it provides little guidance regarding developing remediation goals considered to be adequate for protecting ecological receptors. In practice, a variety of organizations have successfully completed elements of ecological land reuse (including habitat restoration) as functional parts of environmental remediation projects. Some of these successes are highlighted in case studies contained in this document and *Making the Case for Ecological Land Reuse* (ITRC ECO-1 2003).

While restoring habitat, objectives target the elimination of threats to HH&E and exposure routes to wildlife to ensure that land remains capable of serving as safe and supporting habitat. The actions to eliminate relevant exposure routes may be designed to be noninvasive while allowing for existing habitat to thrive. Additionally, ecological reuse must not create an exposure pathway; for example burrowing animals would not be reintroduced at a site with residual contamination at depth.

Ecological enhancements can be applied in three ways at impacted properties, as determined by the characteristics of the property and the nature of the impacts:

1. From the outset, strive to create or restore a safe, sustainable wildlife habitat as a final cleanup goal at compromised sites that once served as habitat (such as a contaminated estuary).

2. Use sustainable habitat as a complement to a traditional remedy to enhance cleanup outcomes at sites that did not previously function as significant habitat (such as abandoned industrial land). The technologies and controls used to arrive at the habitat may or may not be green technologies. While this guidance document emphasizes green technologies to support ecological land reuse as part of remediation, the successful use of traditional technologies can achieve the same goals, as depicted in Figure 5-1. Numerous site remediation approaches can be used to ensure that contaminated material left on site is managed and contained in a manner that protects HH&E, while allowing for safe ecological reuse. Some of the more traditional methods include cover systems (ITRC ALT-2 2003), gas

collection and treatment systems (ITRC-ALT-3 2006), groundwater collection and treatment systems, permeable reactive barrier walls (ITRC PRB-3), and diversion walls. Also see the USEPA CLU-IN site (http://www.clu-in.org/) for additional technology descriptions

3. Use natural or green technologies to remove contaminants or secure sites while providing viable wildlife habitat, even though the final use may not be ecological.

A benefits analysis can assist in determining which approach will be most effective. Ultimately, the characteristics of the site itself as well as the characteristics of the surrounding community will influence the outcome and conclusions (see Section 5). Successful internal marketing of ecologically-based remediation projects depends on much more than the economics of a remediation project. Many intangibles influence ecological choices, including community good will, corporate image, shareholder perception, and stakeholder satisfaction. These components of an ecological reuse remediation project will be further discussed in Sections 5 and 7.

Tailoring the cleanup to a specific end use, established early in the process, can avoid unnecessary actions that otherwise increase costs, delay progress, and may not result in remedies that are fully protective of human health and the environment.

As an example of the interaction of traditional remediation and ecological enhancement, consider a site containing persistent bioavailable toxins where the optimal site cleanup was determined to contain elements of habitat applied as a compliment to a traditional excavation-based remedy. Although excavation activities may temporarily reduce the site's ecological function, this action will ultimately enhance the final habitat quality due to the elimination of residual risks associated with the removed toxins. On the other hand, a natural remedy alone may be preferable at a site where the contaminants are less persistent, immobile, or more subject to degradation. In each case, a traditional remedy alone would have brought the restored site to the minimal conventional endpoint necessary to achieve protection of HH&E, but the incorporation of ecological enhancements would greatly enhance the final ecological value, and possibly social and financial assets. A formalized alternatives analysis, known as a Net Environmental Benefits Analysis, or NEBA (Efroymson 2003), may be used to weigh the cost of various remedial options (contaminant removal, engineered controls, or institutional controls) against the environmental costs and benefits of each alternative. An NEBA can result in acceptance of restoring the site to a non-pristine baseline if the benefit from having some habitat value at the site outweighs the potential for adverse effects from contaminants left in place.

Data collected for an eco-risk assessment used to establish cleanup standards applicable to habitat creation can require more complex evaluation than a human health risk assessment. The resulting cleanup goals for ecological protection may or may not be more stringent than for protection of human health alone. Tailoring the cleanup to a specific end use established early in the process can avoid unnecessary actions that otherwise increase costs, delay progress, and may not result in remedies that are fully protective of HH&E. Designing a site restoration project to include long-term sustainable habitat offers the advantage of creating new habitat, protecting habitat found in previously impacted areas, and mitigating the effects of continued urban encroachment, contaminant toxicity, reduced flora and fauna density, stormwater impacts, and reduced aesthetics.

This guidance identifies the flexibility in cleanup authorities where it is demonstrated that preserving existing habitat or creating new habitat is favored by the regulatory program and therefore has an overall benefit to humans and the environment. An overall site cleanup program should consider habitat restoration (creation, enhancement, preservation, etc.) when evaluating marginal risk scenarios where remedial actions may impact the environment or be of questionable effectiveness in managing risk. The program should allow for an approach that balances the management of marginal ecological risk with natural resource benefits from restoration (see NEBA discussion in Section 7.4).

2.1 Using Natural or Ecological Enhancements as a Cleanup Technology

Many remediation projects end with the cleanup of the impacted media. The ultimate goal of a remediation, however, is to reduce or eliminate exposure to releases of chemical substances in a manner that is protective of HH&E, all the while returning land to beneficial use. A well-planned remediation can achieve much more than simply cleaning up the impacted media such as soil, surface water, groundwater, or air. The cleanup remedy must be cost-effective, as discussed later in Section 7, and use durable solutions, which may include conventional or alternative technologies. In certain instances, ecological or naturally occurring elements may be used as all or part of the remedy. To be accepted under most federal or state hazardous waste programs as an alternative technology, ecological elements or enhancements must

- be evaluated in order to demonstrate a level of performance sufficient to meet the goals and requirements of applicable federal or state remediation regulations (in other words, the initial goal of the project is successful remediation of the impacted area);
- include an analysis of the persistence, toxicity, mobility, and bioaccumulative potential of site-related constituents;
- consider short and long-term potential threats to HH&E.

For example, a constructed wetland that offers treatment of relatively immobile and nonbioaccumulative constituents, as well as providing habitat for wildlife, could be a cost-effective, community-friendly, ecologically viable alternative to more costly conventional technologies such as groundwater pump-and-treat. Likewise phytoremediation, where plant species are considered and selected with respect to the potential habitat they offer, can be a cost-effective alternative for soil, source area, and groundwater treatment. In both of these examples, an ecological risk assessment or monitoring program may be necessary to demonstrate that constituents of concern are not accumulating to levels that might be toxic to wildlife attracted by the created or restored habitat. With regards to the need for these programs, two questions remain:

- Is the created or restored habitat and resulting wildlife population or diversity positive for the remediation system, the surrounding ecology, and community?
- If not, can such benefits be efficiently and effectively designed into the system based on cost and resource needs?

Green technologies run into the same regulatory impediments as other technologies when considered for CERCLA, RCRA, Brownfield, Mining, and Voluntary Cleanup sites. For example, some treated sludge may be listed as hazardous waste. If the listed waste is "managed", as legally defined, then it must be managed in accordance with stringent standards and be treated or disposed of in accordance with RCRA standards. Some regulatory programs consider plowing or even seeding as management or treatment of the waste. Materials that are mixed with or derived from these materials are also listed wastes, so harvesting plant growth may require management the harvested material as a listed hazardous waste. Policies have been developed to address these issues (area of contamination interpretations in RCRA and Superfund, RCRA Corrective Action Management Unit rules, and others). In some instances, however, impediments associated with the regulatory mandates for managing listed wastes have thwarted natural remediation efforts that would have been successful from a risk management perspective.

Sites where material other than RCRA-listed waste is present would be subject to an individual state's requirements. For example, in Pennsylvania a permit is generally required for processing nonhazardous regulated waste. If the process is part of onsite treatment conducted under the state's environmental cleanup law, however, a permit would not be required, even though the substantive technical requirements must be followed to assure protection of HH&E. At these sites, seeding and harvesting can be done as needed without triggering costly management standards. Harvested materials must be characterized for relevant hazardous waste characteristics but generally need not be managed as hazardous waste.

As stewards of natural resources, individuals responsible for addressing environmentally impacted sites have the ability to effect great improvements on stressed ecological communities. While a traditional remedial technology may be required to resolve the potential short- and long-term threats to HH&E, ecological technologies can be used as a good faith effort to promote additional environmental stewardship, improve property value, and increase community good will. They are a cost-effective means of increasing the ability of restored property to support wildlife. In urban settings, where the availability of habitat is limited, islands of habitat on restored lands may prove invaluable in supporting both migratory and permanent resident species, in preparing for its ultimate ecological service, and in providing environmental educational opportunities.

2.2 Natural or Green Remediation Strategies

Ecological/natural remediation strategies may include one or more of the following technologies or techniques, which may constitute an alternative or may also incorporate traditional remediation techniques in the final alternative chosen to remediate a site. Ecological or natural technologies include but are not limited to the following:

- phytotechnologies (http://www.itrcweb.org/gd_Phyto.asp)
- engineered or natural wetlands treatment (http://www.itrcweb.org/gd_CW.asp or http://www.itrcweb.org/gd_MW.asp)
- ET (evapotranspiration) covers and plant hydraulic barriers (http://www.itrcweb.org/gd_ALT.asp)

- remediation by natural attenuation (http://www.itrcweb.org/gd_ISB.asp)
- enhanced in situ bioremediation (http://www.itrcweb.org/gd_ISB.asp)
- biological soil amendments (Sopper, 1993; Brown et al. 2001 and 2005; EPA 2000; and http://www.itrcweb.org/gd_SMART.asp)

Phytoremediation is the use of plants for water and/or soil or groundwater treatment (see *Phytotechnologies*, http://www.itrcweb.org/gd_Phyto.asp). This technology presents a potentially lower cost alternative to excavation, land farming, or shallow air sparging. The plants used for remediation may also be integrated into temporary or permanent green land uses such as water features in parks, landscaping, natural habitat, or preserves. In the case of salt contamination, halophytic plants can be used to preferentially remove salts from soil and soil pore water, and thus may be used to provide both treatment and vegetative cover. The aboveground portions of such plants may need to be periodically harvested to ensure continued removal of salts from the site over time; thus the use of halophytic plants may be more compatible with park, grazing, and landscaping uses than with habitat or conservation uses.

Engineered wetlands are plant/water systems that mimic natural wetland systems and are designed to remove both solid and dissolved contaminants from water. These wetlands are a potentially lower cost alternative to engineered water treatment systems and may reduce the need for injection systems, water transport by pipeline, and/or diffuser discharges to streams and rivers. A large amount of surface area and periodic maintenance may be required for these systems (ITRC Wetlands-2 2003, http://www.itrcweb.org/gd_CW.asp). This technique may not be useful for small sites or in conservation easements or preserves where periodic maintenance would be disruptive to established habitat. Additionally, planners must be cautious not to create an attractive nuisance by enticing, for example, waterfowl into an area when the wetlands are serving a treatment function such as removing metals.

Case Study: Rocky Flats National Wildlife Refuge

Rocky Flats National Wildlife Refuge will be managed by the U.S. Fish and Wildlife Service (Service) when the EPA certifies that cleanup and closure at the Department of Energy's (DOE) Rocky Flats site has been completed and that all response actions are operating properly and successfully. After EPA certification, DOE will transfer much of Rocky Flats to the Department of the Interior and the Service will manage it as a National Wildlife Refuge. DOE will be required to conduct postclosure environmental monitoring and remedy maintenance in accordance with a postclosure, long-term stewardship agreement approved by EPA and Colorado Department of Public Heath and Environment (CDPHE). DOE will also review the cleanup remedy at least every five years with the EPA and CDPHE. The EPA and CDPHE can require DOE to undertake an additional action if post cleanup monitoring indicates the cleanup is not protective of human health and the environment.

The majority of the site has remained undisturbed since its acquisition and provides habitat for many wildlife species, including two species that are federally listed as threatened (bald eagle and Preble's meadow jumping mouse). Establishing the site as a unit of the National Wildlife Refuge System (NWRS) will promote the preservation and enhancement of its natural resources for present and future generations. The Final Comprehensive Conservation Plan (CCP) and Environmental Impact Statement (EIS) for the Rocky Flats National Wildlife Refuge will guide management of Refuge operations, habitat restoration, and visitor services for the next 15 years (208H*http://rockyflats.fws.gov/Documents/FEIS/Chapter_1.pdf*) .

Hydrophilic plants may be successfully used to control water infiltration and seepage. For example, if these plants grow over the top of closed landfills or waste piles they may reduce water seepage more effectively than traditional impermeable cap-and-cover methods. This in turn may reduce water percolation through the waste and reduce water handling and treatment costs (ITRC ALT-2 2003, http://www.itrcweb.org/gd_ALT.asp).

Remediation by natural attenuation (ITRC ISB-3 Reprinted September 1999, http://www.itrcweb.org/gd_ISB.asp) is the reliance on analyzed natural biological systems to metabolize contaminants in soil and ground water. This technique is simultaneously compatible with virtually all ecological land reuses since it neither jeopardizes the use of the surface nor does it disrupt the surface, except for installation and maintenance of monitoring wells. Enhanced in situ bioremediation is similar and normally enhances the existing natural conditions to encourage the remediation or degradation mechanism toward complete mineralization of the contaminants (ITRC ISB-6 1998, http://www.itrcweb.org/gd_ISB.asp).

2.3 Creating Habitat as a Complement to a Traditional Remedies

Carefully designed ecological elements and enhancements may supplement or complement conventional remedial technologies. Remedial technologies typically provide environmental remediation by source control or removal of contaminants. The ability of the media, particularly surface soil, surface water, and sediments, to return to a prerelease functional level has not always been addressed in the remedial process when the remediation process design focuses on human health criteria. Ecological techniques such as improving in stream cover for fish and macroinvertebrates following sediment excavation, installing nesting boxes on a landfill cap, or implementing a woodlot program can cost-effectively return the resource to a productive capacity that would exceed the capacity resulting from conventional remediation techniques. Additionally, these enhanced measures would be expected to receive high marks at sites where local stakeholders are actively involved in selecting the remedial alternatives. This community acceptance is always an important factor in a successful remediation strategy and is one of the nine Superfund criteria used in selecting a remedy.

Ecological elements and enhancements incorporated into site remediation may limit potential environmental liabilities through Natural Resource Damage Assessments (NRDAs).

Ecological elements and enhancements incorporated into site remediation may help manage environmental liabilities under a Natural Resource Damage Assessment (NRDA). Under an NRDA, natural resource trustees have the authority to assess injuries to natural resources and the ecological services associated with the resources that have been diminished or lost as a result of releases of hazardous substances or discharges of oil. Remedial project managers should ensure that natural resource trustees are provided a key stakeholder role throughout the remedial process. Ecological enhancements may arguably offset or mitigate potential claims based upon restoration of habitat function following the remedial process.

2.4 Ecological Enhancements as End-use Goals

One key element of optimized and cost-effective remedial site management is the inclusion of a targeted postremediation or future land use of the property during the development of a remedial action plan. Creation, restoration, protection, or enhancement of habitat define the desired ecological end use, in addition to being complementary to a variety of other end uses of the property. Sites with green end uses can be compatible with a wide variety of ecological/natural remedial options. Many of the ecological enhancement options can be seamlessly incorporated into the land end use itself, especially if incorporated by design as part of the initial remedial selection process. The ecological enhancements then become an integral part of the plant/soil/water habitat system.

Sites with residential end land uses were once considered least compatible with ecological/natural remedial actions, since landowner/seller financial liability considerations often disfavored such uses for remediated sites. Where residential land use could not be avoided (such as in the case of condemnation) the favored remedial actions, such as excavation and refill, were not generally compatible with ecological/natural remedial methods. Recent experience, however, has shown that green land uses, such as parks and greenways, can enhance community and property values and can be an acceptable land reuse, especially in areas where pressures for residential use are high. Ecological enhancements can also be designed into functional elements of residential use such as stormwater routing and retention/detention features. This development, as described in the Woodlawn Case Study, appreciates the added value of intermingled ecological and residential use in the development strategy. Intermingled-use scenarios offer the additional market value of the less crowded open space and recreational value of the ecological enhanced properties.

3. BENEFITS AND CONSTRAINTS

Benefits and constraints provide a rationale for choosing or rejecting remedies with ecological elements or enhancements as an end use. While individual benefits are assigned to specific users for the purposes of this discussion, most benefits help multiple users. Reasons for selecting ecological elements can vary, so the team questionnaire asked respondents to provide their rationale for incorporating ecological elements or enhancements into a remediation project.

Benefits are characterized as environmental, economic, and public; however a benefit should not be restricted to a particular perspective (e.g. industry, regulatory, or public). In many cases the benefit contributes to multiple perspectives: for example, a benefit may directly apply to industry, but indirectly contribute positively to the community and the regulatory agency. Figure 3-1 displays a fairly equitable distribution of why ecological land reuse is targeted for remediation projects. Cost is the most readily quantifiable reason for implementing remedies with ecological elements or enhancements. The majority of the reasons given for implementing ecologically based remediation projects are semiquantifiable (see Section 7 later in this document for a description and examples of quantifiable, semiquantifiable, and qualitative values).

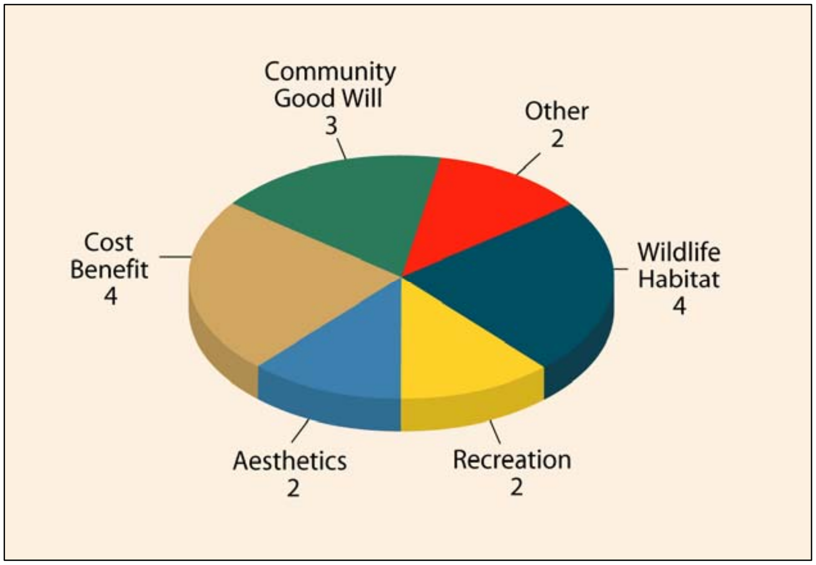

Figure 3-1. What was the goal for selecting ecological land reuse?

3.1 Environmental Benefits

Restoring or creating ecosystems, both during the remedial process and as a final postremediation end use, provides environmental benefits (onsite as well as offsite) to soil, surface water, sediment, and groundwater quality, as well as to human and overall ecological health. These benefits are described below:

- *Attracts wildlife*. Green and natural remediation technologies which include end-use plantings and other habitat elements attract wildlife.
- *Hydraulically controls landfill leachate*. Natural remediation technologies can minimize leachate head buildup in closed landfills, thereby eliminating side or groundwater seepage.
- *Biodegrades environmental contaminants*. Natural biochemical mechanisms can enhance aerobic and anaerobic degradation of various contaminants, including volatile organic compounds, polynuclear aromatics, various other hydrocarbons, and some pesticides.
- *Controls dust*. Both natural remediation technologies and end-use plantings reduce fugitive dust emissions, particularly if the soil is prepared with compost and/or mulch at the time of planting.
- *Reduces sediment transport and soil erosion*. Green and natural remediation technologies and end-use plantings, once established, reduce sediment transport and soil erosion from storm events due to soil stabilization characteristics of plant roots.

- *Stabilizes stream banks*. Plantings can be used along stream banks to prevent erosion and physically filter stormwater runoff, which results in reduced contaminant loading to surface waters.

- *Uses atmospheric carbon dioxide*. Both natural remediation technologies and end-use plantings use atmospheric carbon dioxide and produce oxygen, which directly reduces the greenhouse gases implicated in global warming.

- *Improves ground water recharge*. Both natural remediation technologies and end-use plantings can reduce runoff and improve groundwater recharge

- *Minimizes human and environmental exposures*. In situ natural remediation technologies reduce the need to excavate and haul impacted soil. Excavation and hauling not only use fuel, emit air pollutants, and occupy landfills, but also potentially create additional exposure pathways during the movement of the soil, thereby increasing risk. These traditional methods also provide a risk to heavy equipment operators. For restricted-use sites requiring long-term land use restrictions, ecological and recreational reuse prevents unacceptable human risks to areas of concern.

- *Improves environmental stability*. In situ natural remediation technologies avoid disrupting the soil and associated root structures (as excavation does), thereby improving the stability of the local ecosystem.

- *Provides harvestable resource*. Metals can sometimes be recovered for reuse by harvesting phytoremediation plant biomass. Reusing plant waste provides high organic compost to reduce the dependence on topsoil resources and creates a market for a waste product which can cause environmental problems through uncontrolled use in certain settings.

- *Improves aesthetics*. Both natural remediation technologies and end-use plantings are often more aesthetically pleasing than mowed grass or paved areas.

- *Provides educational opportunity*. Natural remediation technologies, such as plantings, can provide an educational opportunity for students wishing to learn about natural remediation technologies and environmental processes. Where residual contamination or landfills remain, students can learn long-term stewardship of erosion controls, monitoring, and maintenance of engineered remedies.

- *Provides recreational area*. End-use plantings can provide an area for community or employee recreation.

- *Provides migratory pathways*. Both natural remediation technologies and end-use plantings can provide needed landscape ecology for pathways for migratory species and wildlife corridors.

- *Improves plant diversity*. Vegetation may be selected that will enhance the diversity of the existing plant community. In addition, succession planning may be implemented to enhance the plant diversity of future plant communities.

3.2 Economic Benefits

Both natural remediation technologies and end-use plantings can be cost competitive with other traditional remediation technologies and end uses. They also can be an important component of more complex remedies, particularly when addressing final, polishing remedy requirements. Installation, operation, and maintenance costs may be reduced over traditional remedies both for engineered remedies and land management. Specifically, the following economic benefits can be realized:

- *Reuses waste materials*. Composted waste materials (sewage sludge, fly ash, manure, green waste, agriculture waste, food waste, etc.) can be used as a soil amendment for both natural remediation technologies and end-use plantings, thereby reducing the cost of waste disposal.

- *More efficiently use of limited resources*. Limited resources can be better deployed at a greater number of sites if those limited resources can be more cost-effectively deployed by harnessing natural attenuation and biodegradation processes.

- *Enhances institutional controls (ICs)*. When ICs are part of the end use of the site, an ecological component can control the site while providing a beneficial land use (such as a park system which is only open eight hours per day and thus restricts potential exposure to eight hours per day, see inset below). This could be a recreational use, risk-based cleanup outcome with land use or institutional controls (USEPA 2000). The reuse governed by ICs may be viewed as an economic benefit because it has the potential to return the property to productive reuse. ICs can have several other benefits. First, they provide a means of managing property so that it is protective of HH&E without being remediated to unrestricted use concentrations. This saves the owners/operators remediation cost. Second, the property may be placed into economic service that generates revenue for the local or state municipalities. Ecological reuse coupled with institutional controls may be even more financially beneficial since the controls may provide a means of managing areas at parks that are protective of HH&E in ecologically distressed areas. It is precisely this type of reuse that can spark redevelopment of downtown areas. Ecological reuse can also help streamline long-

Case Study: Fernald Closure Project

The projected final land use of the Fernald Closure Project (FCP, a DOE site in Ohio) projects the end use as an undeveloped park with limited public access to the site. Risk evaluations, conducted for each of the site's operable units, used the undeveloped park as the projected final use of the site. A recreational user was the primary receptor used to establish cleanup levels at the site. An environmental assessment (EA) was prepared in 1998 to finalize the land use decision for the Fernald closure plan. The EA proposed that more than 900 acres of the site be restored and dedicated as an undeveloped park. It also proposed a 23-acre portion of the FCP that may be considered for development to support community needs.
(207Hhttp://www.fernald.gov/Future/flu.htm)

term stewardship. An example in which DOE has incorporated ecological end use into the management of legacy sites is included in the Fernald inset and as a case study in Appendix C.

- *May generate revenue*. Ecological end use sites may generate revenue through the provisions of ecological services. Enhanced ecosystems can provide recreational areas for the community and businesses, as well as revenue from commercial or sports fishing, tourism, and other industries.

- *Provides marketing and competitive advantages*. Ecological land reuse can be used as a marketing/competitive advantage to emphasize a company's environmental stewardship, thereby attracting environmentally-conscious clients. Aesthetically pleasing planted areas may provide a competitive edge by attracting more customers.

- *Increases property value*. Ecological elements and enhancements may provide an aesthetic improvement and increase the market value or salability of a property.

- *Provides source of recoverable resources*. Harvested biomass from natural remediation technologies can provide a source of recoverable metals, while harvested biomass from natural remediation technologies and end-use plantings can provide fuel, lumber, or other beneficial end products.

- *Provides potential opportunity to obtain environmental offsets*. Consideration of ecological land reuse may provide an opportunity to allow environmental cleanup cost and requirement offsets when negotiating site cleanup objectives with regulators. If the cleanup objective includes a sustainable ecosystem that will support wildlife resources after remediation, this could be an offset for a pending NRDA claim. If the management of the ecological element coincides with the institutional controls, the overall cost of stewardship can be reduced.

- *Offers tax advantages*. Conservation easements can result in a one-time income tax credit and/or multiyear property tax savings. (see Appendix B in ITRC ECO-1 2003).

These and other economic benefits are analyzed further in Section 7.

3.3 Public Benefits

In many cases, organizations desire to use the ecological enhancements to provide educational opportunities, aesthetic benefits, and natural resources to the local area. Biology, horticulture, ecology, wetland hydrology, plant identification, and environmental remediation are among the topics of educational interest. The natural resources associated with ecological enhancement systems could also serve as seed banks and breeding grounds for species of concern. For site owners and regulatory agencies, these alternatives can provide public relations benefits that may not be available from other strategic options:

- *Improves/increases recreational or tourism opportunities*. Outdoor recreation enhances the livability of a community and thereby the value of the property surrounding or adjacent to it. It provides a desirable landscape and an attractive community.

- *Provides educational opportunities*. During the remediation or redevelopment of environmentally impacted sites, nongovernmental organizations and local community groups such as the Boy Scouts and Girl Scouts, schools, youth programs, bird watchers, nature conservationists, and prairie and wetland enthusiasts may express interest in pursuing reuse alternatives that incorporate ecological elements or enhancements.

- *Improves reputation*. These benefits include enhanced reputation, "green" image, external validation, and sustainable operations. In 1999, the Conference Board, a worldwide business research network, asked consumers what matters most when forming an impression of a company. Most said reputation—it was the number one response. Almost half said they had done business with a company in the preceding 12 months or supported it in some other way if they considered it socially responsible. Half said they had boycotted a company's products in the same period or had urged others to do so when they didn't agree with its actions or policies. Another study by Gregory (2002) showed that business leaders in that year's Fortune top ten most-admired companies ranked consumers as the most important influencers of corporate reputation. Even more than chief executive officer reputation, print media, employees, or analysts, the survey demonstrated the importance of reaching the consumer with strong corporate messages that contribute to market success and business results (ITRC Eco-1 2004, http://www.itrcweb.org/gd_EE.asp).

- *Improves goodwill and good neighbor standing*. Ecological elements and enhancements should be integrated with stakeholder and community planning considerations. These can foster goodwill among facility neighbors immediately adjacent to and throughout the community. Since companies wish to do business with a given community, this goodwill may translate into community acceptance and easier future business development within the community. Ecological reuse can also promote regional cooperative conservation and watershed management.

- *Enhances workforce stability through improved morale*. Long-term employment has a demonstrated benefit for companies.

- *Improves aesthetics*. As mentioned above, improved aesthetics may increase the property value or salability of a parcel.

- *Improves livability*. Ecological enhancements can improve the community image, bring in tourism, and provide recreational usage.

- *Increased natural resources*. The ecological elements or enhancements may convert waste materials into reusable material or generate new salable materials (e.g., harvestable wood as a commodity).

In many cases, nongovernmental organizations (see Appendix D) can provide an impartial assessment of the activities agreed upon by site owners and regulatory agencies and can help the process to move forward with community acceptance. These organizations can also serve to ensure the continued operation and maintenance of these systems, either by monitoring the progress over time (during remediation) or accepting the responsibility directly to manage the end use. In this manner, ecological land reuses lead to sustainable operations and long-term advantages of beneficial public relations.

3.4 Constraints

Even though there are a great many advantages to ecological land reuse, there are also constraints, which over the years have unexpectedly caused public concerns when using some green technologies and ecological enhancements to remediate contaminated sites. These constraints can include the following:

- lack of regulatory acceptance with ecological enhancements
- need for increased creativity
- visual aesthetics
- plant height and density obstructing views
- plant use—could contain noxious or invasive species
- allergies
- attracting undesirable wildlife such as mosquitoes, wasps, snakes, or other perceived nuisance species
- introduction of ecological receptors where none previously existed

Finally, ecological enhancements have the potential to create wildlife imbalances. In some cases, single species plantings such as those often used in phytoremediation can unintentionally encourage ecological imbalances and vulnerabilities to attack by pests or disease. In addition, the natural remediation plantings may have to be protected from wildlife consumption if the plantings will bioaccumulate potential toxins.

4. IDENTIFYING REGULATORY FLEXIBILITY AND CONSTRAINTS

EPA guidance emphasizes that proper closure is essential for a hazardous or solid waste operation or remediation project. EPA’s basic approach to ensuring proper closure and remediation has been to prescribe criteria for a final remedy that meets the closure regulations specified under RCRA; these criteria are historically affected by human health impacts more than by ecological impacts. This approach is a slow-moving program, but has generally been accepted by the public and regulatory community, regardless of whether it offers the best option for site conditions and end use.

While applicable regulations and guidance are available for reclaiming mining sites, voluntary remediation sites, Brownfield sites, and CERCLA/Superfund sites, a slightly higher incidence of ecological land reuse occurs in voluntary cleanup programs. The increased use of ecological elements and enhancements in voluntary cleanup remediation projects indicates that owners and operators of these sites see a benefit to, and have preference for, remediation strategies that incorporate ecological elements or enhancements. Additionally, current regulatory practices for the other programs may complicate establishing an ecological end use for a remediated site with both traditional technologies and green technologies. This may translate into a real or perceived notion that it may be more complicated to get regulatory approval for ecological elements or enhancements in the remediation plan in programs other than voluntary cleanups. Implicit in all these standards, however, is the goal to return land to productive use. A typical example of regulatory support for this goal is the requirement of stakeholder involvement and economic encouragements in the Brownfield programs (ITRC Brownfields-1 2003, http://www.itrcweb.org/gd_Brnflds.asp). Projects that provide returning value to the region, as an additional objective, move quickly and are highlighted as models for success.

Often, ecological considerations are incorporated into remediation and closure projects as an afterthought or, worse, following the completion of the remediation project.

A variety of regulations and guidance (CERCLA, RCRA-C, etc.) require that the design of a remediation or closure project must consider site conditions and encourage alternative designs that are innovative and use site-specific information. These alternative designs are accepted as long as they demonstrate a level of performance that is protective of HH&E and adequately meet the intent of the regulatory requirements. Protection of the environment includes ecological reuse, so ecological remediation designs satisfy the intent of the regulations and create the opportunity for alternative closure and remediation designs.

Ecological elements are often incorporated into remediation and closure projects as an afterthought or, worse, following completion of the remediation project. This approach fails to optimize the advantages of a fully integrated ecological land reuse or of early inclusion of potential stakeholder support for ecological elements or enhancements in the remediation design. The design and construction of the ecological end use as an integrated component of the remediation system will realize more pronounced benefits from the remediation process. This section reviews regulations and guidance related to closure and remediation projects that include ecological end use as an integral part of a project. This review provides clear evidence that ecological end uses are not prohibited, but instead are encouraged, when the property owners, communities, and other stakeholders select such land uses while maintaining the protectiveness of the remedy. The regulatory flexibility necessary to promote ecological land reuse into site remedies design is identified in examples that follow.

4.1 Regulations and Guidance

The RCRA and CERCLA programs have issued guidance to tailor remedies to site-specific end uses including ecological enhancements. EPA's document *Guidance on Completion of Corrective Action Activities at RCRA Facilities,* (EPA 2003, http://www.epa.gov/swerffrr/pdf/final_guidance_rcra.pdf) describes how corrective actions can be completed, with contaminants remaining, using controls tailored to protection for a specific end use for the site. On February 18, 2004, EPA issued its new *Guidance for Preparing Superfund Ready for Reuse Determinations at Superfund Sites* as an element of, and tool for, the CERCLA program. This guidance describes how to document the conditions that will allow a Superfund site to be reused.

Superfund's written policy fully embraces a planning process that anticipates future uses. EPA, through the Superfund Redevelopment Program, encourages the beneficial reuse of Superfund sites while working towards EPA's overriding objective for all sites—protection of HH&E. With forethought and effective planning, communities and natural resource trustees (trustees) can return sites to beneficial use without jeopardizing the effectiveness of the remedy put into place to protect HH&E.

EPA has documented over three hundred NPL sites in reuse, a number of which have treatment systems, monitoring wells, contaminated material, or other features remaining on site. About 35 of these sites are reused for primarily ecological purposes. Superfund cleanup sites are being used for wetlands, meadows, streams, and ponds (where they provide habitat for terrestrial and aquatic plants and animals) as well as for low-impact or passive recreation, such as hiking and bird watching. In addition, many sites that were redeveloped primarily for other purposes, such as commercial or recreational facilities, also contain significant ecological resources or green space. The program recognizes that ecosystems are essential to all aspects of life, that it would be difficult to sustain society without them, and that their value in urban, suburban, and rural areas is often not fully recognized when decisions are made about land use.

The Superfund Redevelopment Program maintains an extensive web site that includes EPA directives and information on the reuse of Superfund sites for ecological and other purposes. Some of the key documents to consult for more information include the following:

- OSWER Directive 9355.7-06P Reuse Assessments: A Tool to Implement the Superfund Land Use Directive, 2001
- OSWER Directive 9355.7-04 Land Use: the CERCLA Remedy Selection Process, 1995
- OSWER Directive 9265.0-33, Guidance for Preparing Superfund Ready for Reuse Determinations at Superfund sites, 2004

EPA's Superfund Redevelopment Program has developed a series of reports to inform interested parties at hazardous waste sites about planning and technical issues that may arise during the remediation process when reuse of a site is intended following cleanup. The reports include guidance for sites with onsite containment or treatment facilities or equipment, The reports also address Superfund sites used for commercial facilities, golf courses, and other outdoor recreational areas and include information useful for other types of site uses as well:

- *Reusing Cleaned Up Superfund Sites: Commercial Use Where Waste is Left On-Site,* EPA 540/K-01/008, 2001 (http://www.epa.gov/superfund/programs/recycle/c_reuse.pdf)
- *Recreational Use of Land Above Hazardous Waste Containment Sites*, EPA 540/K-01/002, 2001 (http://www.epa.gov/superfund/programs/recycle/tools/recreuse.pdf)
- *Reuse of CERCLA Landfill and Containment Sites,* EPA 540-F-99-15, 1999 (http://www.epa.gov/superfund/resources/presump/finalpdf/)

Superfund redevelopment efforts can take a variety of forms:

- A pilot program that, since 1999, has provided over seventy local governments with up to $100,000 in funds or facilitation services for reuse assessment and public outreach to help determine their site's future use.
- Partnerships between EPA, states, tribes, other federal agencies, local governments, communities, land owners, lenders, developers, and parties that are potentially responsible for contamination.
- The publication of redevelopment successes through case studies and fact sheets that illustrate reuse options and lessons that have been learned through pilots and other reuse projects.

While current guidance acknowledges reuse as an objective, it implements reuse retrospectively because it asks how sites can be used only after the remedy has been implemented. EPA, on the other hand, encourages planning and coordination toward a land reuse desired by the potentially responsible party (PRP), community and other interested parties. Several legal avenues can introduce this more proactive approach to remediation into the CERCLA program. Under CERCLA, RCRA is the source of potential "applicable or relevant and appropriate requirements" (ARARs) that govern cleanup (Gill et al. 1999) and may still have a critical impact.

Other sources of legislation and regulation may apply to sites in most states. Other sources of remediation authority may be Brownfields, Voluntary Cleanup, Mined Land Reclamation, and other remediation programs. All states have legislation and regulations protecting HH&E; a few states have policies and guidance that address the need to include ecological considerations in cleanup alternatives. Some of these regulations can be viewed at the DOE Office of Environmental Management Laws and Policy site (http://lts.apps.em.doe.gov/center/stewlink0.asp) and at Long Term Stewardship In the Nuclear Weapons Complex (http://ndep.nv.gov/lts/ndaa_lts.htm).

If the goal is to increase ecological enhancements as part of a remedy, an NRDA claim could be offset and

209HNatural Resource Trustees conduct NRDAs to identify and document the extent of injuries, quantify the injuries, and determine the cost of compensation for the injured resources. Compensation for injured natural resources resulting from releases of hazardous substances or discharges of oil can take the form of monetary damages, restoration projects, or a combination of both. Injuries to natural resources are evaluated by identifying the functions or services provided by the resources, determining the baseline level of the services provided by the injured resource(s), and quantifying the reduction in service levels as a result of the contamination. Regulations for assessing NRD have been promulgated under both CERCLA and OPA.
(210Hhttp://www.epa.gov/superfund/programs/nrd/nrda.htm)

provide regulatory incentives to PRPs to align ecological end-uses with resource protection and recovery. Including ecological end use along with strong stakeholder input into remedial decision making may preclude or reduce future NRDA claims. Ecological land reuse could alleviate NRDA whether an NRDA claim is imminent or not. See DOE CERCLA Information Brief, Office of Environmental Guidance, EH-231-017/0693, June 1993 (http://www.eh.doe.gov/oepa/guidance/cercla/nrda.pdf), for information on NRDA assessments in the DOE. While it may be unclear how these ecological reuses may offset future NRDA claims, there appears to be significant technical and regulatory basis for these discussions.

All environmental regulatory rules governing cleanup decisions require that the protectiveness mandates apply so long as land use restrictions are in effect. Remedy protectiveness reviews and institutional or land use controls must be maintained until residual contamination no longer poses a threat to HH&E. The selection of land use controls as a component of ecological reuse go hand-in-hand during remedy selection. For more information please see: *Institutional Controls: A Site Manager's Guide to Identifying, Evaluating and Selecting Institutional Controls at Superfund and RCRA Corrective Action Cleanups, EPA 540-F-00-005, OSWER 9355.0-74FS-P, September 2000.* (http://www.epa.gov/superfund/action/ic/guide/guide.pdf).

4.1.1 Hazardous Waste Disposal Facilities

> ***At several points the regulations indicate that alternative regulatory requirements may be used to supplant the more specific prescriptive regulations and can be used to support alternative design integrating ecological enhancements.***

CFR Title 40 Subchapter I, Parts 260–279 contains regulations governing the management of hazardous waste facilities. At several points the regulations indicate that alternative regulatory requirements may be used to supplant the more specific prescriptive regulations and can be used to support alternative design integrating ecological enhancements. CFR Section 264.110 (below) affords the opportunity to use "alternative requirements," provided they are protective of HH&E:

> § 264.110 Applicability.
> (c) The Regional Administrator may replace all or part of the requirements of this subpart (and the unit-specific standards referenced in § 264.111(c) applying to a regulated unit), with alternative requirements set out in a permit or in an enforceable document (as defined in 40 CFR 270.1(c)(7)), where the Regional Administrator determines that:
>
> > (1) The regulated unit is situated among solid waste management units (or areas of concern), a release has occurred, and both the regulated unit and one or more solid waste management unit(s) (or areas of concern) are likely to have contributed to the release; and
> > (2) It is not necessary to apply the closure requirements of this subpart (and those referenced herein) because the alternative requirements will protect human health and the environment and will satisfy the closure performance standard of § 264.111 (a) and (b) and c. Complies with closure requirements of this subpart including, but not limited to, the requirements of §§264.178, 264.197, 264.228, 264.258, 264.280, 264.310,

> 264.351, 264.601 through 264.603, and 264.1102. (51 FR 16444, May 2, 1986, as amended at 51 FR 25472, July 14, 1986; 57 FR 37264, Aug. 18, 1992; 63 FR 56733, Oct. 22, 1998)

Key to this regulation is the requirement to protect the environment. Integrating ecological end uses via the inclusion of ecological elements or enhancements into remedies is consistent with protection of the environment. Currently the EPA indicates that protecting the environment may include the replacement of habitat that was impacted on a site, local, or region (EPA 2004).

Section 264.110 does not specify prescriptive regulatory requirements but instead focuses on managing the potential risk associated with a hazardous waste or solid waste management units. The alternative requirements that are protective of HH&E are left to negotiations between the facility owner/operator and the regulators. This section also calls out the need to protect not only human health, but also the environment. While Part 264 of the CFR pertains to permitted hazardous waste facilities, similar regulations are found in Part 265, which apply to interim status hazardous waste facilities.

Similarly, Section 265.110(d) is significant because it affords the opportunity for the regional administrator to use "alternative requirements" protective of HH&E. Again, these regulations do not contain specific performance requirements but instead identify the need to be protective or manage the threat associated with a given hazardous waste activity. Therefore, this section of the regulations clearly supports the design, construction, and operation of alternative remedies, including those that are protective of the environment via the inclusion of ecological element or enhancements.

The RCRA regulations clearly establish closure performance standards for hazardous waste disposal facilities. These standards are found in 40 CFR Sections 264.111 and 265.111 for permitted and interim hazardous waste disposal facilities, respectively, and apply to hazardous waste landfills and other RCRA-regulated units. The standards state the following:

> The owner or operator must close the facility in a manner that:
>
> a. Minimizes the need for further maintenance; and
> b. Controls, minimizes, or eliminates, to the extent necessary to protect HH&E, post-closure escape of hazardous waste, hazardous constituents, leachate, contaminated runoff, or hazardous waste decomposition products to the ground or surface waters or to the atmosphere.

The intent of these standards is reiterated along with other previous closure performance criteria: to protect the environment by protecting surface impacts from runoff, surface water, groundwater, and air (in addition to protecting human health). EPA encourages alternative standards that are tailored to protecting HH&E via the inclusion of ecological elements and enhancements into remediation strategies while returning land to a productive end use (see EPA 2003 for further discussion).

Corrective action deals with responding to releases or past disposal events. Section 264.101 of 40 CFR identifies the performance standard related to implementing corrective action. The first portion of the federal corrective action regulations is copied below:

> § 264.101: Corrective action for solid waste management units.
>
> (a) The owner or operator of a facility seeking a permit for the treatment, storage, or disposal of hazardous waste must institute corrective action as necessary to protect HH&E for all releases of hazardous waste or constituents from any solid waste management unit at the facility, regardless of the time at which waste was placed in such unit.

This regulation again identifies the protection of HH&E as a goal. Therefore, at RCRA-regulated facilities with a historical release of solid or hazardous waste, protection of the environment should be considered as part of the final remedy. Similar statutes and regulations pertain to interim status or nonpermitted RCRA regulated facilities. One example is found in Colorado's regulations related to corrective action activities associated with interim status treatment, storage, and disposal facilities:

> Section: 265.5 Interim status corrective action orders.
>
> (a) Facilities that are or were subject to the requirements of Part 265 shall not have releases of hazardous waste or hazardous constituents into the environment which may be or are harmful to human health and the environment. Whenever on the basis of any information, the Department determines that there is or has been a release of hazardous waste or hazardous constituents into the environment from an interim status facility, the Department may issue an order under authority of Section 25-15-308(2), C.R.S. requiring corrective action or such other response measure as it deems necessary to protect human health or the environment. Any order issued under this section may include a suspension or revocation of interim status authorization to operate if the Department has reasonable grounds to believe and finds that the owner and operator has been guilty of a deliberate and willful violation resulting in such releases, or that the public health, safety or environment imperatively requires emergency action. Any order issued under this section shall state with reasonable specificity the nature of the required corrective action or other response measure and shall specify a time for compliance. Any order issued under this section may designate or establish corrective action management units or temporary units in accordance with 264.552 and 264.553.

The Federal Code of Regulations and many of the states' regulations related to the RCRA Program require the protection of the environment in addition to the protection of human health. Protection of the environment may and should include the implementation of ecological elements and enhancements. These requirements are far reaching in that they not only pertain to the RCRA Subtitle C regulatory program, but may also serve as ARARs for the CERCLA program.

4.1.2 Flexibility in Brownfield Legislation

On January 11, 2002, President Bush signed the Small Business Liability Relief and Brownfields Revitalization Act (Pub .L. No. 107-118, 115 stat. 2356, "the Brownfields Law"). The Brownfields Law amended CERCLA by providing funds to assess and clean up Brownfields, clarified CERCLA liability protections, and provided funds to enhance state and tribal response programs. Other related laws and regulations impact Brownfields cleanup and reuse through financial incentives and regulatory requirements. Brownfields legislation also emphasizes protection of the environment:

> ***Title II--Brownfields Revitalization and Environmental Restoration***
>
> Sec. 211. Brownfields Revitalization Funding
>
> (C) Site-By-Site Determinations- Notwithstanding subparagraph (B) and on a site-by-site basis, the President may authorize financial assistance under section 104(k) to an eligible entity at a site included in clause (i), (iv), (v), (vi), (viii), or (ix) of subparagraph (B) if the President finds that financial assistance will protect human health and the environment, and either promote economic development or enable the creation of, preservation of, or addition to parks, greenways, undeveloped property, other recreational property, or other property used for nonprofit purposes.

4.1.3 Flexibility in State Solid Waste Regulations

The federal regulations pertaining to municipal solid waste facilities include provisions for the use of alternative requirements as part of the closure process as identified below:

> (3) The Director of an approved State may establish alternative requirements for the infiltration barrier in a paragraph (b)(1) of this section, after public review and comment, for any owners or operators of MSWLFs that dispose of 20 tons of municipal solid waste per day or less, based on an annual average. Any alternative requirements established under this paragraph must:
> (i) Consider the unique characteristics of small communities;
> (ii) Take into account climatic and hydrogeologic conditions; and
> (iii) Be protective of human health and the environment.

In addition to ecological elements or enhancements being incorporated into the closure process, they should also be considered as part of the corrective action process as identified below in the Federal Solid Waste Regulations.

> Part 258—Criteria For Municipal Solid Waste Landfills Subpart E—Ground-Water Monitoring and Corrective Action
>
> Section: 258.58 Implementation of the corrective action program.

(a) Based on the schedule established under §258.57(d) for initiation and completion of remedial activities the owner/operator must:

(1) Establish and implement a corrective action ground-water monitoring program that:

(i) At a minimum, meets the requirements of an assessment monitoring program under §258.55;

(ii) Indicates the effectiveness of the corrective action remedy; and

(iii) Demonstrates compliance with ground-water protection standard pursuant to paragraph (e) of this section.

(2) Implement the corrective action remedy selected under §258.57; and

(3) Take any interim measures necessary to ensure the protection of human health and the environment. Interim measures should, to the greatest extent practicable, be consistent with the objectives of and contribute to the performance of any remedy that may be required pursuant to CFR40 §258.57. The following factors must be considered by an owner or operator in determining whether interim measures are necessary:

(i) time required to develop and implement a final remedy;

(ii) actual or potential exposure of nearby populations or environmental receptors to hazardous constituents;

(iii) actual or potential contamination of drinking water supplies or sensitive ecosystems;

(iv) further degradation of the ground-water that may occur if remedial action is not initiated expeditiously;

(v) weather conditions that may cause hazardous constituents to migrate or be released;

(vi) risks of fire or explosion, or potential for exposure to hazardous constituents as a result of an accident or failure of a container or handling system; and

(vii) other situations that may pose threats to human health and the environment.

As with regulations pertaining to hazardous waste facilities, remediation planners can take advantage of this opportunity to implement ecologically-based closures in accordance with the provision to protect the environment. Again, the closure process for solid waste facilities should incorporate protection of the environment and not human health alone. Protection of the environment may be most readily achieved by the inclusion of ecological elements or enhancements into the closure and remediation processes.

4.2 Conventional Requirements versus Performance Requirements

The regulatory and guidance citations above identify requirements that have long dictated the protection of HH&E. This may be accomplished by direct implementation of the regulations or by taking advantage of and using “alternative requirements.” More recently, however, EPA has adopted policies that are meant to speed remediation and encourage the use of innovative designs (Gill et al 1999). The use of innovative technologies, including ecological elements or enhancements, is consistent with EPA's desire to move remediation projects through the regulatory process and achieve stable sites with final remedies in place that are protective of HH&E.

In addition, the use of risk-based criteria to evaluate the threat to HH&E is being used more frequently to make closure and remediation decisions. Risk-based criteria allow facilities and regulators to evaluate the current and potential future stressors and resulting threats associated with a particular site, facility, unit, or impacted area. The stressors may represent the risk or threat associated with a specific impacted area of contamination or waste management facility. The stressors are then converted to failure modes for closure or remediation projects. The stressors help planners understand how contamination may be released from an area, what media may be impacted, and who or what could then be exposed to the contamination. Alternative requirements may then be used to protect the environment by integrating ecological elements or enhancements into a postremediation end use as an integral part of the final remedy. This flexibility allows for innovation and alternative designs—designs that are geared toward performance-based instead of criteria-based remedies. These remedies incorporate ecological land reuse via the implementation of ecological elements or enhancements and are protective of human health and the environment.

4.3 Example of State Flexibility (Pennsylvania)

Pennsylvania's Land Recycling Program allows a flexible approach to site remedy selection that could readily accommodate the application of ecological elements or enhancements. The owner/operator of a site can choose one or a combination of three risk-based cleanup standards as an attainment endpoint for the remedial efforts. The final site condition can be selected to accommodate the expected end uses for the site. These regulatory standards are performance based and allow the cleanup to be conducted via a nonprescriptive approach, with the final standard attainment being the basic measure of success. Thus, the means by which the site is cleaned up is at the owner/operator's discretion, as is the final site restoration.

5. DECISION MAKING

Decision making is often driven by the need to address immediate threats or by procedures in a regulatory framework. While these are necessary, successful efforts also take a future view and define a clear vision of the desired end use of the site. To accomplish this, designers must consider the site's relationship to the surrounding environment, the needs of the local community, and the feasible solutions to the limitations created from the site contamination. This requires an immediate, yet step-wise process to effectively evaluate the site, the danger, and the goal. More specifically, the three initial steps in this process are: (1) establish the site service capacity, (2) mitigate immediate threats, and (3) assure that established cleanup goals protect HH&E. Figure 5-1 below details this process.

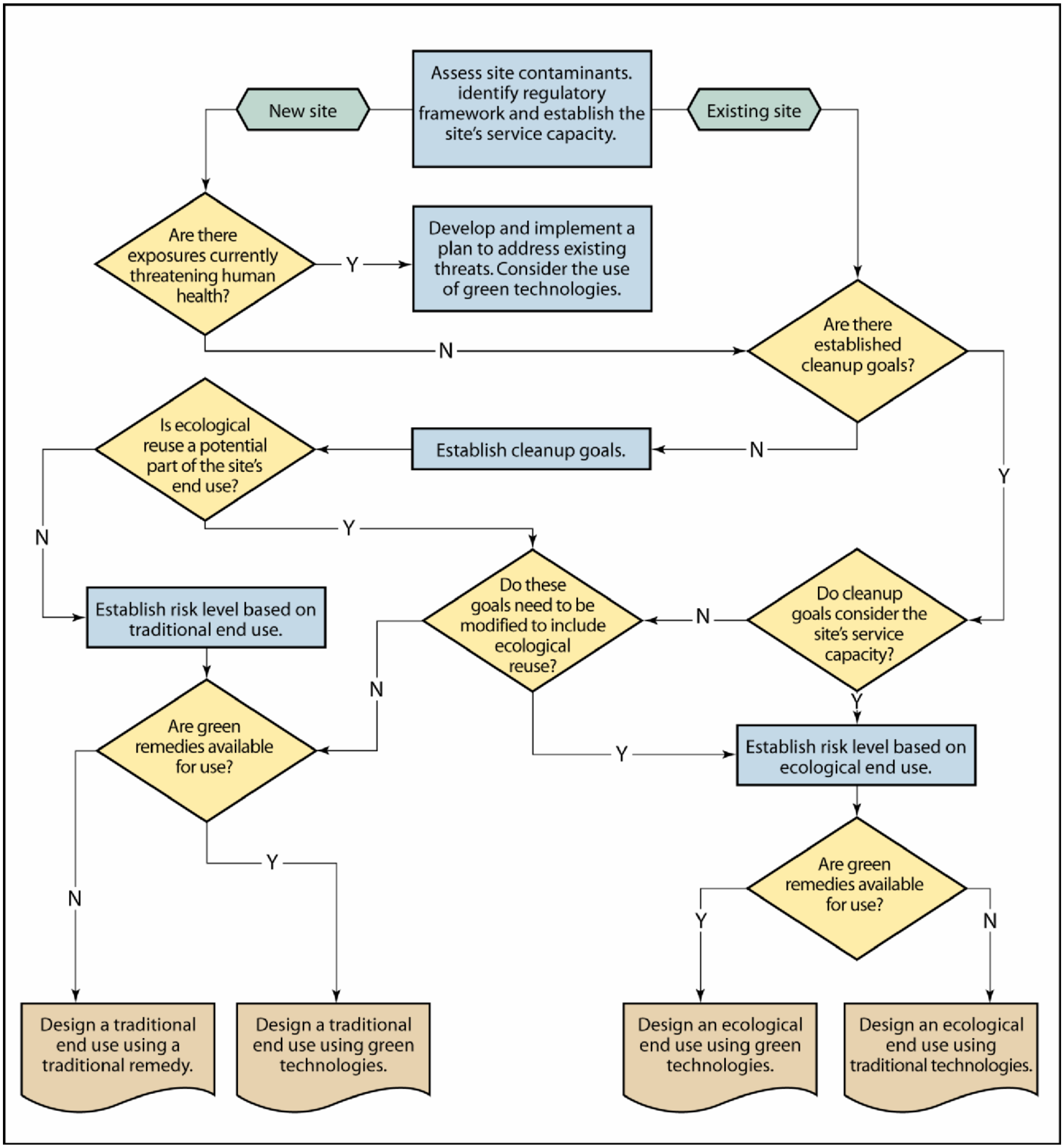

Figure 5-1. Decision making for ecological land reuse at remediated sites

Decision making at a site scheduled for remediation, with an interest in placing the remediated property back into use, requires a clear understanding of the region, expected future conditions of the property, and options to remediate the contamination. This is especially true if the site will include an ecological end use. By integrating ecological elements or enhancements into the cleanup remedy and considering the planned use of the surrounding properties, a natural or created terrain or habitat can intermingle and complement a residential, industrial, and open space infrastructure. The ability of a remediated property to support the community and surrounding landscape depends on the surrounding capacity. Figure 5-2 displays the general elements used to evaluate the capacity of a site.

Identifying solutions to restore site ecological capacity involves finding the best balance between regional needs, site properties, and the protective actions that will return safe feasible uses to the site. The overlap of site properties and regional needs represents the site's potential ecological service capacity. Not all of the capacities can be restored, however, and remain protective of human health and the environment. One objective is to identify the protective actions needed to restore site capacity and perhaps to mitigate those capacities that can not be restored. Efforts that do not address regional needs represent speculative efforts that may be incongruent with regional needs and future planning.

Figure 5-2. Venn diagram of the general elements used to estimate a site's feasible uses considering the capacity of the surroundings

The Venn diagram depicts three primary and interacting circles: (1) site properties, (2) regional needs, and (3) protective actions. The negative site properties caused by contamination can impact the regional needs by causing a loss of capacity. The protective action can help restore the regional needs through mitigation efforts and thus restore the lost capacity. At the same time, the protective actions may improve the site properties by remediating the contamination through speculative efforts. These can all be driven by the potential or feasible uses of a site based on the impacts from the contamination, potential regional needs, and possible or available protective actions.

5.1 Service Capacity

Service capacity: the ability to produce jobs, housing, environmental habitat, mineral resources, agricultural goods, and other societal values.

Defining the site's service capacity. Every site possesses a unique value to society that is dependent on its properties and its relationship to the surrounding region. The ability of a site to produce jobs, housing, environmental habitat, mineral resources, agricultural goods, and other societal values is the "service capacity". The service capacity of a site is dependent on its regional setting. For example, a one acre lot in downtown New York has a very different service capacity than a one acre lot in rural Napa, California. Contamination will diminish the service capacity of a site and may threaten the capacities of the site, the immediate locale, or surrounding region. For instance, contamination may prevent economic or ecologic use of a site while also threatening a regional resource. The goal of a site remediation is to eliminate exposure pathways that pose a threat to human health or the environment, to eliminate any threats to regional resources, and to restore the service capacities of the site to the region. As shown in Figure 5-1 above, the first priority is to address existing threats to human health and regional resources, then the actions necessary to restore the site's service capacity are considered. As an example, the Chattanooga site (Figure 5-3, 5-4, and inset on following page) provides a wetland, flooded woodland and a regenerative nursery, as well as greenscapes intermingled with commercial and educational development. A full case study for this site is included in Appendix C.

Figure 5-3 and 5-4. Coolidge Park adjacent to the North Shore Wetlands Park, Chattanooga, Tennessee. See Appendix C for full case study.

Case Study: North Shore Wetlands Park, Chattanooga, Tennessee

North Shore Wetlands Park is located at a 23.5-acre former industrial site on the banks of the Tennessee River in Chattanooga's downtown. The site was agricultural land prior to the mid 1900's and then a manufacturing facility. The site is west of the Market Street Bridge and Coolidge Park, an eight-acre urban park. It now contains the following:

Ecological Features	***Historical Features***	***Educational Features***	***Recreational Features***
Created Wetland Flooded Forest Regenerative Nursery	*Cherokee Trail Meig's Allee Bridge Blockhouse Underwater Wrecks*	*Outdoor Center Amphitheater Interpretive Features*	*Canoe Launch Riverwalk*

The three-year community planning effort involved hundreds of meetings and thousands of people. The Tennessee Riverpark Master Plan outlined a 25-year development process for the 22-mile riverfront corridor on either side of the Tennessee River. Over 1,600 people turned out to see the Master Plan unveiled at the Convention Center in 1985.

Evaluation and restoration of ecological capacity is an important part of the service capacity consideration. As the site's ecological capacity is not always obvious, it may take an environmental professional to provide input on the ecological needs of the locale and region and the role of the site in meeting those needs. It is helpful to consult with, for example, state conservation and natural resource agencies, land use, planning, and fish and wildlife agencies on the appropriate ecological end-use goals for a specific site. Additionally regional universities, conservation groups, and other stakeholders are useful resources for input into the development of the service capacity of a region.

5.1.1 Factors to Consider When Assessing the Site's Service Capacity

Restoring service capacity restores value to society as an outcome by design.

Site service capacity should be evaluated early in the project (with the help of stakeholder input if possible), and should consider a variety of uses. This evaluation will ultimately be coupled with cost considerations as identified in Section 7. A typical land-use assessment and land-use plan will address capacities such as housing, employment, and recreation, but may overlook environmental capacities such as wildlife habitat or wildlife corridors. Sometimes planners tend to select a single use at the expense of others; a better strategy may be to consider the ecological values and find ways to maintain those values even when the site is used for other purposes (see the Woodlawn case study in Appendix C).

There are several challenges to identifying and restoring ecological capacity. Ecological capacity might consider the variety of species, the population of various species, or the enabling of species to thrive, expand, or migrate. The ecological capacity of an area might improve if barriers to migration routes were removed, overcome, or not established by an engineered system. Greenways may improve sporadic and isolated plots of habitat by providing connections to other isolated plots of habitat, thus allowing species to migrate, repopulate, and diversify. Creating habitat that has been lost or improving the native habitat can increase the ecological service capacity of an area and improve the survivability of species at or near the site, including endangered species[2]. What may appear to be a useless piece of land ecologically and, therefore, more suitable for sociophysical (the physical environment of human society) development may be a unique habitat to certain species that have adapted to that environment and cannot live elsewhere. If the land is developed, then primary habitat is lost.

Much ecologically rich land is usually in riparian corridors. This is often where people want to farm, where people want to live, and where people want to hunt and fish. Thus, there is pressure to discount ecological values in favor of sociophysical development. It may take extra effort to communicate the ecological importance of a site so that its value to the region can be properly understood and integrated into the remediation project and future use planning. Ecological value goes beyond that which is immediately valuable to human life, and it can be difficult to weigh the value of a system whose value is not obvious until it is gone. Nonetheless, proper weight should be given to the inherent ecological value and considered in the land-use decision making process. This ecological remediation valuation is discussed further in Section 7.

Planning to meet human needs can be done while keeping essential attributes of natural systems intact.

5.1.2 Ecological Factors

Wilson (2004) has identified a number of ecosystem services which are categorized into four functional characteristics. It is difficult to assign a dollar value to the functions of ecosystems and to the elements contributing to the functioning ecosystem. This categorization offers a basis for identifying and evaluating the services an ecosystem can provide and thereby improve the total ecological valuation of the site as remedial design is occurring. Table 5-1 (Wilson 2004) is an illustration of these potential ecosystem functions and the services they perform.

Table 5-1. Ecosystem services (modified from Table 1, Ecosystem Services, Wilson 2004)

Ecosystem Functions	Ecosystem Service Examples
Regulating Ecosystems regulate essential ecological processes and life support system through bio-geochemical cycles and other biospheric processes. These include things like climate regulation, disturbance moderation, and waste treatment.	Climate & Atmospheric Regulation • Carbon Dioxide Sinks • Oxygen production • Ambient VOC Uptake
	Disturbance Moderation • Storm protection • Flood protection • Regulation of runoff • Fire Protection
	Freshwater Regulation • Water catchments

[2] For more information on the endangered species act, go to http://www.epa.gov/region5/defs/html/esa.htm

Ecosystem Functions	Ecosystem Service Examples
	• Groundwater recharge • Drainage and natural irrigation
	Waste Treatment • Pollution control & detoxification • Filtering dust compounds • Abatement of noise pollution
	Biological control • Control of pests and disease • Reduction of herbivory (crop damage)
	Habitat Refuge • Nursery, feeding, and breeding ground for harvested species • Maintenance of biodiversity and genetic resources • Habitat for resident and migratory species
Supporting Ecosystems also provide a range of services that are necessary for the production of the other three services categories. These include nutrient recycling, soil formation, and soil retention.	Nutrient regulation • Nutrient filter • Remineralization of organic and inorganic matter • Trapping sediments and pollutants
	Soil formation and retention • Maintenance of productive soils • Prevention of damage from erosion and siltation • Maintenance of arable land
Provisioning The provisioning function of ecosystems supplies a large variety of ecosystem goods and other services for human consumption, ranging from food and raw materials to energy resources and genetic material.	Food and raw materials • Edible shellfish • Fuel wood • Marketable animal, plant, and fish species
	Water supply • Provision of water for irrigation • Drinking water and industrial use • Medium for transportation
	Genetic and Medicinal resources • Crop resistance to pathogens and pests • New drugs and pharmaceuticals • Chemical models and tools
	Pollination • Pollination of marketable crops • Maintenance of wild plant species and populations
	Ornamental resources • Resources for fashion, handicrafts, and jewelry • Pets, furs, and feathers • Raw materials for decoration and souvenirs
Cultural Ecosystems provide an essential reference function and contribute to the maintenance of human health and well-being by providing spiritual fulfillment, historic integrity, recreation, and aesthetics.	Recreation and Amenity • Non-consumptive recreation and water sports • Aesthetic quality—proximity of houses to environmental amenities • Recreational hunting and fishing • Enjoyment of scenery
	Inspirational and historic • Cultural heritage sites • Archeological treasures

Ecosystem Functions	Ecosystem Service Examples
	• Spiritual and religious meaning

5.1.3 Regional Factors

Determining the ecological value of a site, by its very nature, requires a review of how the site interacts with the region around it. Proximity to wildlife refuges, streams, rivers, parks, wetlands, and riparian habitats should be evaluated to determine the suitability of the site or portions of the site to add to the ecological value of the property. Planners should consider specific aspects of each site:

- Does the site have the potential to provide habitat for migratory or resident species?
- Is this potential habitat in short supply and needed?
- How does this ecological capacity compete with or compliment other regional needs? For example: Can a partnership be created with surrounding land owners to encourage regional eco best practices like grass banking, a conservation easement like Wyoming's conservation easement program (http://nature.org/wyoming), or Weldon Springs a DOE Superfund cleanup resulting in metropolitan prairie (http://www.lm.doe.gov/documents/sites/mo/weldon/factsheets/history.pdf).
- Does the site contain a parcel of land that currently features or could potentially support some of the habitat components (food, water, cover, space) required by wildlife. These parcels can be large or small.
- Is the site adjacent or close to an established wildlife protection area? Examples include national wildlife refuges, national parks, state parks, state wildlife management units, county parks, and private preserves operated by land trust organizations or conservation groups. Sites located adjacent to or nearby these preserves can work to improve their own habitat values. This serves to effectively increase the overall size of the preserve without expanding preserve boundaries.
- Does the site feature or is it located near key ecosystem services/functions? Examples would include breeding, feeding and stopover areas along major migratory routes for birds (such as raptors, neotropical songbirds), and/or butterflies (such as the monarch or painted lady). Does the site serve as a migration route for terrestrial animals (such as the pronghorn antelope)? Does the site play a role in watershed protection? For example, do tributaries run through or along the site?
- Is the site located near or does it serve as an ecological corridor or greenway that promotes the relatively undisturbed movement of wildlife? As the landscape becomes increasingly fragmented, connectivity (or linkage) of green areas is critical so wildlife can access critical resources (food, water, shelter, space).

- Is the site located near or does it contain wetland areas? Wetlands attract wildlife. Riparian habitats along rivers and lakes provide outstanding habitat for a diversity of species. The complex and lush vegetative communities that often characterize riparian areas provide food and shelter for large numbers of species. This is especially true in the more arid western regions of the United States. Marshes in coastal regions are also important.

- Does or could the site serve as an environmental or ecological research area or promote environmental education or tourism efforts?

- Is the site located in a critical area that could be used as part of a statewide or region-wide conservation plan? Most states and/or counties have such plans. Local conservation efforts tend to have the greatest impact when integrated into part of a larger conservation strategy.

- Is the site in a regional watershed protection priority area where ecologically enhanced land helps control flooding, urban runoff, or migration of contaminated water?

The availability and need for various types of land uses such as agricultural, urban, suburban, recreational, or commercial are important to a region.

5.1.4 Site Factors

Site properties to consider include whether: 1) the property elevations indicate upland or wetland habitat, 2) the acreage available is large enough to provide meaningful habitat, 3) threatened and endangered species are or are not present, and importantly, 4) the type of contamination will impact ecological use. The current or historical uses of the property may also dictate the appropriate actions. If the property is currently in use, then it is possible that the site capacity is not significantly diminished and ecological opportunities may be more to compliment the existing uses. Site factors to consider include but are not limited to the following:

- soils
- hydrology, surface water, and groundwater
- fauna
- flora
- contaminant type and remaining contamination with associated land use controls
- community or human factors (for example, a bike path adjacent to the properties)
- air quality (avoid a point source from a soil vapor extraction, or SVE, system)
- existing infrastructure

The process for collecting data on site contamination is important but to some degree may be dictated by the program regulating the site. Ideally, data collection should be viewed as an iterative process to cost-effectively reduce remedy uncertainty and support the process of restoring the site's service capacity. Data on contaminant type and distribution is needed to help define which end uses are viable, as well as the remedies needed to support those uses. With some idea of the capacities intended to be restored, the data collection can be targeted to clarify actions necessary to restore the site while assuring its use is protective.

5.1.5 Protective Actions

Mitigate immediate principal contamination threat. The first priority for action at a site is to be sure that no exposure pathways immediately threaten human health and that offsite migration is contained. Then efforts turn to restoring the service capacities identified from the assessment of regional needs and site properties. The overlap between regional needs, site limiting properties, and the available technologies and actions that can successfully restore uses, provides a list of feasible uses that can be successfully restored.

Assure there are cleanup goals. Next, clean up goals that are protective of the desired end use must be determined. For example, a wildlife management area may or may not require the same level of cleanup if human access is controlled. On the other hand, if crops are raised on the property, human exposure to the soils, water, and ingested crops may mandate extensive cleanup. Institutional controls and other land use controls are often necessary remedial or corrective action components to the end uses.

Ecological use should be identified as a service capacity of the site to be remediated. The ecological service capacity may be evaluated as not significant, but its service capacity should still be evaluated. Then the question becomes "how can the lost ecological service capacity be returned?" The questions of ecological benefit are often complicated by concurrent ecological loss. For instance, a site that may contribute significantly to waterfowl habitat may still have some detrimental characteristics (e.g. invertebrate toxicity). Thus, a net environmental benefit analysis (NEBA) may be needed to define an acceptable course of action (Efroymson 2003). Joseph P. Nicolette, a co-author on Efroymson 2003, describes NEBA in the inset on the following page.

What is Net Environmental Benefit Analysis (NEBA)?

A NEBA is an approach that allows for a systematic evaluation of changes in natural resource values (ecological and human use) associated with land management alternatives (e.g., remedial alternatives) so that consistent comparisons across alternatives can be conducted to achieve the greatest net environmental benefit at the lowest cost, while maintaining protection of human health and the environment. This approach is described in detail in Section 7.4.

The NEBA framework shares the same theoretical foundation as benefit-cost analysis. An important distinction is that, in NEBA, the ecological and human use effects of an action are considered. The NEBA approach identifies and values the primary environmental services that an area or portfolio of holdings may provide given different land uses and actions (such as managing wildlife, building roads and infrastructure, siting facilities, discharging effluent, restoring stream habitat, etc.). The type, quantity, and quality of environmental services provided by an area or waterway are determined, in part, by the surrounding geographic landscape (i.e., land uses). The NEBA approach uses the recent emphasis (NOAA, DOI, USFWS) in the natural resource sciences to consider environmental services within a landscape context. Proposed actions will affect the quality and quantity of ecological and human use services produced at the site or parcel differently. Some services may be improved, some may not be affected, and some may be harmed. A systematic evaluation of these changes in service capacity is needed to make consistent comparisons across alternatives and to optimize the achievement of environmental objectives at least cost.

NEBA is a method comprised of a set of agency approved and litigation tested techniques and tools for quantifying the benefits of alternative land uses or actions (e.g., remedial actions) that affect the environment. The NEBA approach and quantification tools can be used to:

1. *estimate value of environmentally sensitive areas;*
2. *develop and evaluate a suite of alternatives;*
3. *provide a basis for balancing economic, human, and natural resource drivers affecting proposed alternatives;*
4. *support measures to weigh and rank alternatives that meet cost-effective objectives;*
5. *provide a means to expand the range of potentially acceptable alternatives;*
6. *provide documentation that provides a defensible alternative analysis and selection;*
7. *provide a basis for establishing appropriate mitigation measures; and*
8. *provide performance-based measures that can be used to conduct monitoring and adaptive management activities.*

When properly planned and implemented, the NEBA approach provides a systematic, consistent, and defensible process that can significantly enhance stakeholder support for selected environmental and land use planning decisions. This process also promotes the selection of decisions that demonstrate a balanced win for the environment and the stakeholders.

-Taken from: Natural Resource Valuation and Net Environmental Benefit Analysis (valuing ecological and human use services) by Joseph P. Nicolette, currently Vice President, ELM Consulting, LLC.

> ***Off-site wetlands mitigation*** *should be in the same general vicinity or close to the impacted wetlands site. A mixture of on-site and off-site compensatory wetlands can be considered as well; however, the functional scoring should be the basis for the type and amount of on-site and off-site compensatory mitigation.*
>
> ***In-kind*** *wetlands compensation for a wetland loss involves replacement of a wetland area by establishing, restoring, enhancing, or protecting and maintaining a wetland area of the same physical and functional type. In-kind replacement generally is required when the impacted resource is locally important.*
>
> ***Out-of–kind*** *compensation for a wetland loss involves replacement of a wetland area by establishing, restoring, enhancing, or protecting and maintaining an aquatic resource of different physical and functional type (ITRC Wetlands-2 2005).*

Some site capacities may have been lost; however, that does not mean the capacity can not be restored to the region. For instance, wetland habitat may have been an historical capacity, but is now replaced with a large landfill that may not be feasible to move. The lost capacity could be returned by creating new habitat in other areas (e.g., offsite mitigation). Other capacities can be treated similarly (payment to housing trust funds in lieu of building housing, replace water source with treated municipal water, etc.). These mitigation measures may be far more beneficial, effective, and timely at returning needed capacity to the region than to attempt to fully restore the site. Remediation, however, is the focus and cannot be jeopardized in lieu of added ecological capacity. Again, a good regional assessment should help identify the offsite or out-of-kind mitigation opportunities that best address the need (such as connecting fragmented habitat, etc.)

Ecological capacity can also be returned during the process of restoration to another use (for example, cleanup to prepare for housing or industrial use). Various green technologies offer temporary ecological capacity while they are in use (see ITRC ALT-2 2003; ITRC Wetlands-1 2003; ITRC Wetlands-2 2005; ITRC Phyto-2 2001).

5.2 Selection of Green versus Traditional Technologies

Even when an ecological end use is not a stand alone cleanup option, so-called "green technologies" can be used to provide years of ecological benefit while the site is undergoing cleanup of principal threat contamination. Green technologies are approaches that use plants to draw water, extract toxics, assist in microbial digestion of toxics, provide cover, or in some way aid in the accomplishment of the remedial objective while also temporarily providing greenspace, open space, a livable environment, and/or habitat. Green technologies are viable remedial components for long-term response actions for residual contamination issues. Examples of these green technologies may include, but are not limited to, constructed wetlands, rain gardens, filter strips, and bioswales as ecological enhancements. Table 5-2 provides a comparison of conventional remedies and ecological remedies.

Table 5-2. Traditional versus green technologies

Target Goal	Traditional Remedies	Ecological Remedies
Dig and haul (Source Zones)	Excavation, source removal, hot spot removal	
Caps and barrier containments	RCRA covers, slurry/sheet pile walls, permeable reactive barriers	Vegetative covers, tree hydraulic barriers,
Soil treatment	Land farming, Bio-piles	Phyto/bioremediation composting
In situ plume treatment	Sparging/soil vapor extraction system	Deep-rooted systems (trees, prairie species)
Groundwater control	Pumping/extraction systems	Tree hydraulic systems
Ex situ treatment systems	Granular activated carbon, advanced oxidation, bioreactors, catalytic/thermal oxidizers	Phytoextraction, photosynthetic oxidation, plant bioreactions, constructed wetlands

5.3 End Use

During the planning phase of a remediation program the performance of the effort should be scaled to what the owner, regulatory oversight agency, and the nearby community expects the forecasted use of the property after completion. This guidance naturally focuses on ecological end uses (see Table 5-3, Section 5.3.2). Ecological end uses may be the ultimate final use of the property or an integrated element of a larger planned use that is agreed upon by the affected community. Regardless of the ultimate disposition of the property, the remediation process may still take advantage of green or natural technologies.

5.3.1 Designing for Ecological End Use Using Traditional Remediation Technologies

There are many instances where ecological reuse or enhancements can be part of the remedial solution; the elements described in Section 5.1.4 still apply. Key stakeholders should be involved in defining how the property will be used. Additionally, the remedy and land use controls should be tailored to efficiently reduce any risk of toxic exposure to future users or impairment of neighboring resources.

Commonly used traditional remedial approaches at hazardous waste sites or RCRA Corrective Action facilities include such actions as excavation, capping, gas collection, and treatment, groundwater pump and treat systems, in situ treatment, solidification and stabilization, and barrier wall installation. These are actions that usually result in a significant impact to ecosystems at the point of remediation, and the resulting loss of vegetative communities and associated wildlife populations. An option to protect or improve the biological conditions at the site, however, can be identified as the preferred end-use option and incorporated into the design of the remedial action. The greatest flexibility with respect to the type of ecological end-use options available or the manner in which they may be implemented will occur if end-use planning and stakeholder input occurs early, often, and as part of the remedial selection and design process. The ultimate goal of the ecological end use is the development of a complex habitat capable of supporting an assortment of habitats that are sustainable, and, if possible, self sustaining.

Ecological end-use options will vary widely, depending upon the location of the site with respect to future growth demands, geography, topography, elevation, climate, soils, and hydrology. As a result of this variability in sites, it is not possible to dictate specific end-use decisions or activities that are applicable to all sites. Instead, planners at individual sites should consider three general issues in designing and planning an ecological end-use option appropriate for their location. Those general issues include biodiversity, type of contamination, and scope of the ecological end-use project. These issues should be considered regardless of whether the end use is associated with traditional technology or any green or natural technologies.

5.3.1.1 Biodiversity

Biological diversity, or biodiversity, refers to the variety of life in all of its forms and levels or organization (Hunter, 1990). Planners for an ecological end use at a given site should approach their project with the goal of generating a diverse ecosystem. The sustainability of a project will be based on how the ecosystem works, the various interactions that occur between biological components (such as plants and animals), and the abiotic components, such as soil and water.

Harker et al. (1993) establishes a series of principles and guidelines to be applied spatially in the design of an ecological reuse project, as well as to the development of individual communities as part of the project:

Spatial Principles and Guidelines

1. Large areas of natural communities sustain more species than small ones;
2. Many small patches of natural communities in an area will help sustain regional diversity;
3. The shape of a natural community is as important as the size;
4. Fragmentation of habitats, communities, and ecosystems reduces diversity;
5. Isolated patches of natural communities sustain fewer species than closely associated patches;
6. Species diversity in patches of natural communities connected by corridors is greater than disconnected patches;
7. A heterogeneous mosaic of natural community types sustains more species and is more likely to support rare species than a single homogeneous community; and
8. Ecotones between natural communities are natural and support a variety of species from both communities and species specific to the ecotone.

Community Principles and Guidelines

1. Full restoration of native plant communities sustains diverse wildlife populations;

2. An increase in the structural diversity of vegetation increases species diversity;
3. A high diversity of plant species assures a year-round food supply for the greatest diversity of wildlife;
4. Species survival depends on maintaining minimum population levels; and
5. Low intensity land management sustains more species and costs less than high intensity.

5.3.1.2 Type of contamination

Planning for an ecological reuse project must take into consideration the type of contamination at the site, particularly if the contamination is bioaccumulative and if residual contamination is to be left on site. Bioaccumulative constituents include, but are not limited to, organochlorine pesticides, polychlorinated biphenyls, some chlorinated organic compounds, and metals such as mercury. These constituents have the potential to accumulate in the tissues of organisms and, depending upon the type of constituent, have the ability to concentrate at successively higher levels of the food chain (bioaccumulation). Planning for the ecological end-use project must assure plants and wildlife will not be exposed to the constituents of concern at levels that cause them harm through direct contact or bioaccumulation. The ecological risk assessment process in the remedial investigation (RI) or remedial field investigation (RFI) phase of the site investigation will provide input into the type of constituents that are on site and the levels that may produce a toxicological impact.

5.3.1.3. Scope of the ecological end-use project

The ecological end-use project for a given site will depend on a variety of circumstances, not the least of which is the desire of the site manager. The project can include the development of forests, grasslands, butterfly meadows, or low impact recreational activities such as bird watching. The end-use project manager must consider input from local, state, and possibly federal regulatory agencies, as well as resource management agencies in order to identify the specifics of the proposed ecological end-use project. The scope of the project will be defined by a number of site-specific characteristics that are summarized in the USEPA's *Guidance for Preparing Superfund Ready for Reuse Determinations at Superfund Sites* (EPA 2004). Those characteristics include:

- *Size of the site*. The larger the site, the greater the likelihood that a sufficient amount of land exists to support a viable, self-sustaining ecosystem.

- *Existing habitat at the site*. The less disturbance of existing habitat at the site, the greater potential for successful restoration.

- *Proximity to existing undisturbed areas*. Natural areas that exist adjacent to, or in close proximity of the site can effectively increase the habitat area.

- *Surrounding land uses*. The type of land use activities that occur in the property surrounding the site can affect the ability of the onsite ecological reuse project to become fully functioning.
- *Topography*. Sites with extremes in topography are more difficult to restore than sites with level topography.
- *Hydrology*. Sites with a natural water supply have a greater potential to support a water dependent ecological reuse, such as a wetland.
- *Site access*. The control of public access through such devices as institutional controls heightens the potential for a project to achieve expected functions.

5.3.2 Designing for an Ecological End Use Using Green Technologies

When an ecological end use (Table 5-3) is the primary objective, green technologies can be used in the process of remediation to provide years of ecological benefit while the site is undergoing cleanup and preparation for its ultimate ecological service. Green technologies include approaches that use plants to draw water, extract toxics, assist in microbial degradation of compounds, provide cover, or in some way aid in the accomplishment of the remedial objective and can also providing habitat while in use (see ITRC Phyto-1 1999 and Phyto-2 2001). Appendix C includes case studies of successful selection of an ecological end use.

Table 5-3. Mixed end uses

End Use	Ecological Enhancement	Traditional Element
Wildlife preserve	Habitat	
Pocket park	Raised bed garden, small mammal and bird shelter, butterfly garden, waterscape/wetland, vegetative cover	Benches, play sets, parking lot, barbecue pit, hiking trails
Open space	Pocket parks, walking paths, green landscape, wildlife management area	Parking lot
Aquaculture	Ponds	
Recreational	Parks, recreational facilities (walking paths), educational facility (arboretum)	Restricted or prohibited use, grass fields
Water storage/stormwater management	Constructed wetlands, rain gardens, filter strips, and bioswales	Detention/retention, riprap, diversion dams, concrete lined channels
Golf courses	Vegetative cover, water features, constructed wetland	
Urban garden	Raised beds, garden plots	
Residential/urban development, including cluster development	Pathways, shrub barriers, green roof, riparian buffers, vernal pools, vegetative medians, green infrastructure (recycled material)	Residential homes construction, streets, schools, parking lots, side walks, community centers
Industrial development	Green infrastructure Constructed wetlands for waste water stocked with fish, wildlife habitat (nesting, resting, feeding, cover)	Warehouses, manufacturing, storage

5.3 End Use Conclusion

During the planning phase of a remediation program, the effort should be scaled to what the owner, regulatory oversight agency, and the nearby community expects for the forecasted use of the property after completion. Ecological end uses may be the ultimate final use of the property or an integrated element of a larger planned use that is agreed upon by the affected community. Regardless of the ultimate disposition of the property, the remediation process may still take advantage of green or natural technologies. Applicable regulations require and recent EPA guidance encourages protection of the environment. Protection of the environment may be achieved by the implementation of ecological elements or enhancements. These enhancements have the potential of leaving a legacy of ecological benefit and enrichment in a community long after the remediation project is completed.

This section began by introducing the concept of service capacity. The service capacity is linked to the best use option for a given site undergoing remediation. The evaluation of a site’s service capacity also includes the early opportunity for stakeholder involvement regarding future land use and planning. The future land use and planning integrates the ecological, regional, and site factors as they may relate to potential protective or remedial decisions and to future land use. Not all future land use may be conducive to ecological elements or enhancements; however, in specific situations where ecological elements or enhancements may be integrated into the remediation process, whether using conventional or green remediation technologies, the significant potential exists to provide additional benefit to the owners, operators, and community through the very ecological elements used to remediate the site. Again, Table 5-1 provides an abbreviated list of how ecological elements and enhancements, by early identification of end uses, may be integrated into the remediation strategy to provide such value.

6. ECOLOGICAL REUSE PLANNING AND TARGET ECOSYSTEMS

Section 5 dealt mainly with the planning concepts related to the evaluation of service capacity, community needs assessment, resource availability, and the associated regulatory and political facets of the remedy decision or selection process. This section provides information regarding the implementation of ecological elements or enhancements following the initial planning phases as discussed in Section 5 and identified in the final boxes in Figure 5-1. Ecological elements or enhancements may accompany a variety of remediation technologies, whether they are components of a traditional remediation project recovering lost resources or additions to a remediation project specifically designed to enhance the existing or pre-existing ecological setting.

> ***"Ecological trajectory" begins with the disturbed site and ends with the recovery of a system that meets the goals of the restoration project.***

The successful use of ecological elements or enhancements entails detailed planning and an understanding of the complexities of ecological restoration coordinated with a thorough understanding of the potential performance of the chosen technology to remediate contamination. The goal is to initiate the project site along a developmental pathway called an "ecological trajectory" that will lead, ultimately, to a sustainable ecosystem. This ecological trajectory begins with the disturbed site and ends with the recovery of a system that meets the goals of the restoration project (Society of Ecological Restoration 2004). A critical aspect of any ecological reuse project is allowing sufficient time for the system to become sustainable and viable. The Society of Ecological Restoration notes that the following nine attributes provide a basis for determining when an ecosystem restoration project is completed:

1. The restored ecosystem contains a characteristic assemblage of species that occur in a reference location or are consistent with predisturbance ecological characteristics and provide appropriate community structure.

2. The restored ecosystem consists of native plant species.

3. All of the functional groups necessary for the continued development and/or stability of the restored ecosystem are represented or have the potential to colonize by natural means.

4. The physical environment of the restored ecosystem is capable of sustaining reproducing populations of the species required for development along a desired trajectory.

5. The restored ecosystem functions normally for its ecological stage of development.

6. The restored ecosystem is suitably integrated into a larger ecological landscape.

7. Potential threats to the health and integrity of the restored ecosystem have been eliminated.

8. The restored ecosystem is sufficiently resilient to endure normal periodic stress events.

9. The restored ecosystem is sustaining and has the potential to persist indefinitely under existing environmental conditions.

6.1 Planning an Ecological Land Reuse Project

For an ecological reuse project to progress along a trajectory to a sustainable state, it must begin with proper planning. The following sections outline the general steps required to implement an ecological reuse project. The development of an ecological reuse project begins with the assembly of a multidisciplinary team to design the project. Especially with any ecological land reuse project (such as a wetland-based project), a wide assortment of experts may be needed, including remediation specialists, biologists, ecologists, horticulturists, engineers, agronomists, geologists, and soil scientists.

6.1.1 Define Goals and Objectives

The first step in developing the ecological reuse project is to clearly state the goals and objectives of the project. The goals are site specific or broader depending on the service capacity evaluation results. Goals can relate to the number and composition of plant species restored, the structure of vegetation, or functions of the plant community and aesthetics (Harker et al., 1993). Generally, the statement of goals for the ecological reuse project identifies the site conditions to be achieved by the project. The objectives are usually more specific measures to achieve those broader goals. The end-use goals may influence the goals of the remediation; however, confirmation of the completeness of the remediation and post closure care of waste or contamination remaining on site is monitored as defined by the applicable regulatory authority. Note that the goal of the cleanup and the goal of the end use may have different monitoring and evaluation parameters. The ITRC Alternative Landfill Technologies team is currently completing a guidance document on post closure care of landfills (due out in 2006). This guidance also describes the importance of establishing the property end use while defining the performance goals of a closed landfill. See the ITRC ALT Guidance Document page at www.itrcweb.org for the publication of this document and other related documents. In addition, DOE has a process for developing Superfund exit strategies (DOE 2000, http://www.eh.doe.gov/oepa/guidance/cercla/exitstrategies.pdf). Both of these guidance documents provide information

> ***Planning an end-use project:***
>
> - *Goals and objectives*
> - *Site analysis*
> - *Site plan*
> - *Identification and selection of plants*
> - *Site preparation*
> - *Control of invasive species*
> - *Monitoring and maintenance*

describing how to monitor the site's remedial efforts and determine when cleanup is completed and monitoring can be reduced or eliminated.

6.1.2 Conduct Site-Specific Analysis

In the early stages of planning an ecological reuse project, a detailed ecological characterization of the site should be conducted. The characterization should include an evaluation of existing plant communities, soils, hydrology, and wildlife. In addition to this characterization of the site, for planning purposes it may be beneficial to identify and characterize a reference ecosystem to serve as the model for planning the ecological end-use and to later serve in the evaluation of the project. The reference ecosystem should represent a point along the intended trajectory of the restoration and can serve to substantiate the goals and objectives of the ecological reuse project (Society of Ecological Restoration, 2004).The following sections describe specific applicable evaluations that can be conducted as part of the overall site analysis.

6.1.2.1 Hydrology analysis

The hydrology of the site must be characterized, especially if the ecological end use consists of a water dependent activity such as wetlands development. The development of an ecological end use in upland setting requires an understanding of the amount of precipitation as opposed to a detailed hydrologic study. The hydrologic state of a wetland site can be represented by a hydrologic budget, which is essentially the difference in the volume of water moving into the wetland site and the volume of water moving out. Water budgets are influenced by the balance between inflows and outflows of water, surface contours of the landscape, subsurface soil, geology, and groundwater condition (Mitsch and Gosselink 1993; ITRC Wetlands-1, 2003, http://www.itrcweb.org/gd_CW.asp; and ITRC Wetlands-2 2005, http://www.itrcweb.org/gd_MW.asp).

Characterization of the water budget for any wetland can be estimated through modeling and the collection of desktop information from sources such as the National Climatic Center and U. S. Geological Survey. Quantitative data regarding subsurface water conditions can be collected through the use of piezometers or monitoring wells. Sprecher (2000) provides a detailed description of the construction of monitoring wells in wetlands as well as recommendations on categorizing wetlands water budgets.

6.1.2.2 Soil analysis

Soils consist of unconsolidated, natural material that supports, or is capable of supporting, plant life. The upper boundary is air, and the lower boundary is either bedrock or the existence of significant biological activity. Soils are generally divided into two different types: mineral and organic. Soils can be further categorized based on the amount of moisture that is present. A soil profile consists of various soil layers described from the surface downward. These layers, called soil horizons, are generally oriented approximately parallel to the ground surface. A soil horizon usually is differentiated from contiguous horizons by characteristics (such as color, structure, texture) that can be seen or measured in the field. Soil horizons can be divided into major classifications, which are called the master horizons. These master horizons are designated with the letters O, A, E, B, C, and R. The depth and content of these horizons varies greatly depending on the type and location of the soil. Baseline characterization of the soils should include the following:

- soil types and profiles
- soil classification
- soil series
- soil structure
- soil texture
- organic content
- permeability

This information can be developed specifically through field observations or generally through county soil surveys published by the Natural Resource Conservation Service. Additionally, ecological reuse planners should attempt to document the predisturbance characteristics of the site. Such information should be gained by using historical records, maps, or aerial photographs.

6.1.2.3 Flora and fauna analysis

Standard vegetative assessment techniques should be used in conducting either qualitative or quantitative assessments of the vegetative communities, for instance, within the existing wetlands (see ITRC Wetland-2 2005, Section 3.3.1, Figure 6-1). The vegetative parameters that may be considered and evaluated include the following:

- species composition
- description of community stratification (e.g., number of vegetative layers in the community and their percent cover (Figure 3-1, ITRC Wetlands-2 2005)
- relative frequency, dominance, abundance, and/or percent cover of each individual species
- presence of exotic or invasive species

Existing fauna at a site should be noted and recorded to document present and potential wildlife use.

6.1.3 Develop Detailed Site Plan and Implementation Plan

The detailed site plan outlines the procedures to be used in implementing the ecological reuse and specifies how the project will be put into place. The site plan should outline specifications to be used in the construction of the project, as well as schedules and budgets for site preparation, installation of plants, and postinstallation activities. The site plan will clearly outline the boundaries of the project and specify the development of the different communities that may be incorporated into the reuse project. It is important to include well-developed and explicitly-stated performance standards and an exit strategy in the plan.

The use of native plants is recommended when appropriate. These may be slow-growing species that require an annual stabilizing crop during the establishment phase, which will allow native species to later populate the area in as natural a fashion as possible.
Other factors that should be considered and outlined in the planting plan are as follows:

- timing of planting to achieve maximum survival
- methods of planting
- proposed use of mulch (certified inert material straw mulch rather than hay, which may bring in noxious weeds
- potential soil amendment such as organic material or fertilizer
- potential supplemental watering (should only be used for the establishment of the plant community and not as a long-term tool to support the mitigation)
- replanting

Figure 6-1. Site planting (courtesy of Charles Harman, AMEC Earth and Environmental)**.**

As part of the detailed design, a landscape plan must be developed to identify the types, locations, and sizes of the proposed vegetative communities and the individual species that will compose the communities. The landscape plan should be accompanied by a tabulated list of species that identifies the plants by common and scientific name, and the size and available form (e.g., seed, bare root, rhizome, potted) of the plants to be installed and plant benefits. Because of variations in the genetic makeup of a species over a wide geographic area, plant selection should indicate a local source of the plant material to be used in planting and native is preferred. Careful consideration should be given to the selection of the plant species to be used in relationship to the goals and objectives of the project. Spatial and temporal aspects of the plant community as a whole and individual species should also be considered. Figure 6-1 displays plants being staged for planting at a mitigation wetlands site.

6.1.5 Prepare the Site and Implement Plan

Construction of the ecological reuse project requires great attention to detail to ensure that the project is successful. Extremely close attention to these details will ensure that elevations, grades, and planting materials are completed exactly as shown in the mitigation plan and construction details. Some degree of flexibility should be maintained so that field changes can be easily introduced to address site-specific conditions that arise during construction. Field changes, however, should be evaluated with care to ensure that required hydrology, soil, and vegetative parameters are not compromised.

The construction process is an iterative activity that begins with site preparation and finishes with demobilizing staged equipment and allowing for monitoring to occur. Communication with the construction engineer during the design phase to ensures that all aspects and concerns are addressed. Preconstruction and project status meetings at various stages during the process ensure constant familiarity with the design, design changes, and progress of the construction phase of the project. It is also helpful to regularly review the overall goal of the project and to highlight critical construction details. Continued oversight and periodic meetings ensure that the actual design is being implemented in the field as expected and intended.

While maintenance activities during establishment should be used to control invasive species, some measures can be taken to help minimize the encroachment and establishment of invasive species. Rapid-growing/spreading plants establish more quickly and help preclude the colonization of invasive species; however, the preferred plant community often includes slow-growing/spreading species. In these instances, it is helpful to add a rapid-growing/spreading species in the interim to act as living mulch. (see ITRC Wetlands-2 2005).

Prior to beginning construction, which will result in the disturbance of the existing soils, soil erosion, and sediment, control measures should be constructed in accordance with the appropriate state, county, and/or conservation district standards for soil erosion and sediment control. The objective is to prevent sediment from being washed from excavated areas into undisturbed areas where it can cause sedimentation problems. All soil erosion and sediment control measures should be maintained in good condition and left in place until permanent vegetation cover is established.

6.1.6 Control Invasive and Undesirable Species

Undesirable insects, plants, diseases, or other invasives must be controlled to allow the ecological reuse project to move along its intended trajectory. Invasive species left uncontrolled can alter the functional value of the system and even encroach on adjacent properties. Control of the invasive species can be accomplished through the use of manual or natural controls (see inset) or through the application of herbicides or insecticides. Care should be taken when using nonnative species that they do not encroach on nearby properties and out-compete native or existing species. These can unintentionally become invasive and destructive to a stable ecosystem. Several agencies provide site specific information helpful in natural or artificial control of invasive vegetation. See the links below for more information.

- Invasive.org (http://www.invasive.org/). Invasive.org is a joint project of The Bugwood Network, USDA Forest Service and USDA APHIS PPQ, The University of Georgia - Warnell School of Forest Resources, and College of Agricultural and Environmental Sciences Department of Entomology (http://www.ent.uga.edu/).

- Invasivespecies.gov (http://www.invasivespecies.gov/).
  This site is the gateway to federal efforts concerning invasive species. It describes impacts of invasive species and the federal government's response, includes species profiles and has links to agencies and organizations dealing with invasive species issues. Invasivespecies.gov is also the Web site for the National Invasive Species Council, which coordinates federal responses to the problem.

- The PLANTS Database (http://plants.usda.gov/). The PLANTS Database provides standardized information about the vascular plants, mosses, liverworts, hornworts, and lichens of the U.S. and its territories. It includes names, plant symbols, checklists, distributional data, species abstracts, characteristics, images, plant links, references, crop information, and automated tools. The PLANTS Database reduces costs by minimizing duplication and making information exchange possible across agencies and disciplines.

Many local agencies and universities can provide the best information on invasive species and preferred native and non native species for particular habitats in their region of responsibility, including compatible soil types for particular species and plant communities.

6.1.7 Monitor and Maintain the Site for the Long Term

As part of the ecological reuse project, a monitoring plan must be included that identifies how the performance standards will be applied to measure the success of the project. The monitoring plan should include a detailed description of how each of these activities will be accomplished. The monitoring plan must begin with a description of the goals and objectives of the monitoring activity, which should be based on the performance standards that have been agreed upon with the appropriate regulatory agencies. The monitoring program should also outline the parametric and the monitoring frequency. This function may fluctuate depending upon the regulatory body for the site.

The manner in which monitoring is conducted varies depending on the circumstances of the site and the performance standards. Data needs for evaluating the performance standards must be balanced with the cost and effort of conducting the monitoring. As an example, the ITRC Wetlands-2 document estimates that "mitigated wetlands should be monitored for 5–10 years (20 years for forested and similar wetlands systems) and mid-course corrections should be required."

Some of the more important aspects of monitoring are the contingencies that are in place to correct deficiencies identified by the monitoring. This effort can be as simple as having supplemental plants on hand for replanting lost stock to ensure that vegetative success ratios are met or means by which invasive species identified in the mitigation site are addressed. Should damage by an herbivore be identified as a significant problem at the project area, actions such as fencing or individual plant guards should be considered. Devices to enhance predator use of the site could also be considered. In the event of failure due to hydrologic deficiencies or excesses, then contingency plans should be in effect for a complete redesign and reconstruction of the project.

6.2 Targeted Ecosystems for Ecological Reuse

Whether a traditional remedial technology or an alternative green technology is implemented at a remediation site, the reuse of the property for ecological means can be either considered as part of the remedy or as a complement to the remedy. In general, the goal of the ecological reuse will be the development of a functioning ecosystem that is consistent with historic ecosystems in the region or current reference areas chosen as the standard for building purposes. The choice of the type of system will depend upon a variety of factors, including location of the site, baseline or reference system, climate, topography, soils, hydrology, and various nontechnical factors such as public and regulatory constraints. The following sections summarize the basic categories of ecosystems that can be selected for a site.

6.2.1 Upland Restoration

Upland sites with xeric or mesic hydrologic conditions would require the incorporation into the ecological reuse plan of communities dominated by woody species such as forests and shrubland, or open communities dominated by herbaceous species such as grasslands and meadows (including prairies and savannahs). These upland resources are discussed in more detail below. Uplands impacted by significant subsidence could create a retrofit opportunity to establish wetland environments. Examples are landfill subsidence whereby the wetted area is redesigned to allow and encourage infiltration into a waste system to initiate and maintain bioreactor degradation. It should be noted, however, that intermittent ponding may not provide adequate hydraulic characteristics to develop the necessary saturated conditions to sustain the development of hydric soils common to a wetland. In this case, long-term maintenance may be required. Sections 6.2.2 and 6.2.3 further discuss restoring or creating a wetland environment.

6.2.1.1 Forest and shrub restoration and end use

Forests or shrublands can be incorporated as ecological end uses either following the implementation of a traditional remedial action, such as excavation, or as a complement to increase the value of resources at a site where either a traditional remedial action or green technology is implemented. At sites where a forest or shrubland is to be reestablished following removal of the resource, restoration techniques to introduce the target system would be employed. Eyre (1980) provides a listing of forest cover types that can be used as a basis for selecting species for a forest restoration project.

Howell (1986), as quoted in Harker et al. (1993) notes that the re-creation of an upland forest can be evaluated in two ways:

> One emphasizes community structure and species composition, and judges the success of a restoration effort by asking how closely the resulting community resembles the natural, or 'model' community with respect to characteristics such as relative abundance, age-class structure, spacing, and distribution of a particular species. An assumption underlying this 'compositional' approach is that if these species groupings are fairly accurately reproduced, then the dynamics and functions of the communities will also resemble those of the model community.
>
> The second way of establishing goals and evaluating the success of restoration projects emphasizes ecosystem functions, often with little or no reference to species composition. From this point of view, for example, the presence or absence of a particular species is less important than the provision of functions and processes such as nutrient cycling, erosion control, or biomass production.

The creation of a canopy layer of the re-created forest community is the most critical part of the targeted ecosystem. Howell also notes that, in the event that complete restoration of the forest resource is chosen as the goal of the ecological end use, one of six approaches to implementing the forest restoration can be used, depending upon goals of the project, intensity of project management available, and financial considerations. Those approaches include the following described in Harker et.al., 1986:

1. Plant canopy trees in ultimately desired densities or proportions, mulch the ground beneath the canopy specimens, and plant desired mid-story and understory species immediately;
2. Plant and mulch canopy trees as in the above approach, but plant groundcover that grows well in exposed areas with unrestricted sunlight and add woodland understory and mid-story species as the shade develops from the growing canopy;
3. Plant trees in a less than ultimately desired density, with grassland plants in an understory. As shade develops, plant additional canopy specimens, and finally plant desired understory and mid-story specimens;
4. Plant trees in greater than desired densities and allow natural thinning, or implement thinning, as the canopy develops. Add mid-story and understory specimens at a later date;
5. Plant fast growing canopy specimens as a cover crop and under plant with more desired canopy specimens. Upgrade the understory as the canopy progresses; or
6. Do not plant; instead allow natural succession to drive the forest restoration.

In the event that an existing forest or shrubland is located onsite and the desire is to improve the value of the resources in conjunction with the implementation of the remedial action, then some of the forest management alternatives or resource improvement activities that are available include:

- woodlot management, including selected thinning
- removal of invasive/undesirable woody species
- addition of nesting boxes or platforms, and animal feeders
- planting additional species in areas that are cleared
- addition of snags

At one hazardous waste site in New England, a riparian forest was restored to the banks of a river following the removal of contaminated soils. The project approach began with identifying the target community through a review of available literature on regional forests and forest species. Prior to remedial activities, the bank areas to be excavated were cleared of existing vegetation. Where it was possible from an engineering standpoint, existing supercanopy specimens (predominantly eastern cottonwood, *Populus deltoids*, and black willow, *Salix nigra*) that were present in the riparian habitat were allowed to remain. Once soil removal activities and the placement of a nonwoven geotextile mat in the base of the excavation have been completed, actions to restore the habitat structure were initiated. The first activity was the placement of backfill within the excavation areas to restore the banks to their original grade. A six-inch layer of topsoil was then placed over the backfill to serve as the medium for plant establishment and to restore the final grades along the bank. The topsoil that was used was a loam, with a minimum five percent organic content.

In some areas, the vegetative community was reestabished by planting a riparian community based on the New England floodplain forest community. Common New England floodplain forest community species used in the replantings included:

Table 6-1. Species used in floodplain forest replanting

Canopy	Understory/Shrub
Red maple (*Acer rubrum*)	Northern spicebush (*Lindera benzoin*)
Silver maple (*Acer saccharinum*)	Northern arrowwood (*Viburnum recognitum*)
Black willow (*Salix nigra*)	Silky dogwood (*Cornus amomum*)
American elm (*Ulmus americana*)	Red-osier dogwood (*Cornus sericea*)
White ash (*Fraxinus americana*)	Winterberry holly (*Ilex verticillata*)

Red maple, silver maple, and black willow were the dominant species in this community. As such, they accounted for 75% of the replacement canopy trees. American elm and white ash, as associate species, together accounted for 25% of the replacement canopy trees. Planting of the silver maple and black willow was biased towards the adjacent river. Red osier dogwood and winterberry holly plantings were also biased towards the river.

Following restoration of the grade, trees were installed using standard planting practices. All specimens were container grown with obtained species being four feet to six feet tall. Canopy species were planted uniformly with a basic spacing of twelve feet between specimens. The canopy specimens were planted on a random mixed basis so as to ensure a heterogeneous distribution of species in the canopy.

Based on the data from the habitat assessment, the understory species were planted in a patchy manner so that 40% of both banks were covered by understory species. To allow for good structural distribution and juxtaposition of habitats, the understory vegetation was planted (to the extent possible) in oblong patches thirty feet wide by fifty feet long. Silky dogwood, spicebush, and arrowwood were intermixed on a random basis within the oblong patches. The patches were scattered to be at least forty feet apart.

In order to develop dense areas of habitat for future wildlife usage, all understory species were planted on four-foot centers. Each planted shrub was two to three feet in size and was container grown. All plants were delivered and staged onsite prior to planting. Planting pits were dug one-foot larger than the plant container and pit depth was to the depth of the plant container. When the trees and shrubs had been properly set, the pit was thoroughly watered during and after backfilling. Enough topsoil was used to bring the surface, when settled, to the required grade.

Plants were not removed from containers until immediately before planting. Roots were examined to determine if they were pot bound. Roots that were pot bound were separated prior to planting. Plants were placed in the dug pits in such a manner so as to allow further growth without additional constriction of the root ball. After planting and watering, each plant was mulched with wood chips from on-site cleared vegetation or loose straw and was fertilized with a 10-10-10 (phosphorous, potassium, nitrogen or PKN) slow-release fertilizer. The fertilizer was applied at the product recommended application rate.

6.2.1.2 Meadow restoration and end use

Meadows are open expanses of land that are covered mainly by herbaceous species such as grasses, forbs, and legumes. One of the overriding determinants of a grassland ecosystem is the amount of precipitation that an area receives. Grasslands usually do not receive enough rainfall to support the growth of trees (or they experience a disturbance regime, such as fire, grazing, or mowing, that does not allow for the development of a dominant woody community). At locations where attempts to establish a meadow are made and there is sufficient rainfall to support trees, active management steps may be required to ensure that succession does not move the meadow to a shrubland or forest.

Open meadows can be easily incorporated into the design of a remedial action, whether as a restored resource at a site where excavation may have removed the meadow from service or in conjunction with a traditional remedial technology. For example, a grassland or meadow can be incorporated into a traditional or alternative final landfill cover system (see ALT-2 2003, http://www.itrcweb.org/gd_ALT.asp).

Harker notes that the following steps should be followed in restoring a grassland or meadow:

1. Planting should be accomplished through the use of either seeds or greenhouse grown specimens;
2. Many prairie forb seeds require cold treatment after collection to prevent drying and dormancy or scarification for those seeds with hard seed coats;
3. Controlled burning, usually after the third year of growth, is a highly effective management tool to inhibit undesirable plants. At locations where controlled burning is not an acceptable tool, anthropogenic management activities such as mowing may be necessary to manage the meadow; and
4. The planting of legumes may require the inoculation of the seeds with appropriate rhizobia bacteria for nitrogen fixation.

The choice of plants can be made with the goal of attracting a variety of wildlife, including emphasizing the use of wildflowers to attract various butterfly species, or emphasizing the use of seed forming grasses or legumes to attract certain bird species.

6.2.2 Freshwater Systems

Hazardous waste sites are often associated with a freshwater system of some kind. As such, the ecological elements or enhancements of these systems can easily be incorporated into the remedial design. In some instances the restoration would be part of the remedial action, as in sites where dredging of contaminated sediments from a stream channel or lake bed, or excavation of the riparian boundary of a stream would necessitate that actual restoration of the resource. In other instances, the restoration of the aquatic resource could be conducted in conjunction with the implementation of the remedy in other parts of the site.

In general, aquatic systems are considered and evaluated based on their form. Lotic habitats are running water habitats such as rivers and streams. Lentic habits include inland depressions containing standing water such as lakes and ponds. Lentic habitats can be further divided into several zones, including the littoral zone (the shallow-water zone at the edge of the lake or pond where light reaches the bottom). The limnetic zone is the open water area of a pond and reaches to the depth below light penetration. The profundal zone is the open water area of a pond or lake that begins at the depth of light penetration and extends to the bottom of the water body. The benthic zone is the bottom of the standing water body. The following sections discuss the two general forms, lotic and lentic, in greater detail.

6.2.2.1 Stream corridor restoration and end use

The restoration or enhancement of a stream corridor as the ecological end use of the resource can be accomplished through a variety of instream or riparian activities. Excellent sources of information on restoring and enhancing lotic habitats for stream corridor restoration include: *The WES Stream Investigation and Streambank Stabilization Handbook* (Beidenharn et al. 1997), *Stream Corridor Restoration: Principles, Processes and Practices* (Federal Interagency Stream Restoration Working Group, FISRWG, 1998), and *Integrated Streambank Protection Guidelines* (Washington State Aquatic Habitat Guidelines Program 2002). *Applied River Morphology* (Rosgen 1996) is a reference commonly used in the classification of streams and the development of goals and objectives for various stream categories.

The ultimate goal of a steam restoration project is the development of water quality conditions and habitat circumstances necessary to support a diverse aquatic community. This is generally accomplished by stimulating the development of heterogeneous habitat conditions within and along the stream channel. As with any restoration project, the planning for the project begins with a detailed assessment of current stream conditions. If the restoration is to be incorporated following the removal of contaminated soils or sediment, then a baseline characterization of the form and function of the existing stream and a determination of the objectives (predisturbance conditions) of the stream restoration must be reached. If the restoration is to be conducted in conjunction with a remedial action at another part of the site, then common disturbances must be assessed; these disturbances can include stream channel alteration, water quality impairment, the presence of exotic species, loss or riparian vegetation, and alterations to the streambank.

After the detailed assessment of the stream is completed, planning for an aquatic restoration project will incorporate actions to address three general areas: stream channel restoration, streambank stabilization, and streambank vegetation. Planning for stream channel restoration considers actions to enhance habitat to generate and support a more diverse aquatic community. While the long-term restoration of a stream can best be achieved by relying on natural processes, common engineered habitat structures can be used in the short term to begin the process. FISRWG (1998) notes that the following considerations should be made in the incorporation of habitat structures as part of an instream aquatic restoration:

- The potential adverse impacts from failure of a technique should be assessed before it is used.
- Techniques that change the channel slope or cross-section have a high potential for causing channel instability. These techniques should be carefully analyzed and considered before employment.

- The potential impact of flood elevations should be analyzed before these and other techniques are used.
- Many techniques will not endure on streams subject to general bed degradation.
- Some form of toe protection will be required for many of the instream techniques to endure where scour of the streambank toe is anticipated.
- Regulatory permits and considerations should be taken into account.

Some common instream structures are used to develop habitat (FISRWG 1998):

- *Boulder clusters*. Groups of boulders can be placed in the base flow channel to provide cover, create scour holes, or create areas of reduced velocity.
- *Wiers or sills*. These are log, boulder, or quarry stone structures placed across the channel and anchored to the streambank and/or bed to create pool habitat, control bed erosion, or collect and retain gravel and fines.
- *Fish passages.* These are instream changes which enhance the opportunity for target fish to freely move upstream.
- *Log/brush/rock shelters.* Structures placed in the lower portion of streambanks can enhance fish habitat, prevent erosion, and provide shading.
- *Migration barriers.* Obstacles placed at strategic locations along stream can prevent undesirable species from moving upstream.
- *Wing deflectors.* These are structures that protrude from either streambank that do not extend all the way across the stream and deflect flows, and generate scour holes by accelerating flow.

Streambank stabilization is required for disturbed or reconstructed streambanks to prevent further erosion. While geotextiles or engineered rock gabions can be used ("hard" engineering) the preferred approach, if stream energies allow, is to incorporate natural or "soft" engineering approaches that provide as much natural habitat as possible. Some common streambank treatments to prevent and decelerate erosion and increase habitat include the following (FISRWG 1998):

- *Brush mattresses*. These are combination of rapid-growing live stakes, live facines (i.e., bundles of live stakes), and branch cuttings installed to physically protect streambanks and provide cover.
- *Coconut fiber rolls*. These are biodegradable, linear, yet flexible structure composed of tightly bound coconut husk fibers. They are used to protect gradual slopes from erosion and trap loose sediment encouraging plant growth.
- *Dormant post plantings*. Plantings of certain species embedded vertically into the streambanks can increase channel roughness and reduce stream flow velocities.
- *Vegetated gabions*. These are standard rock gabions with live branch cuttings placed between the rock filled baskets to take root and consolidate the structure and bind it to the toe of the slope.
- *Tree revetments*. A row of interconnected trees secured together and anchored to the toe of the slope can reduce surface water velocities along streambanks, trap sediment, and provide a substrate for plant establishment.

- *Vegetated geogrids.* These are alternating layers of live branch cuttings and compacted soil.

The final action in restoring a stream is in the development of a diverse riparian habitat bordering the stream channel. Plant species in the riparian zone help regulate stream temperature, filter upland runoff to remove sediments and nutrients, stabilize streambanks, provide an outside source of organic material (such as leaf-fall), and provide habitats for terrestrial and aquatic wildlife. See Section 6.2.1 for approaches to restoring forest and grassland habitats located in the riparian zone.

6.2.2.2 Lake and pond restoration

As with lotic habitats, lentic systems (ponds and lakes) can be restored or enhanced as part of an ecological end-use project. The restoration objectives in lentic systems are similar to those for lotic systems: to create a functioning habitat that will support and sustain an aquatic community. The size and complexity of the project will depend, in large part, on the size of the water body and the size of the remedial action in relationship to the water body. Lakeshore stabilization techniques similar to those outlined in the previous section for streams may be necessary for lakes that are of sufficient size to generate windblown waves. In very large lakes with a large fetch that can develop extreme waves, significant measures to protect the bank and stop erosion may be necessary.

In the littoral zone, vegetative plantings incorporating emergent plant species such as those outlined in Section 5.2.3 may be used to establish habitats for fish, amphibians, and aquatic invertebrates, as well as water dependent bird and mammal species. Emergent plants are those species in which at least a portion of the foliage and all of the reproductive structures extend above the surface of any standing water. In the limnetic zone, floating-leaved plants and submerged plants can be used to establish important fish habitat. Floating-leaved plants are characterized by leaves that float on the surface of the water and are attached to the bottom by long stalks. These species are usually found in shallow-water habitats ranging from 12 to 40 inches. Typical of this type of plant are water lilies (*Nymphaea* sp.) and spatterdock (*Nuphar* sp.). Submerged plants are those species in which all foliage is found underwater. This includes eelgrass (*Zostera* spp.) and pondweed (*Potamogeton* spp.). All of these growth strategies also provide a valuable energy source and substrate for aquatic invertebrates that support many higher trophic level organisms. In addition to the use of plant species to generate habitat, brush and rock piles can be placed in restored areas at suitable depths to provide habitat, breeding areas, and refuge for fish.

Fish stocking is also a tool to help restore the aquatic resource. This approach can be used for small water bodies that have been dramatically impacted by remedial actions. Fish stocking is also recommended if the goal of the project is to enhance the species composition or age structure of an existing fishery. The decision as to whether a warm-water or a cold-water fishery will be attempted will depend upon the size and depth of the water body, the site location in relation to elevation and climate, and the intended end use of the water resource. If restocking is used as an approach in a water body, extreme care should be taken in deciding upon the species and feeding strategy of the selected fish species (carnivore, omnivore, and herbivore). Care should be taken to prevent the introduction of voracious herbivores that might remove all plant material from the water body or voracious carnivores that might entirely remove the prey community and leave a depopulated community over time. Consultation with state fisheries biologists is highly recommended when attempting restocking. State fisheries biologists are a valuable source of information and can alert the project team to common region-specific pitfalls for restocking projects.

6.2.3 Wetland Restoration and End Use

Wetlands are unique and sensitive ecosystems which provide valuable functions in the environment. Wetlands provide necessary feeding, reproductive, and rearing habitat for numerous aquatic and terrestrial organisms; erosion and flood control; groundwater recharge; primary production and nutrient cycling; and contaminant sequestration and transformation. Wetlands can be freshwater, brackish, or marine, are found at various elevations, and occur along coasts as well as inland. They can be found virtually anywhere that hydrologic conditions exist for their development and perpetuation.

The Clean Water Act defines wetlands as “those areas that are inundated or saturated by surface or groundwater at a frequency or duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas” (40 CFR 230.3). “Wetland” can refer to marshes, swamps, bogs, and fens, all of which are characterized by frequent or prolonged presence of water at or near the surface, soils formed under saturated conditions, and habitation by plants adapted to saturated soil conditions.

Wetlands are generally characterized by the presence of three basic parameters: soils, hydrology, and vegetation (ITRC Wetlands-1 2003 and ITRC Wetlands-2 2005). Water is usually present at the surface or within the root zone of wetlands for extended periods of time during the growing season. As a result of the saturated conditions, the soils present in wetlands develop certain unique conditions that are different from upland soils. Where subsidence creates an environment favorable or nearly favorable for the hydrologic needs of a wetland, maintenance may be required for long periods of time to establish the hydric soils of a wetlands and thereby supporting wetlands plant species. Also, in response to the saturated conditions, wetlands support vegetative species that are adapted to living in wet conditions. The following sections more thoroughly describe the parameters used to identify and characterize wetlands.

The most common means of characterizing wetlands is under the system developed for the U.S. Fish and Wildlife Service (Cowardin et al. 1979). As described in Cowardin, wetlands types can be broken into five basic categories: marine, estuarine, riverine, lacustrine, and palustrine. The major categories or systems are based mostly on their position on the landscape. Each of these systems can be further broken down into subsystems, classes, subclasses, and dominance types based on the type of vegetation present and/or the bottom substrate for the wetlands.

Marine wetlands include the open ocean overlying the continental shelf and wetlands occurring along the associated coastline. Estuarine wetlands consist of deepwater tidal flats and adjacent tidal wetlands that are usually mostly enclosed by land and have at least sporadic access to the open ocean. The water associated with these wetlands is at least occasionally diluted by freshwater and generally extends from a point upstream where the salinity level is 5 parts per thousand (ppt) to the seaward limit of wetland emergent species (Cowardin et al. 1979).

Riverine wetlands include all wetlands and deepwater habitats found within a river channel, with the exception of wetlands dominated by trees, shrubs, persistent emergent species, emergent mosses, and lichens. Palustrine wetlands include all nontidal (for the most part they are inland) wetlands dominated by trees, shrubs, persistent emergent species, emergent mosses, or lichens. Palustrine wetlands are bounded by uplands or any other type of wetlands and may be situated shoreward of lakes or river channels or in floodplains. Lacustrine wetlands include wetlands and deepwater habitats found in topographic depressions or dammed river channels, which lack trees, shrubs, emergent species, mosses, or lichen and exceed 20 acres in size. Riverine, palustrine, and lacustrine wetlands are all generally freshwater systems (Cowardin et al. 1979).

In many parts of the country, it is very likely that wetland end uses can be incorporated into the remedial design and final use for hazardous waste sites because wetlands are commonly found at these locations. In a review of sites managed under CERCLA, Hayes (1988) noted that approximately 74% of CERCLA sites in EPA Regions 1, 2, 3, and 4 were associated either directly or indirectly with wetlands. EPA (1989) also found that contamination had been observed in wetlands or was projected to occur in wetlands at 85% of the CERCLA sites evaluated for the 1989 study.

Issues related to wetlands mitigation (compensatory actions in response to permitted injuries to wetlands) are regulated by law and managed by the EPA and U.S. Army Corps of Engineers (USACE), as well as many states. The ITRC Wetlands Mitigation Team is developing a document that describes the various procedures to be used in specific wetlands mitigation activities (ITRC Wetlands-2 2005). In summary, incorporating wetlands as an ecological end use at a hazardous waste site will generally include four different types of actions:

Case Study: Weldon Spring

DOE is returning the Weldon Spring Site to a natural and native ecosystem and is in the process of creating a 150-acre prairie around the disposal cell that extends to the site boundary. When complete, the prairie will be one of the largest plantings of its kind in the metropolitan St. Louis area. The design for the new prairie began in the early 1990s when native grasses were deemed to be the best solution for site restoration. In late spring of 2002, the first permanent planting of prairie grasses and forbs was conducted. Since then, nearly 100 different prairie species have been planted.

In addition, DOE has contributed to the restoration of surrounding ecosystems impacted as a result of project activities. DOE supported funding for the construction of a sixty-acre wetland complex in a nearby state conservation area and implemented an extensive monitoring program to ensure its successful establishment. DOE has also constructed approximately thirty additional acres of wetlands on adjacent conservation lands. All wetlands currently serve as a valuable environmental resource by increasing biodiversity and attracting large migratory waterfowl populations (for more details, see http://www.wssrap.com/transform.htm).

1. restoration of existing degraded wetlands through either reestablishment or rehabilitation
2. enhancement of an existing wetland to improve its physical, chemical, or biological characteristics to heighten, intensify, or improve specific wetland function
3. if the second alternative is impractical, preservation of a wetlands site by removing the threat to, or preventing the decline of, a wetland by an action in or near a wetland
4. under special circumstances, creation of a wetland in an upland or deepwater site where a wetland did not previously exist

The following section discusses wetland end uses as they apply to both freshwater and marine/estuarine environments.

6.2.3.1 Freshwater wetlands

Freshwater wetland reuse can include restoration of a contaminated wetland or creation of a new wetland or enhancement of a degraded wetland. In each instance, the action to restore, create, or enhance the wetland will be based on wetland mitigation practices that are described in ITRC Wetlands-2 (2005). The type of wetland (marsh, scrub/shrub, swamp) to be incorporated into the ecological end use will depend upon the hydrology of the baseline or reference area wetlands used for the mitigation model. The vegetative form of a wetland (such as a marsh) is the physical expression of the wetland hydrology that is present, governed by plant dispersal and establishment.

Marshes are wetlands frequently or continually inundated with water, characterized by emergent, soft-stemmed vegetation. Many different kinds of marshes exist, ranging in form and geologic origin from the prairie potholes to the Everglades, in landscape position from coastal to inland, and in water chemistry from freshwater to saltwater. Marsh hydrology may be driven by surface water, groundwater, or a combination of both. Most nutrients are plentiful, and the pH is usually neutral, leading to an abundance of plant and animal life.

Swamps are wetlands dominated by woody plant species. There are many different kinds of swamps such as the forested red maple wetlands of the Northeast, the widespread and expansive bottomland hardwood forests found along the floodplains of rivers of the Southeast, and cypress swamps. Swamps are characterized by saturated soils and standing water during certain times of the year. Organic soils of swamps form a thick, black, nutrient-rich environment for the growth of water-tolerant trees such as bald cypress (*Taxodium distichum*), Atlantic white cedar (*Chamaecyparis thyoides*), and black gum (*Nyssa sylvatica*). Swamps have two major classes: shrub swamps and forested swamps. Not only do many species of plants and wildlife use swamp habitats, some require large areas of swamp wetlands for successful breeding.

6.2.3.2 Marine and estuarine wetlands

A wetland associated with water from ocean or estuarine sources may be found at a hazardous waste site. Restoration, creation, or enhancement of tidally influenced wetlands has the added challenge of addressing wetlands dominated by plants that require certain salinities to survive, and the logistics of executing a restoration effort in a tidal environment. As with freshwater wetland systems, tidal wetlands can also be categorized based on the dominant vegetative communities they support. Tidal forests are limited in the U.S. to the mangrove swamps of southern Florida. The most common marine and estuarine wetland systems are the tidal marshes found along coastlines in middle and high latitudes. They are most prevalent in the United States on the eastern coast from Maine to Florida and continuing on to Louisiana and Texas along the Gulf of Mexico. These are generally categorized into two distinct zones, the lower or intertidal marsh, and the upper or high marsh.

As noted in ITRC Wetlands-2, special considerations must be given to addressing wetlands that are saline and tidal in nature. Garbisch (2002) advises that when constructing tidally supported wetlands, the conveyance of water to and from the site must be kept unrestricted to allow for nutrient exchange and salinity moderation. He also notes that mitigation plans should clearly state and show that all vegetated areas are well drained to ensure that ponding, which would lead to high water temperatures and hypersalinization, does not occur unless that is part of the design (e.g., "panes" in salt marshes).

6.2.4 Shoreline Restoration and End Use

Shoreline restoration or enhancement can be selected as part of the ecological end-use project for the site in the appropriate setting. Beach replenishment projects generally consist of dredging sand from offshore deposits and pumping it through pipelines onto the beach. Grading techniques are then used to either distribute the material over the beach or to grade the material to generate sand dunes. Extensive monitoring at every phase of the project is needed to protect aquatic plants, fish, and birds. Sand dune plantings are used to generate critical plant communities required to prevent dune erosion and provide habitat for various species of birds.
In shoreline settings in more urban areas, restoration activities that might be considered include the following:

- development of coastal meadows
- recontour and softening of the shoreline
- development of fish passages
- restoration of historically filled wetlands
- improvement of estuarine circulation
- improvement of tidal flushing
- stabilization of habitats

6.2.5 Wildlife Habitat Measures

In coordination with the habitat establishment activities that are described above, habitat enhancement features can assist in the development of wildlife and aquatic habitat functions. These are simple structures that require little or no maintenance, yet as the planned ecological end-use project develops, they provide increasing habitat quality over time. Examples of enhancement features are as follows:

- woody debris such as logs, stumps, brush piles, and snags
- upland islands in the middle of wetlands, lakes, or ponds

- open-water features such as tidal guts and small pools
- nesting boxes for waterfowl or raptors and roosting structures for other avian species
- bat boxes
- vegetative buffers

7. COST AND BENEFIT CONSIDERATIONS

Remedies incorporating ecological elements or enhancements to support ecological end uses for previously contaminated sites offer protection of HH&E as well as cost savings and income opportunities. Additionally, returning idle land to useful ecological service and optimizing the site's service capacity creates value to the owner and the surrounding community. These opportunities require a thorough understanding of the lifecycle of a project and the costs and cost-saving potential of the site designed with an ecological land reuse in mind. This section describes a holistic approach for evaluating cost considerations in the selection of ecological land reuse using natural and green remedies alongside more traditional remediation approaches. A holistic approach considers numerous cost/benefit variables, rather than simply focusing on the bottom-line economics of the remediation.

Remediation strategies incorporating ecological elements or enhancements may have non-numeric upside potential. This may appear to be intangible at first, but can prove to be very real when integrated into a business development strategy. As pointed out in Section 3.3, one of the major benefits of incorporating ecological elements or enhancements into cleanup remedies is corporate reputation; hence, this begins of the process of integrating the remediation project strategy with the business development strategy. To quantify and demonstrate goodwill a company must do its homework for a specific remediation project, and the community must be involved early in the process to clearly indicate a desire to integrate some ecological elements or enhancements into the remediation strategy.

Ecological elements may not prove to have the best quantifiable costs and benefits in the strict economic analysis; however, the ecologically based remediation project often generates valuable community goodwill. When a company seeks to open additional profit centers in the community, the corporate goodwill generated during the remediation project may translate to improved corporate reputation within the community. The increased goodwill and corporate reputation make it easier for the company to approach the community planning board for its newly proposed business venture. The planning board, with positive support from the community, finds it easier to approve the business development venture. This apparently intangible goodwill, generated by inclusion of the stakeholders in the process and incorporation of the ecological elements in the remediation project, now turns into very real and tangible business development cost savings. The intangible goodwill saves the company the expense of hiring a business consulting/lobbying firm to work with the planning board, public meetings, potentially selecting less desirable business location, opposition by the citizens and possibly the press, or possibly losing out on a business opportunity to a competitor. Cumulatively, these are significant and real cost savings.

This section contains information about cost evaluation, but the semiquantifiable and nonquantifiable asset valuations later in this section may prove to be even more important than the dollars and cents associated with a remediation project. How much is an improved corporate reputation worth? Is it worth putting in a quarterly shareholder report? Could it even be worth a gain of some new investors or an incremental change in the cost of a share?

When valuing an ecological element or enhancement, the project team needs to consider the complete life cycle of the project. From technology selection to final disposition of the property, there are numerous cost elements to be considered. A comparison of the relative economic advantages of two alternative approaches, one having moderate initial costs, high O&M costs, and a short duration and the other having low initial costs, moderate O&M/administrative costs and a long duration can be made through a net present value (NPV) analysis. These cost elements can be broken down into three general categories:

- quantifiable values
- semiquantifiable values
- nonquantifiable values

Elements in the following text and figures (Figure 7-1 and Table 7-1) should be considered for every potential alternative in a project to fully evaluate its value in comparison to other alternatives.

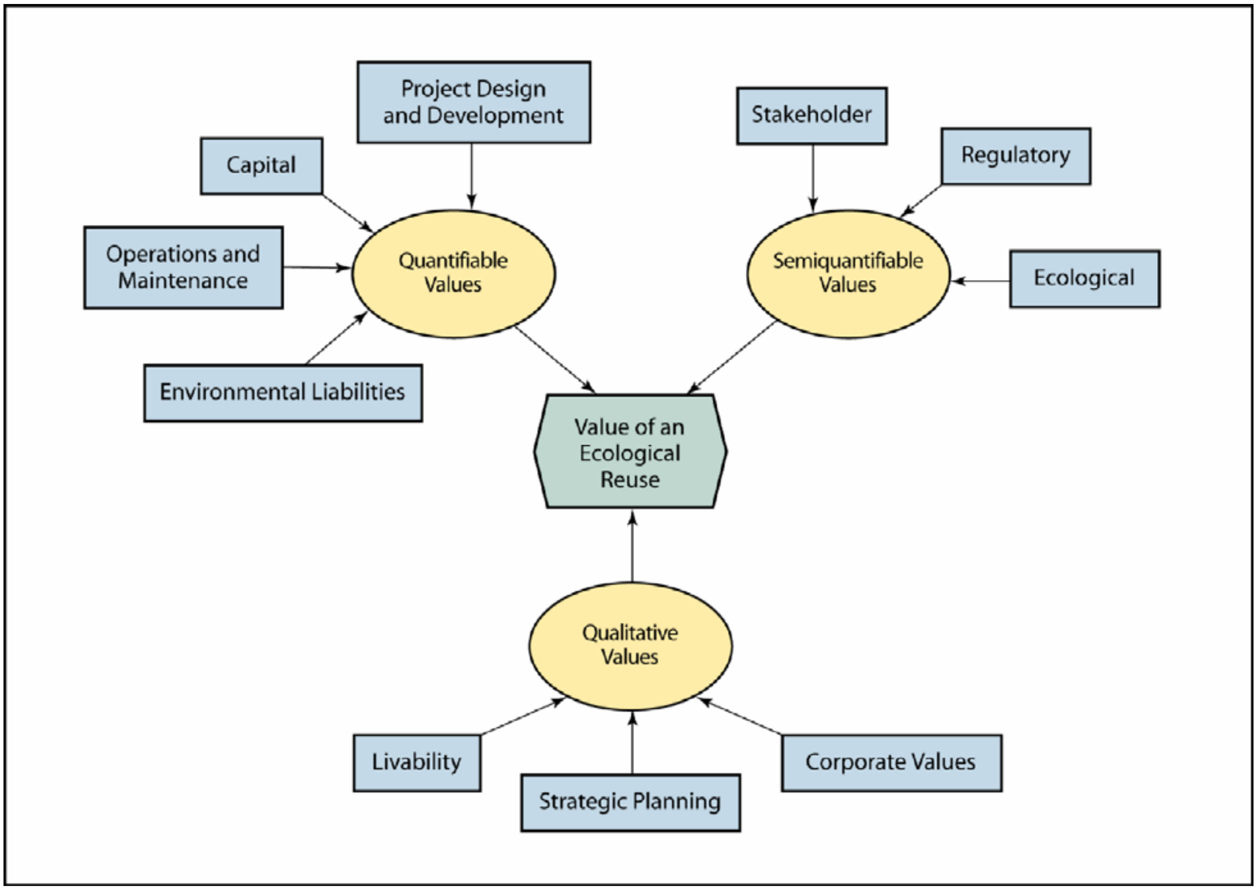

Figure 7-1. Influence diagram of quantifiable, semiquantifiable, and qualitative values

Table 7-1. Additional details of the value determination of an ecological land reuse

Quantifiable Values	Semiquantifiable Values	Qualitative Values
Project Design and Development	**Stakeholder**	**Livability**
• Meet remedial goals	• Community engagement	• Aesthetic appearance
• Alternative endpoints	• Social mores	• Noise, odor, visibility
• Cost recovery	• NGO engagement	• Health, safety, security
• Risk / site assessments	• Regional needs /compatibility	• Community character /sense of place
• Permitting and contracting	• Education opportunity	
• Security	• Recreational opportunity	**Corporate Values**
• Attractive nuisance	• Avoid property condemnation	• Core values and policies
	• Corporate shareholder value	• Company pride
Capital		• Moral /ethical responsibility
• Technology development	**Regulatory**	• Cultural alignment
• External funding	• Innovative approach	• Enhanced reputation
• Operations & maintenance	• Reimbursement solvency	• Employee morale

Quantifiable Values	Semiquantifiable Values	Qualitative Values
• Monitoring	• Relationship status	
• Reporting	• Precedence	**Strategic Planning**
• Property tax payments		• Public & government relations
• Project length	**Ecological**	• License to operate
	• Biodiversity benefits	• Sustainable legacy
Environmental Liabilities	• Erosion control	
• NRD offsets	• Stormwater management	
• Future use liabilities	• Conservation or mitigation	
• Supplemental environmental projects	• Greenhouse gas effects	
• Long-term cost liabilities		

7.1 Net Environmental Benefit Analysis

Decisions regarding the selection of remedial alternatives rarely include a formal quantification of their effect on natural resource service values. As a result, the potential exists for a remedial action to either create more natural resource harm/injury than the risk that is driving it or provide a marginal benefit for the effort expended. A net environmental benefit analysis (NEBA) is an approach that provides for the quantification of the effect on natural resource service values that would be associated with the implementation of an action (such as a remedial action) and compares these effects to predicted changes in the risk scenarios and costs. The NEBA approach allows for a systematic evaluation of changes in natural resource values (ecological and human use) associated with remedial alternatives so that consistent comparisons across alternatives can be conducted to achieve the greatest net environmental benefit at the lowest cost, while maintaining protection of HH&E. A NEBA can be particularly useful when the balance of risks and benefits from remediation of a site are ambiguous. Recent publications present a general framework for the NEBA method and include the use of the habitat equivalency analysis (HEA) approach for quantifying impacts to ecological receptors (Efroymnson et al. 2004).

7.1.1 Where Does NEBA Fit Within Regulatory Processes?

Regulatory agencies are obligated to (1) assess and understand the potential natural resource injury that may be incurred by remedial actions and (2) consider the relationship between risk reduction and cost. The NEBA approach is consistent with EPA risk management objectives; according to EPA Superfund ecological risk assessment (ERA) guidance:

> The risk manager must balance (1) residual risks posed by site contaminants before and after implementation of the selected remedy with (2) the potential impacts of the selected remedy on the environment independent of contaminant effects.
>
> In instances where substantial ecological impact will result from the remedy (e.g., dredging a wetland), the risk manager will need to consider ways to mitigate the

impact of the remedy and compare mitigated impacts to the threats posed by the site contamination.

The NEBA approach provides a framework to help comply with this guidance.

7.1.2 Integrating Remedial and Natural Resource Concerns

In 1999, the EPA OERR issued Office of Solid Waste and Emergency Response (OSWER) Directive 9285.7-28 P to the Superfund National Policy Managers in Regions 1 through 10. This directive was guidance intended to help Superfund risk managers make ecological risk management decisions that are based on sound science, to improve consistency across Regions, and to present a characterization of site risks that is transparent to the public. It provided risk managers with principles to consider when making ecological risk management decisions and questions risk managers and risk assessors should address.

During remedy selection, the EPA Directive asks that the risk managers examine the likelihood of the response alternatives to achieve success and the timeframe for a biological community to fully recover. The EPA suggests that an evaluation of ecological effects resulting from implementation of various alternatives be discussed in the feasibility study (FS) or the engineering evaluation/cost analysis (EE/CA) and should include input from the ecological risk assessor and the federal and/or state trustees responsible for the resources that may be impacted by the response. Despite the EPA 1999 guidance, the risks to resources due to the remedy are rarely formally quantified in common practice. The NEBA provides a methodology by which remedial impacts or benefits can be quantified. The methodologies include the use of HEA to quantify ecological gains or losses and benefits transfer to quantify human use benefits or losses. The NEBA approach allows for a systematic evaluation of changes in natural resource service flows associated with remedial alternatives so that consistent comparisons across alternatives can be conducted to achieve environmental objectives at the lowest cost.

7.1.3 Integration of NEBA into the CERCLA Process

The best time to conduct a NEBA is in conjunction with an FS. This allows for full consideration of natural resources issues to be integrated with the development of remedial alternatives. A NEBA can also be used to help screen out FS alternatives so that alternatives with disproportionate cost/benefit issues can be eliminated.

7.1.4 NEBA and Natural Resource Damage Assessment

The purpose of a NEBA is not to quantify natural resource injury to support an NRDA. The purpose of a NEBA is to provide information to support the identification of a remedy that provides the greatest net environmental benefit at the lowest cost, while maintaining protection of the environment. In some cases, the PRP will be faced with a formal claim for lost natural resource services through a regulatory-driven NRDA. Although NEBA is completely separable from an NRDA, it can play a primary role within the overall strategy regarding an NRDA. Regulators have discretionary authority to invoke an NRDA action. A NEBA can minimize the likelihood of a PRP facing a formal NRDA action through the development of a NEBA-supported site closure strategy. A NEBA-supported site closure strategy would identify the alternative that minimizes remediation-related NRI (natural resource injury), best addresses NRI caused by past practices, and potentially includes offsetting restoration where necessary.

A NEBA allows the consideration of any actions that may augment ecological services to compensate for any ecological losses. For example, an ecological risk assessment may find that natural attenuation of contaminants in groundwater is not associated with unacceptable risks. Regulators representing interested stakeholders, however, may have concerns surrounding the uncertainty of those risk values. Drawing upon the scientific findings of landscape ecology[3], a proposed remedial action of natural attenuation coupled with additional green remedial techniques or site restoration to increase ecological services can be considered. The overall package of remedial actions combined with restoration is then evaluated using a NEBA to assess their combined impact on the total ecological services provided by a site.

7.1.5 NEBA Quantification Models

Within the NEBA approach, various economics-based methodologies can be used to quantify changes in ecological and human use service values. Traditionally, land value has been the dollar value set by real estate appraisals and reflects the local market conditions for commercial, industrial, and residential uses. Recently, natural resource agencies (NOAA, DOI, USFWS and others) have indicated their desire to value land (habitats) based upon the natural resource services (such as ecological, human use, and passive use) that these habitats provide to the public. Natural resource services are defined as the functions performed by a natural resource for the benefit of another natural resource and/or the public. NOAA guidance further classifies natural resource services as either (1) ecological services—the physical, chemical, or biological functions that one natural resource provides for another natural resource and thus indirectly provides value to the public (for example, the provision of food for wildlife, protection from predation, and nesting habitat, among others); or (2) human use services—the human uses of natural resources or functions of natural resources that provide direct value to the public (such as fishing, hunting, bird watching, boating, nature photography, and education, among others).

For measurement purposes, economists generally classify environmental benefits into three categories: direct human use services (recreation, aesthetics, timber harvest); indirect human use services (climate moderation, flood control, ground water recharge, nutrient uptake, basic ecosystem support services); and passive use services (preserving wildlife habitats for future generations). The NEBA approach uses a combination of some of the same tools as are used in benefit-cost analysis (for example, benefits transfer methodology) and some recently developed methodologies (HEA) to measure these environmental benefits depending upon the nature of the decision and how the information will be used. Economic methodologies have been developed to quantify changes to these value categories given actions that impact (habitat disturbance, development, contamination) or benefit (conservation, management, habitat restoration) the level of services being provided by a specific parcel of land. Within NEBA, these methodologies are used to quantify the natural resource service values associated with potential alternative

[3] Landscape ecology is the study of the distribution patterns of communities in ecosystems, the ecological systems that affect those patterns, and the changes in those patterns and processes over time. An example of landscape geology is the examination of ecological systems on a macro scale such as a flyway or land-based migratory pathway (broad corridors used by migrating birds and animals).

management actions. HEA is the primary ecological economic model used in an NEBA, while benefits transfer is commonly used to quantify human use gains/losses.

7.2 Quantifiable Values

Quantifiable values (Figure 7-1 and Table 7-1) contain elements in which values can typically be assigned to a cost figure. Quantifiable values include, but are not limited to:

- project design and development
- capital costs
- operations and maintenance
- environmental liabilities

Quantifiable values (Figure 7-1 and Table 7-1) contain elements in which values can typically be assigned to a cost figure.

Ecologically-based or natural remedial technologies often require lower capital, O&M or other one-time investment than traditional technologies; however these savings may be offset by increased monitoring or reporting requirements and/or longer remediation project life. Depending on the amount of earthwork, soil amendment, and plant and/or habitat materials required, ecological land uses may or may not offer the potential for reduced capital or one-time outlays. In some cases, the need for remediation equipment, and its associated cost, may be reduced due to the use of alternate remediation end points based on low risk to plants and animals and based on limited human access. Risk scenarios may allow for simpler site assessments, and thus reduce assessment cost. Overall remediation-related costs may be reduced due to the use of alternate remediation end points based on ecologically-based land use (low risk to plants and animals, limited human access). O&M costs may be reduced both through modification of the remediation endpoint and augmentation of higher O&M traditional remedial systems with natural remediation techniques. In addition, O&M costs unrelated to remediation typically decrease as the land use approaches a more natural state.

A holistic approach to quantifiable values can be best illustrated with the following examples using current year dollars:

> *Example 1 (part 1):* A site has a dissolved benzene plume moving toward residences. The MCL is 5 ppb, and there is no risk to the residents. Horizontal three phase extraction has already been successfully pilot tested at this site for hydraulic control; however, the local residents would prefer not to see equipment in or near their yards. Phytoremediation has been evaluated for this site and, technically, it has been accepted as a suitable remediation strategy. Based on the quantifiable values (see Figure 7-1 and Table 7-1) the following comparison is made in Table 7-2:

Table 7-2. Traditional horizontal three-phase extraction system versus ecological phytohydraulic barrier system

3-Phase Extraction System		
Capital	$1,000,000	installation now
OM&M	$150,000/yr	for 5 years future
TOTAL NPV (2.5% Rate)	$1,682,000	
Ecological Phytohydraulic Barrier System		
Design and Development	$110,000	R&D spent already
Capital	$200,000	installation now
OM&M	$75,000	for 2 years establishment future
OM&M	$10,000/yr	for 8 years after establishment future
TOTAL NPV (2.5% Rate)	$499,000	
Cost Avoidance (Value Added)	$1,183,000 ($1,682,000 – $499,000)	

In this case, there is an economic incentive to use the phytohydraulic barrier system, but the remedial track record with horizontal three-phase extraction is more established. For project managers who are adverse to risk or in cases where the economics are not so clear cut, the decision maker will need to consider other factors before deciding to use the ecological enhancement.

> *Example 2 (part 1):* A refinery site has a dissolved benzene and MTBE plume moving towards a creek. The creek is the down gradient property boundary and the refinery is highly visible from a major regional bike path running parallel to the creek. Drinking water standards must be met before the plume leaves the property boundary.
>
> Historically the creek was impacted by free phase hydrocarbons and an extensive pump-and-treat system with product skimming pumps was used to control groundwater gradient and recover product floating on the water table. Ultimately the creek was moved and rebuilt in an area not impacted by petroleum hydrocarbons and is protected from further impacts by a 2000-foot-long slurry wall. Revegetation of the new creek area was required by the USACE and coincided with refinery and stakeholder goals to create a green belt on the refinery side of the creek. 600 to 1,000 gallons per minute of groundwater continues to be pumped from 21 wells and treated through two large air stripping towers.
>
> The current remediation plan is to create a phytoremediation natural attenuation treatment buffer zone behind the slurry wall to address remaining soil contamination and to treat and meet ground water standards at the point of compliance. Approximately 10 acres in a zone adjacent to the creek and slurry wall have been under active revegetation and irrigation for the past several years. The establishment of the phytoremediation attenuation treatment zone would allow shutdown of the groundwater pump and treat system.

Shown below in Table 7-3 is a comparison between costs for the operation of the pump and treat system and the ecological reuse phytoremediation natural attenuation zone system. Points of comparison are taken from Figure 7-1. In almost all cases the dollar values shown below are not estimates but are based on actual costs.

Table 7-3. Pump and treat versus ecological reuse

Project Phase	Pump and Treat	Ecological Reuse Treatment Zone
Design & Development	$0, sunk cost, already in place, estimated at $200,000 (in 1990 dollars)	$50,000 for GW modeling, plant selection
Capital	$0, sunk cost already in place, estimated at $1,000,000 (in 1990 dollars) Land occupied by system not available for refinery use	$100,000 for planting and irrigation system installation Attenuation zone located in creek floodplain
Operation & Maintenance	$300,000 per year for power, air, chemicals, operator time, servicing, permit requirements	$30,000 per year for additional planting, irrigation system maintenance, annual revegetation report. Note: costs should drop to $10,000 per year once USACE replanting requirements are met and ultimately drop to zero once irrigation is no longer required
Environmental Liabilities	If system fails, containment is lost Must meet NPDES permit requirements	System does not rely on pumps, wires or pipes to operate; attenuation zones work independent of human attention.

7.3 Semiquantifiable Values

The second category of cost elements is impact values (semiquantifiable values, Figure 7-1). Values in this category are traditionally not easy to quantify; however, generally, these items can be grouped or prioritized according to importance to the NPV analysis. For example, a poor relationship with a community could lead to increased litigation. It might not be possible to estimate the impact of this easily, but it can be assumed that in a high potential case certain estimable costs could double (high priority rank). Conversely, in a situation where a good community relationship exists, one could assume that there would be no multiplier to the estimable costs (low priority rank). Information needed to make this determination can come from historical work on other projects, benchmarking studies, and academia. Partnerships with conservation organizations have many advantages, including leveraging resources, providing technical guidance, and rewarding incentives for environmental innovation. NGOs and nonprofit organizations can also provide third-party credibility and an objective evaluation of projects. They can provide a reputable and unbiased review of a restoration, remediation, and management program for a contaminated facility.

Semi-quantifiable costs are traditionally not easy to quantify; however, these items can generally be grouped or prioritized according to importance to the NPV analysis.

Semiquantifiable values can include:

- stakeholder involvement
- regulatory acceptance and approval
- ecological considerations

Example 1 (part 2): Here, a component of community engagement (stakeholder involvement) has already indicated a need for aesthetic quality to be met in this neighborhood. If this impact value is not satisfied by the installation of the horizontal 3-phase extraction, then potential repercussions can occur, such as litigation for trespass and other damages. The impact of this should be low since it is a small community that has not expressed displeasure with the pace of investigation, has willingly worked with all involved parties, but it has expressed an interest in additional green space. There are no conflicts with regional needs (stakeholder involvement) as there are no plans for future development which would require a faster remedial action. There is not a high regulatory demand at this site since the risk is very low (regulatory); however, the regulating body seems open to an alternative solution to appease the community concerns. The remaining items under semiquantifiable values fall into much the same category of low impact on costs (perhaps 0-5% of the quantifiable values in the negative for the horizontal extraction). For examples in which there would be a high impact, anywhere from 30-100% of the quantifiable values could be added to account for the semi-quantifiable factors. Our new economics reflect this change, as shown in Table 7-4:

Table 7-4. Traditional horizontal three-phase extraction system versus ecological phytohydraulic barrier system, revised

Traditional Horizontal 3-Phase Extraction System		
Capital	$1,050,00 0	Installation now (+5%)
OM&M	$157,500/yr	For 5 years future (+5%)
TOTAL NPV (2.5% Inflation, 9% discount)	$1,728,000	
Ecological Phytohydraulic Barrier System		
Design and Development	$110,000	R&D spent already
Capital	$200,000	installation now
OM&M	$75,000	for 2 years establishment future
OM&M	$10,000/yr	for 8 years after establishment future
TOTAL NPV (2.5% Inflation, 9% discount)	$499,000	
Cost Avoidance (Value Added)	$1,229,000 ($1,728,000 - $499,000)	

The cost avoidance increased from $1,183,000 to $1,229,000. By adding the semi-quantifiable factors to the analysis, the savings are even larger for using the ecological enhancement.

Example 2 (part 2): The city officials, EPA, state regulators, and citizen and bike path groups were keenly interested in remedial options in the area of the creek.

City officials grant building, occupancy, and other permits and levy operational taxes. EPA and state agencies administer corrective action orders and operational permits for the refinery. Citizen and bike path groups can influence, oppose, or support agency and refinery actions and operations. While these groups have little interest in the responsible parties' quantifiable values, they can have a great influence on those costs. Shown in Table 7-5 below are actual observations about these groups relative to the two treatment systems:

Table 7-5. Comparison of interested party influence, pump and treat versus ecological reuse

Interested Party	Pump and Treat	Ecological Reuse Treatment Zone
Stakeholder (City, Bike Path, Citizens)	Concern about groundwater treatment outfall to creek from aesthetic and water quality standpoint	• No point source discharge to creek • Strongly in favor of revegetation and habitat creation
Regulatory (EPA, State, City)	• Comfortable with conventional Pump & Treat • Recognize system has limitations and long-term operational issues	• Conceptually in favor of habitat creation • Point of compliance requirements must be met • Concern about contingency treatment should Treatment Zone fail • In favor of robust system that does not require company viability to function
Ecological	No effect on surface ecology	• Creates habitat • Creates greenbelt • Creates positive buffer zone between community and refinery

7.4 Qualitative Values

Finally, certain elements will not be feasible to quantify; however, these elements do have an impact on the project. These elements are qualitative values (Figure 7-1). When there are two projects that have similar estimable and impact values (in terms of NPV), the qualitative values may sway the choice of technology and end use.

When two projects that have similar estimable and impact values (in terms of NPV), strategic values may be the deciding factors.

Qualitative values can include the following:

- livability
- corporate values
- strategic planning

Example 1 (part 3): The strategic value of community character and sense of place is satisfied with the ecological enhancement option since the residents are

Appendix A

Acronyms

Appendix B

Glossary

APPENDIX C

Case Studies

CASE STUDIES

C.1 NEW BEGINNINGS - THE WOODLAWN WILDLIFE AREA (PORT DEPOSIT, CECIL COUNTY, MARYLAND)

C.1.1 Site Description

The property lies in a mostly rural setting north of Baltimore in Cecil County, Maryland, and is surrounded by rapidly expanding residential development in a formerly agricultural area. Its history of industrial use began in the 1950s, when the 37-acre site was used as a sand and gravel quarry. During the 1960s and 1970s, it was used to dispose of agricultural, municipal, and industrial wastes from the surrounding area. As with most landfills at that time, the undersurface of the landfill was not lined with an impermeable barrier, enabling infiltration of contamination from the landfill waste into groundwater. Consequently, EPA placed the site on the NPL in 1987. A thorough environmental investigation was undertaken to identify existing and potential future impacts to groundwater, soil, surface water, or air quality from landfill wastes, and to select a restoration strategy. Vinyl chloride detected in the groundwater was attributed to waste materials disposed in the landfill by Bridgestone Americas Holding, Inc. (formerly Firestone) while the landfill was in operation. The company took responsibility for managing the site and purchased an adjoining 58-acre property to better enable site access to complete the study while establishing monitoring wells to track possible groundwater contamination. It is this portion of the property that has become a focal point for wildlife habitat enhancement, as well as providing natural resource education to the surrounding community.

C.1.2 Site Reuse Description

Since the site was documented not to pose a threat to human health, wildlife, or the environment, Bridgestone Americas Holding, Inc. explored the possibility of returning the land to the community and partnered with the WHC in 1997 to develop a sustainable wildlife conservation area. Since January 2000, WHC and Bridgestone Americas Holding, Inc. have collaborated extensively with local community members, youth groups, schools, extension services and local conservation groups. Together, these groups have worked toward a common vision for both the landfill and adjacent areas—restoring and conserving high wildlife habitat value and providing environmental education opportunities.

Appendix D

Nongovernmental Organizations involved in Ecological Restoration

Appendix E

State Survey

Appendix F

ITRC Contacts, Fact Sheet, and Product List

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