
The Incorporation of an Ecosystem Services Assessment into the Remediation of Contaminated Sites

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LIST OF ABBREVIATIONS

CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
GIS	geographic information system
MEA	Millennium Ecosystem Assessment
NPL	National Priorities List
PRA	participatory rural appraisal
OSWER	Office of Solid Waste and Emergency Response
RCRA	Resource Conservation and Recovery Act
WRI	World Resources Institute

EXECUTIVE SUMMARY

Green remediation, known as the incorporation of practices to reduce the environmental footprint of cleanup actions at contaminated sites, is a relatively new and growing field. Green remediation offers opportunities to reduce negative effects on the environment (such as greenhouse gas emission) that may occur from remediation activities at contaminated sites and to reduce associated consumption of natural resources such as energy and water. This report recommends an approach for assessing a site's ecosystem services (the benefits that humans derive from ecosystems) prior to site remediation as a means to qualitatively or quantitatively track ecosystem changes associated with cleanup activities and to identify opportunities for avoiding or mitigating a cleanup project's negative effect on the ecosystem.

Based on literature research and personal communications, the report presents background information on the concept of ecosystem services, as well as steps interested parties can take to mitigate or avoid impacts to ecosystem services at a site level throughout the remediation process. The report outlines replicable practices that remedial project managers can utilize when attempting to mitigate adverse impacts on an ecosystem. This report also describes the current state of data collection methods and issues pertinent to the ecosystem service assessment process, with the ultimate aim of fostering production of a replicable methodology that can lead to greener cleanups. The target audience includes remedial project managers, potentially responsible parties, regulators, operators, and other stakeholders with an interest in the remediation of contaminated sites

1. INTRODUCTION

The U.S. Environmental Protection Agency (EPA) Office of Solid Waste and Emergency Response (OSWER) works to preserve and restore land by promoting protective waste management practices and by assessing and cleaning up contaminated sites. The remediation of contaminated land protects human health and the environment and enables communities and other stakeholders to pursue future use or reuse of the land and its resources for economic, environmental, and societal purposes. The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the Resource Conservation and Recovery Act (RCRA) provide the legal authority for these actions. Cleanup projects are required to comply with a number of state and federal statutes as well. OSWER cleanup programs address contaminated soil, groundwater, surface water, sediments, air, and other environmental media. The cleanup programs in the United States can be broken down into seven market segments:

- Superfund, including cleanups on the National Priorities List (NPL)
- RCRA corrective actions
- Underground storage tanks
- U.S. Department of Defense (DOD)
- U.S. Department of Energy (DOE)
- Other federal agencies
- States and private parties (including brownfields)

All of these programs include common elements such as initial site assessment, site stabilization when needed to protect against imminent threats, site characterization, remedy evaluation and selection, implementation, and when applicable, long-term management (EPA, 2004).

1.1 Green Remediation

The remediation of contaminated waste sites is an action undertaken to protect human health and the environment; however, impacts from the cleanup process need to be taken into account, such as energy use, greenhouse gas emissions, and disruptions to the water cycle. Green remediation is the practice of considering all environmental effects of remediation and incorporating changes to remedial operations to minimize the environmental footprint of cleanup actions. Green remediation involves more than merely adopting a specific technology or technique; it is a compilation of practices that will help reduce negative impacts on the environment, therefore maximizing the environmental benefits of cleanup. There are key opportunities for green practices to be utilized during all phases of remediation, from site assessment to remedy implementation to long-term management. At each stage, as well as in the day-to-day management of onsite activities, there are opportunities to improve upon traditional remedial methods. However, since all sites are unique, project managers will need to take into account challenges and characteristics specific to the site and tailor their plans to achieve green remediation objectives. The EPA has identified five core elements of green remediation, which include energy, air, water, land and ecosystems, and materials and waste (EPA, 2008).

1.2 Report Overview

This report focuses on the land and ecosystems core element of green remediation, which fosters effective land management and ecosystem protection. Ecosystem services are the benefits that human populations derive from ecosystems. There is a growing recognition of the significance of ecosystem services as well as the dramatic impact human activities can have on these essential services. Identifying the services existing at a contaminated site prior to the remediation process is a necessary component of reducing negative affects that remediation may have. This type of assessment would provide project managers with the knowledge necessary to limit negative effects on ecosystems from remediation and daily activities at the site. An ecosystem services assessment would also develop a baseline that would assist project managers and stakeholders in the creation of a revitalization or reuse plan. This type of assessment, as well as other green remediation strategies, can be applied to each of the cleanup market segments. In a recent publication, the Science Advisory Board highly recommended the evaluation of ecosystem services and their contributions to human well-being from the earliest stages of remediation (EPA, 2009a).

This report compiles pertinent information that can be utilized to foster the development of a replicable methodology to identify and evaluate ecosystem services prior to remedial planning and cleanup of a contaminated site. Such a methodology will provide technical guidance to project managers and other cleanup program stakeholders on approaches to identify, map, and mitigate impacts to ecosystem services at a site level. The intended result is to prompt project managers to evaluate and revise their remedial operations, within the normal decision and review processes, in order to minimize remedial impacts on ecosystem services.

2. OVERVIEW OF ECOSYSTEM SERVICES

Ecosystems are dynamic, complex systems of plant, animal, and microorganism communities and the nonliving environment, interacting as functional units (Millennium, 2005a). An ecosystem involves physical, chemical, and biological activities that influence the flows, storage, and transformation of energy and materials through the environment. Through these functions and processes, ecosystems provide services that contribute to the well-being of human populations. “Ecosystem services are the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life. They maintain biodiversity and the production of ecosystem goods...” (Committee, 2005).

Ecosystem services can be categorized by how human populations benefit from them. Ecosystems provide services that human populations directly consume or from which they benefit, such as timber, water, and food. These services are often the most readily identifiable and can often be managed in a sustainable manner. In addition, ecosystems provide services from which humans indirectly benefit, also known as intermediate services. These services do not provide a direct good or opportunity to society; however they support ecological resources or maintain biological processes required by the ecosystem. Examples include services such as pollination, nutrient cycling, and climate regulation. Each ecosystem will provide a variety of both direct and indirect services. For example, a terrestrial forest ecosystem may provide services directly to human populations, such as recreation through hiking trails, medicinal and

genetic resources through native plant species, and raw materials from the sustainable production of lumber. In addition, it may also provide services such as climate regulation through carbon sequestration, water regulation, and the formation of soil, all from which humans benefit indirectly.

Humans have had dramatic impacts on the provision of ecosystem services. Impacts include such things as traditional air and water pollution, global warming, pervasiveness of invasive species, and land conversions. Contaminated sites are excellent examples of the profound impacts that humans have enacted on ecosystems. It is important to realize that changes in the quantity or quality of ecosystem services will affect human populations. Considering the vital role that ecosystem services play, even small-scale ecosystem changes occurring at contaminated sites can alter the current benefits and potential future benefits humans may derive from the regional environment. For example, if the remedy selected will involve heavy vehicular traffic, there is a potential for wide-scale soil compaction at the site. This compaction will reduce the soil's ability to absorb rainwater, thereby increasing runoff and soil erosion. This may result in a reduction in vegetation growth and subsequently wildlife habitat. Due to the high volume of traffic through the site, there is the potential that society may lose services such as erosion control, recreational opportunities, habitat for wildlife, aesthetics, and water regulation. Considering the fact that services are site-specific, all of these services may not be provided at every site, however this is an example of how one cleanup activity can have dramatic effects on a variety of ecosystem services.

If ecosystem services are taken into account prior to remediation, there is an opportunity that some of the site's services could be preserved and negative effects from remediation could be avoided or reduced. "Humans depend on ecosystem properties and on the network of interactions among organisms and within and among ecosystems for sustenance, just like all other species (Millennium, 2005a)." Contaminated waste sites extend from urban to rural settings and encompass ecosystems of all kinds including forests, estuaries, rivers, wetlands, grasslands, mountain ranges, and coastal areas. These sites have the potential to provide significant services to society and their value needs to be recognized prior to remediation. This report will assist in the assessment of contaminated site's ecosystem services and outline simple practices and techniques to help project managers circumvent these preventable impacts.

2.1 Millennium Ecosystem Assessment

When undertaking an ecosystem services assessment, project managers can choose whether to follow the Millennium Ecosystem Assessment (MEA) approach to ecosystem services or the final ecosystem services approach. The United Nations-sponsored MEA program breaks ecosystem services down into four categories: regulating, supporting, provisioning, and cultural services.

- Regulating and supporting services are often least recognized and appreciated by society. Regulating services are the benefits that humans obtain from the regulation of ecosystem processes. Examples include waste treatment, disturbance regulation, and climate regulation.

- Supporting services are those functions that are necessary for the production of all other services. Supporting services include nutrient cycling, pollination, soil formation, and habitat.
- Provisioning services are physical materials or products obtained from ecosystems. This includes things like fresh water, food derived from wild sources, and medicinal resources. Provisioning services are all services from which humans benefit from directly.
- Lastly, cultural services are the non-material or the intangible benefits humans receive from ecosystems. This includes recreational opportunities such as bird watching, hiking, and eco-tourism and religious, educational, and existence values (Millennium, 2005a).

See Table 1 for a comprehensive list of ecosystem services and the corresponding role that they hold in the ecosystem.

Table 1: Ecosystems Services in MEA Format
(Adapted from Millennium Ecosystem Assessment)

Ecosystem Service	Ecosystem Function	Examples
Regulating Services: benefits obtained from the regulation of ecosystem processes		
Gas regulation	Regulation of atmospheric chemical composition	Ozone for UVB protection, carbon dioxide and oxygen balance
Climate regulation	Regulation of favorable climatic conditions such as temperature and precipitation at local and global levels	Greenhouse gas regulation
Disturbance regulation	The ability of ecosystems to dampen impacts from environmental fluctuations	Storm protection, flood control, drought recovery and other aspects of environmental variability mainly controlled by vegetation structure
Water regulation	Regulation of hydrological flows	Timing and magnitude of water transportation, recharge and precipitation
Biological control	Trophic-dynamic regulations of populations	Predator control of prey species, pest and disease regulation
Erosion control and sediment retention	Retention of soil within an ecosystem	Prevention of loss of soil by wind, runoff, or other removal processes, landslide prevention
Waste treatment	The storage and recycling of nutrients through dilution, assimilation and chemical re-composition	Waste treatment, pollution control, detoxification
Supporting Services: functions necessary for the production of other ecosystem services		
Nutrient cycling	Storage, internal cycling, processing and acquisition of nutrients	Nitrogen fixation
Pollination	Animal-assisted pollen transfer between plants, without which many plants cannot reproduce	Native bees pollinate crops
Soil formation	Soil formation and fertility processes	Weathering of rock and the accumulation of organic material
Habitat	Habitat for resident and transient populations	Nurseries, habitat for migratory species, habitats for local plant and animal species
Provisioning Services: physical materials obtained from ecosystems		
Water supply	Storage and retention of water	Provisioning of water by watersheds, surface waters and aquifers
Food production	That portion of gross primary production extractable as food	Production of fish, game, wild foods
Raw materials	That portion of gross primary production extractable as raw materials	The production of lumber, fuel, fiber

Genetic resources	Sources of unique biological materials and products	Products for materials science, genes for resistance to pathogens and crop pests
Medicinal resources	Natural biota with a variety of medicinal uses	Drugs and pharmaceuticals derived for commercial or domestic use
Cultural Services: nonmaterial services rendered from ecosystems		
Recreation	Providing opportunities for recreational activities	Eco-tourism, sport fishing, bird watching, hiking
Aesthetic	Sensory enjoyment of the environment	Open space, scenic views
Science, Education	Use of natural areas for scientific and educational enhancement	Historical sites, field laboratories and experiments
Cultural, Spiritual, Religious	Value environment due to belief system	Religious and ceremonial sites, national symbols, heritage value
Existence	Value placed on a resource knowing it exists, even if no benefits are accumulated	Preservation of species, overall biodiversity

2.2 Final Ecosystem Services

The MEA’s categorization structure is helpful in understanding the numerous roles that ecosystem services play and the diversified benefits that they provide to human populations. This categorization conveys the idea that ecosystems are socially, economically, and environmentally valuable in ways that are not always intuitive. In contrast to MEA’s categorization, this report recommends that project managers take a slightly different approach and focus on final ecosystem services and selected intermediate services. The final services approach draws services from each of the four MEA categories described, however it only addresses services that are directly enjoyed, consumed, or used by society (Resources for the Future, 2006). Final ecosystem services can also be thought of as the end-products of nature. By focusing primarily on direct services, this approach simplifies the evaluation process and allows project managers to more readily identify ecosystem services and assess potential impacts from remedial actions. The recommended approach aims to assist project managers, the community, and other interested stakeholders in understanding the direct connection between the protection of ecosystem services and the preservation of human well being. Figure 1 represents an example of the final ecosystem services approach regarding the services that suitable soil and native vegetation provide and regulate. This is a simplified representation and does not emphasize the connections between the services themselves; however it clarifies the relationship between final ecosystem services and the benefits humans receive.

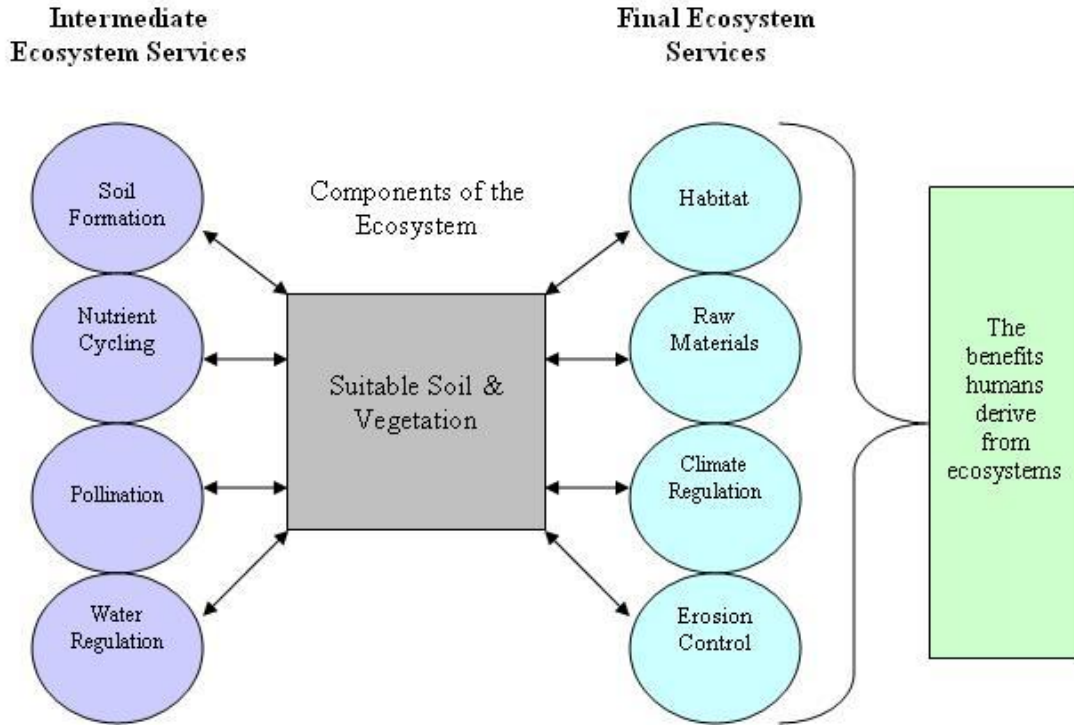


Figure 1: Final Ecosystem Services Regarding Soil and Vegetation

Final ecosystem services encompass disturbance regulation, water supply, food production, raw materials, genetic and medicinal resources, and cultural services.

2.2.1 Disturbance Regulation

Ecosystems alleviate the impacts from natural events such as hurricanes, floods, and droughts. For instance, coral reefs and mangrove forests act as buffers for waves and protect the coastline from storm damage. Vegetation can increase the soils absorption capacity, thereby reducing the potential for and intensity of flooding.

2.2.2 Water Supply

Water supply refers to the filtering, storage and retention of water in streams, lakes, aquifers, and watersheds. Soil and vegetation assist in the filtration process and the delivery of water to groundwater sources. This service refers to the water processes that support the consumption of water by households, industry, and agriculture.

2.2.3 Food Production

Food production refers to the provision of wild food sources such as fish, game, natural plants, and fungi. Forms of subsistence agriculture and aquaculture have been considered by some as part of this category. This does not include food derived from cultivated land or domesticated animals. Suitable habitat for vegetation and wildlife is necessary for the provision of most wild food sources.

2.2.4 Raw Materials

Raw materials include renewable sources of materials such as lumber, fuel, and fiber. These materials come from a variety of ecosystems and support the production of private and public goods.

2.2.5 Genetic and Medicinal Resources

Genetic resources refer to the use of natural materials for scientific purposes. The use of wild genes is essential for the productivity of cultivated plant species and the continuation of critical processes such as resistance to pathogens and deadly crop diseases. Natural vegetation is also used for a variety of medicinal processes such as in the production of pharmaceuticals derived for commercial use.

2.2.6 Cultural Services

Cultural services refer to the benefits humans derive from recreation, aesthetics, scientific, and cultural experiences with nature. Humans also place an existence value on the environment or value in knowing that a resource exists such as the preservation of species.

2.3 Intermediate Services Added to the Final Ecosystem Services Approach

In addition to final ecosystem services, project managers may be able to limit the negative effect of site cleanup activities on certain intermediate services. For the purpose of an ecosystem services assessment at a contaminated site, such intermediate services include: climate regulation, erosion control and sediment retention, waste treatment, and habitat,

2.3.1 Climate Regulation

The climate regulation service refers to the regulation of favorable climatic conditions such as temperature and precipitation at local and global levels. Vegetation as well as surface waters such as lakes and rivers assist in the moderation of climate as they sequester and release carbon dioxide.

2.3.2 Erosion Control and Sediment Retention

Erosion control is the reduction or prevention of soil loss due to wind, water runoff, and other removal processes. Soil retention is essential in the provision of other services such as water supply, raw materials, and disturbance and climate regulation. Suitable vegetative cover is often critical to the prevention of soil erosion because it increases soil infiltration capacity and reduces runoff.

2.3.3 Waste Treatment

Waste treatment refers to an ecosystem's ability to store and recycle organic and inorganic nutrients through dilution, assimilation, and chemical re-composition. Wetlands and other aquatic ecosystems play a key role in this process, acting similarly to water purification systems.

2.3.4 Habitat

As previously mentioned, humans often value the existence of animal species. The provision of available habitat is critical for the continued existence of local and transient animal populations. This includes regular habitat areas, as well as breeding and nursery areas (de Groot, 2002).

3. IMPLEMENTATION OF AN ECOSYSTEM SERVICES ASSESSMENT

In order to combat unnecessary negative impacts on ecosystems, it would be extremely beneficial to identify and evaluate ecosystem services at a site level, prior to, and throughout remedial planning and remedy implementation. In a recent publication, the EPA’s Science Advisory Board stated that, “in the traditional approach, the data collection for site characterization captures the degree and pattern of chemical contamination but does not collect information about the ecological condition of the site...” (EPA, 2009a). As a result, replicable steps need to be constructed for remedial project managers to utilize when undertaking an assessment of a site’s ecosystem services. A model methodology and assessment process is outlined below. An ecosystem services assessment includes four major steps:

1. Service identification
2. Site prioritization
3. Identification of impacts
4. Mitigation of impacts

The service identification and site prioritization phases should take place during site characterization or the initial stages of remedial planning, whereas impact identification and mitigation should take place during remedy evaluation and selection. This will allow for a data collection period and early assessment of the site’s services, which can be applied during the subsequent decision-making processes. Figure 2 illustrates when the ecosystem services assessment phases would occur during each standard remediation stage. According to the World Resources Institute (WRI) “identifying these (ecosystem services) up-front will enable decision makers to proactively manage any associated risk and opportunities” (WRI, 2008).

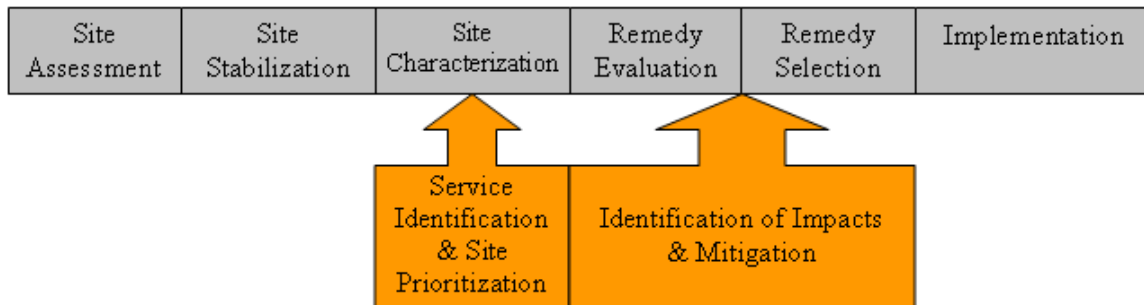


Figure 2: Ecosystem Service Assessment Placement

Evaluating the ecosystem and the services it provides prior to implementation may also present valuable insight and opportunities to project managers and the community. This information could be an invaluable tool to utilize during the creation of revitalization and reuse plans. It should be noted that revitalization refers to the process of returning land from a contaminated state to one that supports a functioning and sustainable habitat, whereas reuse refers to the outcome of the cleanup process where measures have been implemented to create, restore, protect, or enhance the site. Reuse can result in the creation of parks, playgrounds, and low-impact recreational opportunities such as hiking and bird watching (EPA, 2009b). If ecosystem

services are identified prior to the remediation process, project managers will be aware of and can use the existing services as a starting point in these plans.

It must be stressed that in no way should an ecosystem services assessment degrade the level of cleanup necessary to protect human health and the environment. Information collected while assessing ecosystem services should not be used to compromise the protectiveness of the cleanup. There are a variety of opportunities to reduce negative impacts on services while maintaining a high remediation standard. For example, at the Myers Property Superfund Site, the existing ecosystem was taken into account while maintaining a necessary level of remediation. This seven-acre site is located in a rural, residential area of western New Jersey and had contaminated soil, buildings, and shallow groundwater. The site runs adjacent to a creek used for recreational fishing and contains a wetland area with trails for the local community. Keeping this information in mind, project managers chose to remove the contaminated soil and sediments surrounding the tree roots through hand digging. This process allowed approximately 30 trees to remain in place throughout the wetland area (Vaughn, Personal Communication, 2010). As a result, the local community continued to benefit from services such as better aesthetics, climate regulation, erosion control, and habitat for local wildlife and vegetation. Not only was this remedy protective of the site's ecosystem, it also offered the shortest remediation timeframe.

3.1 Service Identification

To partake in an ecosystem services assessment, the first step is to identify what services the site provides. Currently, the best method to approach this would be to utilize a comprehensive list of ecosystem services. (See example in Table 1.) Only a subset of the services on the overall list will apply to any one site. As a result, it will be necessary to methodically evaluate the list and ascertain which services apply. Depending on how large the site is, service identification may be relatively simple or intricately complex. This is why it is helpful to primarily focus on final ecosystem services. It would become difficult to assess the elaborate ecosystem components which support ecosystem services such as nutrient cycling and gas regulation. It may also be helpful to garner support from an ecologist or other applicable parties during this phase to reduce uncertainty and hasten the process.

Another way to approach service identification would be to initially define the type of ecosystem involved. When the type of ecosystem is identified, it may help narrow down the applicable services that need to be considered. For example, a drylands or desert ecosystem will probably not provide an ecosystem service such as erosion control. When taking this type of approach, project managers should be aware that ecosystem services are site-specific. Although it would be unlikely to find sources of erosion control in a desert ecosystem, it is not impossible. This type of approach should be used as guidance only, not a comprehensive solution. It is also important to note that the site may contain different types of ecosystems. Project managers can delineate the site on those ecosystem lines and assess the areas individually. The development of a tool that would assist in the process would be extremely helpful. Table 2 provides an example of what this type of tool may look like and address. It is a tool that can be used as an initial gauge for what services may be at a site and can be utilized for final and intermediate service identification, depending on the project's needs. The chart is broken down into MEA's four service categories, which is represented by the varying color scale. The cultural services section of the table is listed

as potentially provided by each ecosystem, since they are often determined by individual preferences.

Table 2: Ecosystem Services Defined by Ecosystem
 Adapted from WRI's *Ecosystem Services: A Guide for Decision Makers*

		Marine	Coastal	Wetlands	Inland Water	Forest and Woodlands	Grasslands and Drylands	Mountain	Urban
Regulating Services	Gas regulation								
	Climate regulation								
	Disturbance regulation								
	Water regulation								
	Biological control								
	Erosion control								
	Waste treatment								
Supporting Services	Nutrient cycling								
	Pollination								
	Soil formation								
	Habitat								
Provisioning Services	Water supply								
	Food production								
	Raw materials								
	Genetic resources								
	Medicinal resources								
Cultural Services	Recreation								
	Aesthetic								
	Science, education								
	Cultural, Spiritual, Religious								
	Existence								

Since this assessment strictly deals with contaminated sites, it is very likely that project managers will come across services that have been contaminated or degraded due to the history of the site. However, these services should still be identified and kept in consideration. There is

the potential that these services could be addressed during the remediation process and their contributions to human well being can be restored.

In the future, specific consideration should be given to the applicability of this type of assessment at contaminated sites in urban settings. As shown in Table 2, there are a limited number of ecosystem services potentially provided by urban environments. This may not always be the case so a site-by-site consideration will be needed to determine whether or not to undertake a complete ecosystem services assessment. If project managers carrying out this identification phase do not identify any onsite services, they do not need to continue the assessment. In that situation, the site would benefit from a revitalization plan in order to restore the natural environment. On the other hand, if the urban site does provide services, the project managers can continue the assessment as planned.

3.2 Setting Site Priorities

Once the site's ecosystem services are identified, decision makers can begin prioritizing the services. Since there may be a multitude of services provided by one site, it may not be possible to evaluate and mitigate negative remedial affects on each service due to circumstantial constraints such as lack of time or funding. This may especially be the situation at a larger site or a site that encompasses multiple ecosystem types. If this is the case, decisions will need to be made to determine which services are priorities to preserve or which require reduced impacts. This phase will involve evaluating the identified services and determining if they are relevant to the remediation process or to the community. Figure 3 is a simplified representation of the relationship between site priorities and services provided by the site. The site's priorities will be a subset of all the services provided by a specific site, which in turn are a subset of all possible ecosystem services. At this point, it may be beneficial to separate services that are intact from services which have been degraded from contamination. If the degraded service is being remediated during the cleanup process, it is a site priority and will not need to be separately addressed during this phase.



Figure 3: Service Identification and Prioritization

This is an area of the assessment process in which project managers can decide how comprehensive an assessment they want to complete and how accurately they measure the

condition of the site's services. Specific questions and conditions to consider when setting site priorities include:

- **Scarcity:** Is the service in short supply relative to demand? What are the quantity and the quality of the service? Would the impact push the service across a threshold that leads to a shortage in production? If a service is degraded or has low production levels naturally, then even a mild impact may result in a dramatic decrease in the service's ability to continue functioning. For example, if the site houses an endangered species, it would be necessary to mitigate impacts to any applicable habitat since there is a limited number of the species left.
- **Vulnerability:** How sensitive is the service to a disturbance? Is the production of the service likely to be affected in a minor or serious manner? For instance, if the site contains a grove of young trees, they may be providing services such as erosion control and habitat. However, since they are young, their ability to withstand disturbance will not be as effective as a grove of mature trees with stronger root structures.
- **Substitutes:** Are there any other areas or ecosystems in the region that provide the service? Are there any man-made substitutes? "A substitute for an ecosystem service could include a manufactured product or physical structure that provides a similar service" (WRI, 2008). For example, in the early 1990s New York City debated whether to install a water filtration plant or take further measures to protect the watershed from which the City receives 1.3 billion gallons of drinking water per day. This may not always be the case, but the City found it was more cost effective to protect the ecosystem instead of constructing the man-made substitute. The WRI states that regulating and cultural services are more likely to be site specific so substitutes are not likely to be found; whereas provisioning services such as raw materials or food production are more likely to have substitutes.
- **Reversibility:** If the service is impacted, will the environment be able to naturally restore itself? For example, if site vegetation is going to be removed, will vegetation grow back? Will habitable soil remain? Or is this a service that will be addressed during the revitalization process? Will plans be put in place that once remediation is completed, the environment will be restored? At the Barker Chemical Site, project managers graded and reseeded native vegetation in order to stabilize and revitalize the land after remediation, as shown in Figure 4.



Figure 4: Reseeding the Barker Chemical Site

These suggested considerations may provide guidance and assist project managers in making difficult decisions. Setting of site priorities can also be done in terms of trade-offs. When looking at it from this perspective, a manager assesses what can be gained by protecting one service versus what would be lost by not protecting a different service (WRI, 2008). Project managers can evaluate what sectors of the community or ecosystem will benefit from the provision of a service and what sectors will lose out from the decrease of another service. Again, this process may be relatively easy if there are a limited number of services provided, although this is not always the case. If these considerations have not aided the decision-making process, then project

managers can move on to other tools such as community involvement and economic valuation to assist in setting site priorities.

3.2.1 Community Involvement

One method for setting site-specific priorities for ecosystem service assessment is the solicitation of community involvement. Ecosystem service priorities will often vary according to user. For instance, community members, local businesses, and indigenous populations may all value different services that the site provides or they may all value the same services but for different reasons. Depending on the level of community involvement in the remediation process, this would be an appropriate time to garner their input on what ecosystem services are significant to them. Recognition of the ecosystem services that are most valuable to the local or regional community may provide considerable insight and assist in the process of setting site priorities for ecosystem services, as well as the remedy selection and revitalization processes.

Input can be garnered from the surrounding community through small group deliberation on the necessity of each service to the general public. In this way, project managers cannot only hear what the community's priorities are but also the reasons behind their opinions. "The purpose of deliberation is to 'reach agreement on what should be done by or on the behalf of society as a whole' (Farber, 2002)." This type of involvement will provide project managers with a more complete picture of the values that the local populations derive from the ecosystems services.

3.2.2 Economic Valuation

Another method for prioritizing ecosystem services is economic valuation of the services. Market and non-market valuation methods could be utilized in an attempt to allocate quantitative values to ecosystem services. The results of this type of assessment can draw attention to the value of ecosystem services as if they were traded in markets. Economic valuation attempts to apply a monetary value to services, in order to provide a common measurement for comparison. Some services such as food production and raw materials are physically traded in markets, so economic valuation for these services will be more readily available. However, other services such as pollination and erosion control can be extremely difficult to value. Nevertheless, their valuation is equally important if not more since their critical role is often overlooked.

Many valuation techniques are founded on the ideas of willingness to pay or willingness to accept (Farber, 2002). Willingness to pay is based upon how much people are willing to spend to preserve a resource. In contrast, willingness to accept is based upon how much people would need to be paid in order to accept a change in the condition of the resource. These measures may seem similar but they are usually used in different circumstances. Willingness to pay is often utilized when society does not own the resource or control access to the service. Willingness to pay is also used to measure increases in ecosystem quality, whereas willingness to accept is used when measuring decreases in ecosystem quality. Willingness to accept is also utilized when society does own access to the resource; however, these estimates tend to be higher than data collected using the willingness to pay approach, so this technique is used less often.

Based on existing literature regarding commonly accepted methods for economic valuation, several techniques could apply to ecological services at sites undergoing cleanup (Table 3).

Table 3: Economic Valuation Methods

Method	Background	Examples of Applicable Services
Benefits transfer	Uses estimations of benefits obtained from a service in one context, to estimate values of service in a different context or site.	Recreation, disturbance regulation, aesthetics, water supply
Choice modeling	A survey approach in which respondents are asked to choose their preferred option for a set of alternative scenarios.	Habitat, recreation, raw materials, biological control, climate and gas regulation, water supply
Contingent valuation	Hypothetical scenarios are posed to the public which involve some valuation of alternatives. Their responses are elicited based on their willingness to pay for each alternative scenario.	Climate and gas regulation, erosion control, disturbance regulation, existence value, water supply
Travel cost	For society to utilize a service, it may require travel. The service is valued based on society's willingness to pay to utilize the resource.	Recreation, aesthetics, medicinal and genetic resources, cultural/religious, science/education
Replacement cost	Services may be replaced by a manufactured product or physical structure. The cost to produce the man-made substitute represents the value of the service provided.	Can only be utilized when replacement options exist - water supply, waste treatment, disturbance regulation, science/educational opportunities
Avoided cost	When services are functioning properly, it allows society to avoid certain costs. The service is valued based on this cost.	Disturbance regulation, waste treatment, biological control
Factor income	Values services based on their impact and enhancement of salaries. For example, commercial fisheries will have an increased catch and therefore income when there are available services such as fish habitat and clean water.	Recreation, aesthetic, science/education, medicinal and genetic resources, raw materials, food production, water supply, habitat, pollination
Hedonic pricing	The value of a service is derived from its presence/effect on market-priced goods. For example, aesthetic values can be derived from the real estate market by comparing similar properties with and without good views.	Aesthetics, water supply, waste treatment
Conjoint evaluation	The public is asked to make choices between alternative scenarios with different attributes and prices, in order to derive the marginal value of a service instead of the total value.	Climate, water and gas regulation, disturbance regulation, habitat, pollination

Each of these methods has been subject to various levels of scrutiny and has its own set of strengths and weakness. An applicable valuation method may not exist in some scenarios but multiple options for valuation may exist in other cases. Economic valuation can help develop a more tangible representation of the contributions that ecosystems services provide to human well-being and may provide guidance in setting site priorities.

3.3 Identification of Impacts

The next step in assessing ecosystem services at contaminated sites is to identify potential impacts of cleanup on the prioritized services; the impacts broadly encompass:

1. Any impacts from the remedy implementation phase of a cleanup, such as removal of onsite vegetation in order to treat contaminated media below ground surface.
2. The impacts from day-to-day activities taking place on and around the site, such as operating heavy vehicles or using sanitation facilities.

Impacts on ecosystem services are any actions that alter the quality and/or quantity of a service (WRI, 2008). For instance, returning to the example of heavy vehicle use and soil compaction, if this did occur the vehicles would cause a decrease in suitable habitat for vegetation. This is an alteration of the quantity of a service produced. This soil compaction may also result in an increase in runoff, due to a decrease in the infiltration capacity of the soil. This runoff can carry particles of sediment and organic matter into nearby surface water, and the resulting particles will decrease water quality. In this example, the use of vehicles throughout the site results in quality and quantity impacts on ecosystem services. However, this may not always be the case; an impact may result in changes of either quality or quantity but not both.

This example highlights another important aspect of this assessment that project managers must keep in mind. Ecosystems are complex and intricate interacting systems. One single action may have an obvious direct impact on the ecosystem; however, it may also have one or more not-so-obvious indirect effects. Again returning to the earlier discussion example, the direct impact of heavy site traffic is the compaction of soil. In contrast, the indirect effects are the soil erosion, runoff, and potential decreases in water quality. It can be difficult to correctly identify and address indirect impacts because the relationships between ecosystem functions can be difficult to discern. If the project manager wishes to conduct a more in-depth assessment and evaluate the indirect impacts more completely, this might be another step in which it would be beneficial to garner input from an ecologist or similar specialist.

Another aspect to consider is the probability that an identified impact will occur. For instance, the farther away a body of water is to a contaminated site, the lower the probability is that any action will affect the water supply. When the probability of occurrence cannot be identified or is difficult to ascertain, it is best to err on the side of caution and assume that impacts will occur.

3.3.1 Services Impacting One Another

As previously mentioned, ecosystems are complex systems and cannot be viewed as independent, operating parts. The use or degradation of one ecosystem service may influence the availability or the functionality of other ecosystem services at the site. For example, increasing the use of raw materials such as timber may decrease the provision of other services such as local climate regulation and habitat. Some of the occurrences where one service is impacting the provision of another may overlap with previously discussed indirect impacts. However, this can be a different way to assess the situation and may uncover impacts that were previously missed.

This can often make the identification and evaluation process even more complex. Nonetheless, this consideration is essential to completing a realistic assessment of ecosystem services.

3.3.2 Evaluation of Impacts on the Provision of Services

The important question to ask in this part of the services assessment is: what are the relationships between the identified impacts and the provision of ecosystem services? Project managers will need to determine if impacts are anticipated to be negative, neutral, or positive. Impacts should be considered negative if they decrease the available quality or quantity of a service. A neutral impact may affect how the service is produced, but it will not affect the rate of production. For example, at the French Limited Superfund Site in Crosby, Texas, project managers reduced the food supply to local animal populations of alligators and beavers in the remediation area and increased their food supply in other more suitable areas that would not be disrupted during the remediation process. In this case, the animals were affected because they were moved out of their initial habitat; however, they were relocated to an area where they could find appropriate habitat and food sources.

Positive impacts will also occur. Throughout a remediation project, the removal of contaminated waste will result in cleaner soil, water, and/or air, which will positively impact the provision of ecosystem services. This may be another opportunity to consider revitalization and reuse plans. When positive impacts are identified during this process, revitalization plans could be created to continue to build on these benefits.

3.4 Mitigation of Impacts

In the fourth (and final) step of ecosystem services assessment at contaminated sites, project managers may identify lines of action to avoid the negative affects altogether or at minimum mitigate the effects on provision of services. If multiple remedial options are available, project managers have the opportunity to consider the results of the ecosystem services assessment during the remedy selection process (EPA, 2009c).

The focus of green remediation strategies, however, is not remedy selection. A primary objective of green remediation strategies is to construct and operate remedial treatment systems in ways that limit negative impacts on the environment. Reduction of these impacts broadly involves investigating how the necessary treatment technologies can operate while causing minimal harm to ecosystems and how day-to-day activities can be adjusted to additionally reduce negative effects on ecosystems and their services. Specific practices to minimize ecological damage are described in the following section of this report. The process of documenting results derived from the described practices, and additional practices identified as the use of ecosystem service assessment in greener cleanups increases, is anticipated to lead to a replicable model for ecosystem protection during cleanup.

3.5 Practices to Minimize Ecological Damage

Various levels of an ecosystem services assessment can be completed depending on available time, funding, and expertise. If a complete assessment is not applicable or there is limited

flexibility in the remedy selection, there is a variety of actions that can be incorporated into any site cleanup to minimize the damage inflicted upon ecosystems. The following practices are outlined in EPA's "Ecological Revitalization: Turning Contaminated Properties into Community Assets" (EPA, 2009b).

- **Establish work zones and traffic plans:** Designating specific areas where site traffic is and is not allowed through the utilization of a traffic plan will reduce impacts on ecosystem services, as described previously for soil compaction. As illustrated in Figure 5, project managers can also construct compacted roadways restricting traffic to certain areas in order to facilitate transportation and reduce erosion. Plans should be made not only for onsite traffic but also for designating areas where site workers can and cannot utilize equipment. This will minimize unnecessary disruptions to sensitive areas and existing habitat.



Figure 5: Roadway at Barker Chemical Site

- **Minimize excavation and retain existing vegetation:** Large-scale, onsite excavations can disrupt roots of trees or other vegetation, affect uncontaminated soil, and disturb wildlife. Excavation should be minimized and the utilization of in situ technologies should be encouraged, as long as they retain the necessary level of remedy protectiveness.
- **Phase the site work:** Project managers can create remediation plans in which they phase site work. Phasing site work involves remediating one area at a time and ensuring that the area is stabilized before disrupting another. This practice can reduce erosion by allowing revegetation to occur as soon as possible. Site work can also be planned around seasons with frequent, heavy rain in order to avoid substantial erosion. Another issue to consider when constructing site work plans are local animal populations and any susceptible periods, such as nesting or breeding seasons for certain species.
- **Properly store contaminated waste and soil:** During the remediation process, excess waste or soil may need to be stored prior to or after treatment onsite. These storage areas should be located away from slopes, wetlands, surface water bodies, and other sensitive areas to avoid contamination from runoff. Further steps can be taken such as placing a medium between the

storage piles and clean soil or constructing an overhang or utilizing a cover to reduce water infiltration and runoff.

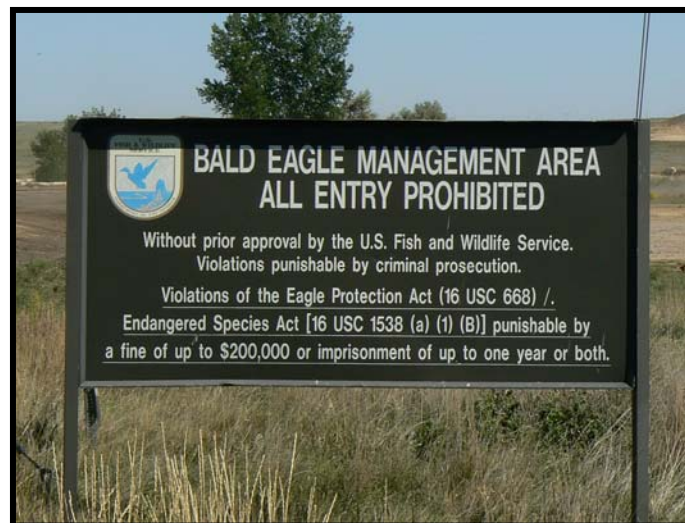
- **Reuse indigenous materials whenever practical:** If needed, onsite materials, such as rocks, brush, felled trees, and roots can be reused at the site, sometimes offering a cost savings. These materials can be used to create new habitats, reduce erosion, or serve as soil amendments.
- **Avoid introducing new sources of contamination:** Cleanup activities may introduce additional sources of contamination to the site if involved parties are not aware of the dangers. Sources of further contamination can come from sanitation facilities, fertilizers, pesticides, petroleum products, and solid wastes Project managers should also avoid the introduction of non-native plant and animal species that can invade a site and destroy existing vegetation and populations.
- **Develop and communicate ecology awareness:** When taking an ecosystem services approach, project managers should inform the full remediation work team, including field contractors, construction leaders, and community involvement coordinators. These communications will provide a site-wide standard and allow project managers to gather support and ideas from other involved parties. During this process, project managers should inform the involved parties of actions to be taken, such as establishing work-zone traffic plans, to increase awareness and participation.

These types of practices can be used at a variety of sites to reduce impacts on ecosystems and their services. The Rocky Mountain Arsenal site, a 27-acre project in Colorado, is an excellent example of the utilization of impact minimization techniques. Site-wide traffic and work plans were put in place to reduce disruption of sensitive areas and existing habitat and to minimize soil erosion and disturbance. A permit system was also established, which monitored activities ongoing at the site to assess if any activities were in conflict with each other. For example, borrow areas were utilized to provide

Figure 6: Borrow Areas Inhabited by Swallows



Figure 7: Bald Eagle Management Area



clean backfill where contaminated soils had been removed. As shown in Figure 6, cliff swallows settled in the excavated face of one of the borrow areas; as a result, work was halted until the swallows migrated to another area. In addition, remediation and construction activities were restricted during a period of the year to avoid sensitive nesting and breeding times in order to reduce disruptions to an on-site bald eagle management area (as shown in Figure 7).

Site managers adopted an awareness of the environment while planning and implementing the cleanup, phasing the site work in 88 stages. Minimally invasive remediation techniques were also selected. Excavation occurred up to the drip line (the outer circumference of tree branches) to allow existing trees to remain intact (Williams, Personal Communication, 2010). The site was remediated in a way that minimized adverse impacts on the existing natural systems while keeping the standard of cleanup necessary to protect human health and the environment.

Whether project managers conduct a thorough step-by-step ecosystem services assessment or follow applicable minimization techniques, their actions will often positively influence the remediation and redevelopment process, potentially leading to improved environmental outcomes of a site cleanup.

4. DATA COLLECTION

An ecosystem services assessment can be conducted in a qualitative or quantitative manner. The approach presented in this report focuses on qualitative results, i.e., the site's services remedial impacts, and mitigation measures are evaluated, however there is no quantitative evaluation of the services. Quantitative evaluations can provide a more detailed and accurate assessment of site conditions.

Project managers can undertake a thorough quantitative assessment whenever the necessary funds and time are available. Interested project managers can use quantitative measures available in existing models, as well as laboratory and field studies. Since multiple ecosystem services will likely be provided at a single site, project managers need to utilize a variety of data collection techniques that can address different methods and scales for service assessment. Applicable data sources include the environmental indicators, remote sensing techniques, and local knowledge. Data from other assessment procedures has the potential to become a useful assessment tool that can expedite an ecosystem services assessment, as described in Figure 8.

Ecological risk assessments (ERA) evaluate the likelihood that adverse ecological effects will occur due to hazardous contaminants at a site. Since ERAs usually only require basic information about the site's ecosystem, they will not be particularly helpful in assessing ecosystem services. However, if generic ecosystem service endpoints (ecological entities & their characteristics) were developed, they could assist the ERA and Natural Resource Damage Assessment (NRDA) processes, as well as facilitate an ecosystem service site assessment (Murns 2009). NRDA's are not conducted on every contaminated site; however they estimate the value of lost resources due to contamination and remediation. If NRDA's are completed then there is the potential that project managers can pull data from them regarding the site's ecosystem and the services it provides. If generic endpoints were developed and employed or NRDA's were utilized for data, they could become excellent data collection tools to utilize during an assessment of ecosystem services.

Figure 8: Potential for Utilizing Assessment Data

Models are simplified representations that can simulate the dynamics of interacting plant and animal species as well as other physical and biological ecosystem processes. They can be applied at the site, regional, or global level. There are models that can assess watershed hydrology, population, climate, ecosystem processes, food webs, and entire terrestrial ecosystems, which may be applicable to evaluating the ecosystem services at a site (Millennium, 2005b). Models can be particularly useful when attempting to assess services such as nutrient cycling, pollination, and gas and water regulation, which indirectly benefit humans.

Laboratory studies on ecosystems services and their responses to various impacts can be informative on response mechanisms and temporal scales. Conditions can be controlled in laboratory studies to allow for assessment of specific actions and associated responses. However, since laboratory studies provide a controlled environment, the wide range of responses and functions of an ecosystem may not be replicated. This concern is reduced when completing field observational studies from which ecologists observe ecosystem functions and processes in relation to disturbances. This poses another complication because multiple variables are in place, making it difficult to make a direct correlation between the disturbances and the ecosystem fluctuations. Laboratory studies and field studies can be excellent sources of information; however, their use may be limited by time or funding. In general, there will likely be applicable studies already completed from which data and information can be extracted to inform project managers interested in a more detailed assessment.

Indicators are defined as “something that provides a clue to a matter of larger significance or makes perceptible a trend or phenomenon that is not immediately detectable” (King, 1997). Environmental indicators could potentially become a helpful tool when assessing ecosystems and the condition of services. Indicators take a quantifiable measurement of the environment, which represents the overall condition of the ecosystem or a specific service. For example, mean temperatures and carbon dioxide concentrations are now accepted as indicators for climate change. It is important to choose indicators that can be measured quantifiably and represent the true condition of the ecosystem service. For example, wildlife population data will be informative when identifying habitats on the site and water-quality sampling will provide information on erosion control capabilities and the availability of clean water. These methods would benefit from further development and standardization but can apply to an assessment of ecosystem services.

Remote sensing and geographic information systems (GIS) can also be utilized to identify ecosystem services and assess their conditions. Ground-based mapping and sensing surveys can be informative for identifying biophysical characteristics of the site, although it is important to keep in mind that this type of technique will best apply to smaller sites. At larger sites, it may be more beneficial to utilize remote sensing techniques, which can be conducted by aircraft, satellite, or ship. Remote sensing data can be utilized to assess current ecosystem conditions and if gathered repeatedly can help evaluate changes or trends in ecosystem condition over time. This technique may also benefit from combined ground-based and remote sensing data used to interpret site conditions and fill any information gaps. Models can also be combined with the remote sensing data to assess factors potentially influencing ecosystem service production, such as evapotranspiration, primary productivity, and species distribution (Millennium, 2005b).

GIS can allow for the assessment of various data sets on the same spatial scale. GIS have been utilized in the past to assess humans' impacts on ecosystems but also can provide information on factors such as roads, land use, and human population densities to assess their relation to ecosystem health. For example, a map could be created to compare areas of vegetation to wildlife habitat in order to highlight areas where disruption should be avoided. Information could potentially be pulled from these types of assessments and applied to site evaluations. GIS also has been used at a site level to assess and compare data collected on contaminated ground and surface water and soils (Gustavson, Personal Communication, 2010). Utilizing GIS for this type of application could be coupled with an assessment of the site's ecosystem and services in order to benefit the overall remediation project.

Local or indigenous knowledge and expertise regarding the existence and condition of particular ecosystem services may also be extremely helpful and can often times be an excellent resource. As previously mentioned, the surrounding community may provide critical insight by informing project managers about site conditions in addition to providing feedback on site priorities. Community involvement in the initial identification phases of an ecosystem services assessment would establish greater community understanding and foster a feeling of involvement, which would be beneficial during the selection of site priorities. It is important to note that local knowledge should be supplemented by other sources of data, to ensure that a complete and accurate evaluation of the site is made. A variety of methods is available to involve the community and collect data through their participation, such as town hall style meetings, surveys, and participatory rural appraisal (PRA). PRA can be done through interviews, mapping, measuring, analysis, and planning conducted jointly with the local community (Millennium, 2005b). Limitations for using this type of data collection in an ecosystem service assessment are discussed in the following section.

5. ISSUES and CONCERNS

Depending on the level of assessment, evaluating ecosystem services can be a difficult and time consuming process due to the complexity of ecosystem services and limited availability of data. Problems can arise when carrying out community involvement plans and economic valuations.

Knowledge about the intricate processes and connections between various components may be limited and uncertain. There is variability in how ecosystems function, which may make it difficult to predict how remedial actions will impact the provision of ecosystem services. In addition, a number of services will be more readily identifiable compared to others. For instance, the identification of wildlife habitat will most likely be a relatively easy process compared with the identification of ecosystem components which provide services such as gas regulation and nutrient cycling. Services that are more difficult to identify include soil formation, pollination, biological control, and the previously mentioned gas regulation and nutrient cycling. Since these services are considered to benefit human populations indirectly, project managers choosing to follow the approach described in this report may not be concerned with these complexities.

Another factor to consider is that services could be provided on varying temporal scales. Production of a service such as disturbance regulation may take place year round. In contrast,

other services such as the production of certain raw materials or genetic resources may be limited to a certain season. This complication may make it difficult to identify services if the identification phase of the assessment takes place during a service's off season. As a result, certain services could be overlooked and unintended impacts may occur. Varying temporal scales may also affect how accurately impacts are assessed. Certain services may respond to disturbances on different time scales, so it is important to assess long-term as well as immediate implications.

Data sources and methods of assessment for ecosystem services are unevenly distributed and vary among the types of ecosystems and services in question. When necessary information and data are hard to obtain, uniform assessment of site services can be difficult. In a number of studies, certain services and ecosystems have been evaluated multiple times. For example, multiple studies show the human benefits derived from wetland and forest ecosystems (Bridgespan Group, 2009). In terms of specific services, most research has focused on provisioning services because those services directly link to economic functions. This approach does not capture supporting or regulating services such as soil formation and biological control. One exception is the recent increase in research on climate regulation due to concerns of global climate change. Without equivalent knowledge of all the ecosystem services available at a site, the potential exists for unwanted or unknown trade-offs and missed opportunities. As the use of ecosystem service assessment expands, increased academic and government research may alleviate this concern.

Community involvement and economic valuation can be extremely helpful tools; however both come with their own set of limitations. Issues regarding community participation may stem from a lack of background knowledge on the concept of ecosystem services. When tapping into the local community to garner their input, it is critical to take the time to explain exactly what ecosystem services are in order to avoid skewed perceptions. Similarly, project managers need to follow up on any information provided by the local community and recognize that information gathered during a community involvement event may reflect priorities of individuals rather than the actual site conditions.

There are concerns over the use of market and non-market economic valuation techniques as well. Valuation techniques that utilize market data for services such as timber and other raw materials usually do not represent the total value of that service. The market price represents a tree's utilization as timber but does not represent other services provided by the tree, such as erosion control and habitat. Market data can also be affected when government agencies control or raise the price of certain goods, consequently changing their market value. In this case, calculation of the service's value should be based on the service's initial, actual value instead of the altered market value. Several non-market valuation techniques involve community surveys to determine local values placed on a service; this approach can be subject to bias if not carefully applied. Related uncertainties may decrease in the future as practices become more standardized.

6. CONCLUSIONS

The introduction of an ecosystem services assessment into the remediation process at contaminated sites is a relatively new concept. The assessment can be used as an effective means

to implement green remediation strategies aimed at reducing negative environmental effects caused by remediation activities and consequently improve the outcome of a cleanup. Specific cleanups mentioned in this report such as those conducted at Rocky Mountain Arsenal and the Myers Property Superfund Site have not completed an ecosystem services assessment using the process described here, although steps were taken to alleviate negative effects on the ecosystems and essential services that they provide. Greater opportunities may be identified if project managers evaluate ecosystem services earlier in the implementation of remediation projects.

This report was constructed with the intent of fostering the development of a replicable ecosystem services assessment process that can track ecosystem changes as cleanup progresses. Further research is needed to evaluate ecosystem dynamics in order to reduce uncertainty of this type of assessment, specifically when identifying potential impacts and their effects on the provision of ecosystem services. Advancement of ecosystem services assessment would benefit from a series of pilot projects focused on developing a standardized approach and facilitating related data gathering and research on the intricate functions of ecosystem services. Pilot projects should be carried out on a variety of ecosystems and study every final ecosystem service and selected intermediate services suggested in this report.

Techniques outlined in this approach can also facilitate the use of existing site conditions as a baseline for revitalization and reuse plans. In addition, OSWER could potentially utilize results from ecosystem service assessments conducted across the nation to monitor and record the environmental benefits accumulated from remediation and revitalization of the nation's contaminated waste sites.

It is important to keep in mind that every remediated site has the potential to provide increased benefits to society. A recent study on biodiversity and ecosystem services found that ecological restoration increased the provision of ecosystem services by 25% (Benayas, 2009). In summary, by conserving existing ecosystem services from harm during the implementation of remediation projects, we retain their benefits and avoid the costs of restoration. A replicable ecosystem assessment process will be a valuable tool in achieving that objective

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