Reusing Cleaned Up Superfund Sites:

Ecological Use Where Waste is Left on Site




On the Cover

Top left
Wetlands created at the Bowers Landfill Superfund site in Pickaway, Ohio provide habitat for plants and wildlife.

Top Right
Post-treatment hillsides environment in the Hillsides area of the Bunker Hill Superfund site in Kellogg, Idaho. A mixture of biosolids and ash was successful in helping revegetate the area to reduce sedimentation and provide a healthy wildlife habitat for elk and other native species.

Bottom left
A meadow provides habitat for plants, birds, and mammals at the Army Creek Landfill Superfund site in Newcastle County, Delaware.

Bottom right
Aerial view of the Northwest 58th Street Landfill Superfund site along the eastern edge of the Everglades wetlands in Dade County, Florida.

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

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Preface

As of December 2005, about 460 cleaned up Superfund sites have been returned to beneficial use. At least 56 are being used primarily for ecological purposes, such as wildlife habitats. Many of the other approximately 404 sites, which were redeveloped for commercial, industrial, or other uses, also contain significant ecological areas. A large number of other Superfund sites, including certain non-time-critical removal sites, and contaminated sites in other cleanup programs, have potential for similar uses after they are cleaned up. The U. S. Environmental Protection Agency (EPA), through the Superfund Redevelopment Program, encourages the beneficial reuse of Superfund sites, while working towards EPA's overriding objective for all sites—to ensure protection of human health and the environment. 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 human health and the environment. Ecosystems are essential to all aspects of human existence and their value in urban, suburban, and rural areas is often not fully recognized when decisions are made about land use.

This report provides technical information useful in planning, designing, and implementing remediation and reuse projects at sites that are to include ecological reuse. It is especially useful for sites where the remedy calls for on-site containment or treatment of contaminants and contaminated materials or post-construction monitoring or treatment. This information may be useful to remediation planners and managers when considering how the remedy and reuse options may affect each other during various stages of EPA's processes for managing NPL sites and non-time-critical removal actions. The document may also be useful to communities, potentially responsible parties (PRPs), Trustees, and other stakeholders planning for the reuse of Superfund sites in coordinating with the cleanup team during all stages of the cleanup process.

Close coordination with reuse and remediation personnel will help in identifying acceptable reuse scenarios that will not hinder the protectiveness of the remedy, sharing information about local ecosystems and contamination, and identifying, selecting, and implementing remediation approaches that will allow the anticipated reuse. The report draws from experiences at completed and current reuse projects, EPA technical guidance, and other sources to describe ecosystem characteristics and remediation approaches that have been used to accommodate ecological uses at Superfund sites where contaminated material has been left on site.

This document is intended for information purposes only, and does not create new or alter existing Agency policy or guidance. It is one of a series of planning reports being developed under EPA's Superfund Redevelopment Program to inform interested parties at hazardous waste sites about planning and technical issues that may arise during the remediation process (during which it selects, designs, and implements remedies) when reuse of a site is intended following cleanup. Other reports in this series provide technical information on the reuse of Superfund sites with on-site containment or treatment for commercial facilities, golf courses, and other outdoor recreational areas.

While the information in this report may be useful in many circumstances that may occur at a wide range of sites, it may not cover all considerations that might apply at federal facilities sites. Hence, managers at those sites are encouraged to coordinate restoration and reuse projects with EPA's Federal Facilities Restoration and Reuse Office. Managers at federal facilities engage in practices similar to those described in this report. In addition, at some federal facility sites, there may be greater opportunities for ecological uses due to certain site attributes and circumstances, such as large land areas and remote locations. In addition, federal statutes promote conservation areas through the creation of national wildlife refuges at former Superfund sites and through conservation authorities granted to the Department of Defense. These authorities are designed to mitigate encroachment from the military and local community by creating ecological use buffers next to active defense installations.

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Section 1. Introduction

Former landfills, abandoned dumps, mining areas, and other contaminated sites throughout the United States, once thought to be of limited or no value, are being transformed into viable habitats where plants and animals can flourish. More than 56 of the approximately 460 Superfund sites that have been redeveloped over the past 25 years are being used primarily for ecological purposes. Cleaned up Superfund sites are being used for wetlands, meadows, streams, and ponds, where they provide habitat for terrestrial and aquatic plants and animals, and 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 components or green space.

Healthy ecosystems are important to all aspects of our lives, and it would be difficult or impossible to sustain our society without them. Ecosystems provide benefits to society both directly and indirectly. Healthy ecosystems provide products such as food, fuel, fiber, and water; regulating services, such as flood control, surface water runoff regulation, habitat maintenance and restoration, and carbon sequestration; and nonmaterial assets such as recreational opportunities, aesthetics, and cultural amenities.

At many successfully redeveloped sites, contaminated material has been left on the property in containment systems designed to protect people and the environment from exposure and prevent contaminant migration. A number of redeveloped sites are also being cleaned up with in-situ treatment technologies that use biological (including phytoremediation), thermal, and physical/chemical processes to treat contaminated material in place. These remediation approaches are used because it is impractical or unnecessary to completely remove all the contaminated material or because excavation or removal actions would do more harm than leaving the material in place. These remedies are practical approaches to reducing exposure and bioavailability of the contaminants, thereby protecting people and the environment from the potential risks and allowing beneficial reuse of a site. To prevent long-term risks to human health and the environment, redevelopment planners integrate into their plans any aspects of a remedy that are designed to monitor and maintain its effectiveness.

This report discusses approaches for ensuring that these containment and treatment systems can accommodate the selected ecological uses while ensuring that reuse activities do not reduce the effectiveness of the remedy. The successful reuse of a remediated site for ecological purposes typically involves careful planning, involvement of Natural Resource Trustees (Trustees), communities, and other parties, and appropriate design, construction, and post-construction operation and maintenance practices. The report is based on the combined experiences of successful Superfund remediation and reuse projects, EPA technical guidance, and other sources.

1.1 Purpose

This report was developed for site managers, communities, property owners, developers, natural resource trustees, and others who might have an interest in Superfund sites at which ecological resources are to be created, restored, improved, or protected. It provides information useful for planning, designing and implementing site cleanups that will support valuable ecosystems while remaining protective of human health and the environment. The information could also be applied at certain non-time-critical removal sites and waste sites addressed under and other cleanup programs. The report describes how redevelopment and remediation efforts can be coordinated to ensure successful ecological projects at sites where some or all of the contaminated materials are to be left or treated on site. It focuses primarily on planning-level issues, not detailed design information. The document does not mandate how communities, property owners, and Trustees plan for the reuse of cleaned up sites. It is generally their responsibility to decide how these properties will be used, so long as the reuse activities do not reduce the protectiveness of the remedy. Cooperation and coordination between the interested groups and regulatory agencies can help ensure practicable solutions.

This report in no way alters established EPA policies on remedy selection for Superfund sites. The national program goal of the Superfund remedy selection process is to “select remedies that are protective of human health and the environment, that maintain protection over time, and that minimize untreated waste” (40 CFR 300.430(a)(1)(i)). In many instances, Superfund remedies include combinations of treatment for "principal threat wastes" (highly concentrated or mobile contaminated material), engineering controls to contain lower-concentration contaminants, and institutional controls (*i.e.*, restrictions on the use of a property that may be implemented through legal or administrative mechanisms, such as easements, to supplement the engineering controls and minimize the potential of exposure to contaminated material remaining on site).

This report is one of several developed under the EPA Superfund Redevelopment Program to inform stakeholders at hazardous waste sites about how EPA may take identified and potential reuse into account when it selects, designs, and implements remedies. Other reports in this series provide planning and design information on the reuse of Superfund sites for commercial facilities, golf courses, and other outdoor recreational areas.

1.2 Who Should Read the Report and Why

Many entities or stakeholders have a substantial interest in the redevelopment of a Superfund site. The **potentially responsible parties (PRPs) or the owner** will need to assess the impacts of the reuse on their potential liability and the long-term stewardship of the site. In addition, a valuable habitat could improve a company’s image, provide amenities to the community, and, in some cases, enable a land owner to trade ecological improvements for land-use concessions elsewhere. **Natural Resource Trustees** may choose to assess damages from releases of hazardous substances, pursue recoveries of damages and costs, and use the sums recovered to restore, replace, or acquire the equivalent of the injured resource (USEPA, 1992). **Local governments** may need to consider whether the proposed reuse is compatible with their land use plans, and may benefit from increased recreational activities for their residents, tourism, and, consequently, tax revenues. **Local citizen groups and individuals** may be concerned with the character of their neighborhood, recreational and employment opportunities, and air and water quality. **Environmental organizations** are often interested in how a redevelopment project may provide the opportunity to protect or improve local and regional habitats. **EPA remedial project managers (RPMs)** and the **state regulators** need to coordinate remediation and reuse efforts at Superfund sites. **Consulting engineers** representing the PRPs or site owners should be able to assure regulators that the planned habitat does not compromise the effectiveness of the remedy. To ensure that the perspectives of all interested parties are considered and that the remediation and reuse of the site complies with all state and federal regulations, coordination with the stakeholders should be initiated early in the planning process and continue frequently throughout the process.

1.3 Superfund Redevelopment Program

EPA prepared this report as part of the Agency's Superfund Redevelopment Program. This program reflects EPA's commitment to consider reasonably anticipated future land uses (RAFLU) when making remedy decisions at Superfund sites, and to ensure that, when possible, the cleanup of Superfund sites allows for reuse for ecological, commercial, recreational, or other purposes while remaining protective of human health and the environment.

Through this program and other efforts, the Agency works with communities to determine remedial action objectives that will allow for RAFLU. Land use is a local matter, and EPA does not favor one type of reuse over another. EPA's primary responsibility is to ensure that the remedy is protective of human health and the environment.

Ecological Reuse Provides Many Benefits:

- New employment opportunities, increased property values, and catalysts for additional redevelopment;
- New recreational and open-space areas in communities where land available for such uses is scarce;
- Better day-to-day property management, leading to improved maintenance of the remedy and continued protection of human health and the environment;
- Improved site aesthetics through the creation of well-maintained properties and discouragement of illegal waste disposal and similar unwanted activities;
- Better quality ecosystems, which can contribute to improved biodiversity in local and regional habitats and other ecosystem services, and reduced bioaccumulation of contaminants in plants and animals; and
- Increased community acceptance of the remedy.

The safe and appropriate redevelopment of sites can provide significant benefits to communities and help ensure that remedies will be maintained. These potential benefits are listed in the text box. Other benefits are evident in case histories in Appendix A and several references (WHC 2005, NC 2005, USEPA 1988, USFWS 1984).

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1.4 Integrating Reuse Plans With Cleanup Remedies

Assumptions about the future use of a Superfund site can have a substantial impact on all aspects of the cleanup process, from the site discovery through remedy selection and implementation. Thus, the RPM and other stakeholders should consider assumed or planned reuse options, if they have been identified, in the design and implementation of response actions, consistent with Office of Solid Waste and Emergency Response's (OSWER) land-use guidance, and consider adjusting the reuse plans or remediation approaches to accommodate each other when cost and protectiveness are not affected (USEPA, 2001b and 1995b). When and how future land use considerations are incorporated into EPA's site management process, and the scope of EPA's authority to accommodate future land use throughout the remedial process, are discussed below.

1.4.1 Consideration of Future Land Uses

The anticipated future use of land is an important factor that EPA considers in identifying, determining, and implementing appropriate response actions (USEPA, 2001b and 1995b). The process for identifying the reasonably anticipated future land use typically begins during the remedial investigation/feasibility study (RI/FS) or Engineering Evaluation/Cost Analysis (EE/CA) stage of the EPA site management process. Assumptions about reasonably anticipated future land use can be considered a part of a number of stages in the cleanup process, including:

1. The baseline risk assessment when estimating potential risk for anticipated future uses;
2. The development and evaluation of remedial or removal action objectives and response action alternatives; and
3. The selection of appropriate response actions that can achieve the cleanup levels required for the protection of human health and the environment for anticipated future land uses.

A useful way to develop reasonable assumptions about future land use is to conduct a reuse assessment. The reuse assessment typically identifies broad categories of potential reuse (*e.g.*, residential, recreational, commercial and industrial, agricultural, ecological). The information in this assessment may also be the starting point for the reuse planning process and lay the groundwork for integrating the consideration of reuse into the cleanup plan. In general, the reuse assessment can be done by the entity conducting the RI/FS or EE/CA. As with other activities performed under the RI/FS or EE/CA, EPA, in coordination with the state, can determine the appropriate level of oversight when PRPs perform this work. While EPA does not expect to be involved in the details of reuse planning, the Agency should ensure that reasonable assumptions regarding future land use are considered in the selection of a response action.

In some cases, property owners, PRPs, and communities may have initiated a reuse planning process. Information from a reuse plan may also be useful for the reuse assessment. As part of the reuse assessment process, discussions are typically held between local land-use planning authorities, local officials, property owners, PRPs, EPA, and the public to understand the reasonably anticipated future uses of the land on which the Superfund site is located. Based in part on these discussions, EPA develops or approves remedial action objectives and identifies remedial alternatives that are consistent with the anticipated future land uses. If there is substantial agreement on the future use of a site, EPA may be able to select a remedy that is consistent with that use and take measures to accommodate it when designing the remedy. Regardless of the site use anticipated or planned, EPA is prohibited from funding, or requiring others to fund, certain “enhancements” to the remedy (Section 1.4.3).

EPA must balance this consideration of anticipated future land use with provisions in the Superfund law and its implementing regulations (National Oil and Hazardous Substances Pollution Contingency Plan, known as the NCP) which establish program management principles and expectations to assist in the identification and implementation of appropriate remedial actions. For example, the NCP details expectations that must be considered with regard to using one or more of a number of approaches, such as treating principal-threat wastes, engineering controls such as containment for low-level threats, institutional controls (ICs) to supplement engineering controls, and innovative technologies (NCP § 300.430(a)(1)(iii)). Also, EPA complies with other federal and state environmental laws when they are “applicable or relevant and appropriate requirements” (ARAR), unless there are grounds for a waiver.

Once EPA selects a remedy, two general land-use situations that could result include:

- If the remedy achieves cleanup levels that allow the site to be available for the reasonably anticipated future land use, EPA strives to work within its authorities to accommodate that reuse; or
- If the remedy achieves cleanup levels that require a more restricted land use than the preferred one, the site will probably not support the community’s reuse preferences and the interested parties will have to discuss other reuse alternatives.

For additional information on how EPA considers land use in the remedy selection process, see EPA’s *Land Use in the CERCLA Remedy Selection Process*, EPA OSWER Directive No. 9355.7-04; and *Reuse Assessments: A Tool to Implement the Superfund Land Use Directive*, OSWER Directive No. 9355.7-06P (http://www.epa.gov/superfund/resources/reusefinal.pdf).

1.4.2 Timing

To allow for evaluations of a variety of remediation and reuse options, any reuse planning that might be undertaken should be initiated as early in the cleanup process as possible. The longer reuse planning is delayed, the greater the possibility that some reuse options will be foreclosed by decisions already made.

Generally, there are two major components of the reuse planning process: developing reuse assessments and creating reuse plans. A reuse assessment, which typically identifies broad categories of potential reuse (*e.g.*, recreational, industrial, residential), is generally developed at the RI/FS stage. The information in this assessment may also be the starting point for additional planning efforts, such as the creation of a reuse plan. Because the land-use categories employed in making the assessment are usually broad, they may not provide sufficient detail to ensure that the remedy being considered could allow for a specific use nor to efficiently be considered in the detailed remedy design. When communities, natural resource trustees, or other parties need more specific and detailed land-use evaluations, they may initiate the second component of the planning process—the creation of reuse plans.

Since reuse plans are often developed after the RI/FS, they may not be available until later stages of the site management process, such as during remedy design or construction. When EPA receives the reuse plans prior to remedy selection, the RPM should use them in the course of developing and evaluating the remedial alternatives. When reuse information is received after the remedy is selected, the site manager may evaluate it to determine whether the proposed reuse is consistent with the selected response action and whether modifications might easily be made to accommodate the preferred reuse. Since changes in schedule or other aspects of the remedy can affect potential risk to human health and the environment and cleanup costs, site managers are encouraged to ensure that reuse options and plans are realistic and obtained as early as possible.

Development of a reuse project can sometimes begin on parts of a site before construction of a remedy is completed. This can be done by segmenting the site into different operable units (OUs) which proceed on different schedules according to the nature of the cleanup approaches, location, and expected completion time; deleting portions of the site from the NPL while cleanup continues elsewhere; and sequencing the cleanup work to coordinate with development needs. For example, at the Ohio River Park Superfund site in Neville Island, Pennsylvania, remedial activities were interrupted when EPA agreed to make part of the site available for replacing the old, unusable Coraopolis Bridge, which was important to the community.

In many cases, a completed remedy may not be able to accommodate the planned use without modification because of technical, legal, or other factors. If, in the future, landowners or others decide to change the land uses in a way that makes further remediation necessary, EPA generally would not prohibit them from conducting additional cleanup actions, so long as the effectiveness of the remedy is not compromised and protectiveness of human health and the environment is to be ensured. It would likely be necessary to evaluate the implications of that change for the protectiveness of the selected remedy. Retrofitting an existing remedy to support reuse requires careful planning, design, coordination with, and approval by, EPA and other regulatory agencies.

1.4.3 Enhancements

EPA cannot fund, nor require PRPs or others, to fund certain “betterments”or “enhancements” of a remedy. Generally, a prohibited enhancement is an action that is not necessary to support the effectiveness of a remedy in protecting human health or the environment. Examples of actions that typically may not be funded include the installation of lights for a parking lot and the addition of extra clean fill beyond that required to make a remedy protective.

Some cleanup activities may be necessary to accommodate the anticipated future use of a site. Hence, it may be practicable for the Region to design, conduct, or phase response actions at a site in a cost-neutral manner that could allow earlier reuse or maximize redevelopment potential without adversely affecting the protectiveness of the remedy. For example, as part of the remedy, EPA may provide corridors of clean soil or other material for future utility access when anticipated use makes the need likely. Likewise, EPA may take future use into account in deciding on the placement of wastes, monitoring or extraction wells, air-stripping towers, or other treatment units, so that they do not interfere with site access or the placement of structures needed for redevelopment of a site. Such cost-neutral actions would generally not be prohibited enhancements.

Most efforts to revegetate Superfund sites are not considered enhancements. Grasses, shrubs, and other plants often serve a practical function of stabilizing a soil cover and preventing erosion, although they also improve the site's aesthetics. Some plants may clearly be part of the remediation process through phytoremediation or as part of an evapotranspiration barrier cap (Sections 3.1 and 3.3). However, some extensive efforts to create or restore the structure and function of an ecosystem to exacting specifications may be considered enhancements, unless the need for the restoration is a result of environmental stressors or damages caused by the remediation.

EPA determines on a case-by-case basis whether an activity or feature constitutes a prohibited enhancement. Although they cannot be funded by EPA, enhancements may be included in a remedial action if they are consistent with and do not interfere with the protectiveness of the selected remedy, provided that the costs are paid by another party, such as a PRP, prospective purchaser, Trustee, or developer, and such party provides sufficient, reliable financial assurance.

1.5 Ecological Reuse of Hazardous Waste Sites

For this report, the term "ecological reuse" at cleaned up Superfund sites applies to a variety of project types. In general, the term refers to a stable, self-sustaining ecosystem habitable by plants and animals, and where little or no human activity is expected to occur. This definition excludes commercial, industrial, residential, and many recreational uses. However, low-impact or passive recreation, such as hiking or bird watching, may occur at ecological reuse areas.

Most ecologists advise that ecosystems that replicate the conditions that would have existed if there had not been a disturbance tend to thrive best (USEPA, 1995e). However, where physical and biological conditions are severely degraded, or where general land use or ecosystems in the surrounding area has changed, it is difficult and sometimes impossible, to return a site to pre-disturbance conditions.

When pre-disturbance conditions cannot be replicated, other types of significant ecosystems may be established. The property can be returned to a stable and functioning system that "belongs" in the region but may not be the system that predated the disturbance. Where the land is severely disturbed, as is often the case with mining areas, the reuse can involve simply revegetating the site with species that are compatible with the surrounding area. Ecological reuse at some sites may entail more than one project type. Some areas of a site may be restored to relatively pristine condition, while other areas are simply planted with native or other compatible species. The remediation and reuse factors discussed in this report are generally applicable to all of these project types. However, some extensive efforts to create or restore ecosystems that are not needed for hazard mitigation may be considered "enhancements" as described in Section 1.4.3.

1.6 Organization of Report

The remainder of this document describes planning and technical factors typically addressed when coordinating ecological reuse with remediation activities. It includes the following:

Section 2 Planning considerations typically associated with developing, restoring, or protecting ecosystems on a Superfund site, such as natural resource management issues, coordination between ecological reuse efforts and the Superfund remediation process, the role of federal, state, and tribal Trustees and other groups, and baseline site configurations.

Section 3 Common remediation methods and ecological reuse planning and design issues typically considered when a Superfund site is to have ecological reuse. These issues include the characteristics of ecological resources at and near the site; remediation system components, design, and implementation; management of remedy construction to minimize adverse environmental impacts; potential environmental impacts of groundwater extraction and treatment and in-situ treatment; and the long-term maintenance of the remedy.

Section 4 Issues that often arise when wetland restoration, creation, or protection are the primary reuse goals.

Section 5 Issues typically considered when stream restoration, creation, or protection are the primary reuse goals.

Section 6 Issues typically considered when terrestrial ecosystem restoration, creation, or protection are the primary reuse goals.

References References on remedy and reuse planning and design, such as EPA guidance manuals, text books, and journal articles.

Appendix A Five sites where successful ecological reuse has occurred on remediated waste sites. The discussion for each site includes its history, contamination problems, key factors considered during remediation and reuse planning and implementation, and lessons learned. These case studies demonstrate how remediation and reuse efforts may complement one another.

Appendix B Acronyms

Section 2. Planning for Ecological Reuse of Superfund Sites

At most Superfund sites, remedies can be designed and implemented to accommodate existing or planned plant and animal habitats and still meet all federal and state regulatory requirements. However, some remedy features can, if not appropriately designed, have detrimental physical, chemical, and biological impacts on local wetlands, streams, and plant and animal communities. For example, pumping and treating groundwater may affect water, mineral, or contaminant levels in nearby wetlands, excavation can disrupt fertile surface soils and wildlife habitats, and the introduction of non-native species of plants and animals can adversely affect native species.

To ensure that habitats are protected, restored, or created in the course of designing and implementing remedies, stakeholders typically consider the physical and biological condition of the site and its relationship to local and regional plant and animal species; regulatory requirements governing waste site cleanup and protection or creation of ecologically significant areas; temporary and long-term ecological impacts of Superfund response actions; and the types of habitats that are to be protected, restored, or created at and near the site.

This section summarizes key planning factors that generally influence the effectiveness of the remediation and success of ecological reuse of a property when contaminated material or long-term treatment systems are to be left on site. It addresses common natural resource management issues, coordination between ecological reuse efforts and the site remediation process, the role of natural resource trustees (Trustees, see Section 2.3) and other groups, and site characteristics and configurations that affect ecological reuse.

Key Planning Issues for Ecological Reuse:

- Common natural resource management issues
- Coordination of ecological reuse efforts with the Superfund remediation process
- The role of Trustees and other groups
- Baseline site characteristics that affect reuse
- Baseline site configurations

Stakeholders will have the greatest reuse flexibility if remediation and reuse plans are coordinated prior to remediation. Nevertheless, ecological reuse can still occur if it is not designed until after the remedy is in place. In this situation, it is especially important that reuse plans are based on accurate, current, as-built drawings of the remedy, rather than on pre-construction designs.

2.1 Major Natural Resource Management Issues

Ecological reuse strategies vary widely among sites depending on the plans of nearby communities and other stakeholders, the condition of the ecosystem at the site and adjacent areas, state and federal regulations pertaining to specific species and habitats, the responsibility of Trustees, and other site-specific factors. Ecological reuse planners will generally be concerned with five broad issues: biodiversity in the area; contaminant bioaccumulation and ecotoxicity;

the presence or potential presence of threatened, endangered, sensitive, or commercially important species in the baseline and post-remediation; avoiding unintended consequences; and defining the project scope.

2.1.1 Biodiversity

Biodiversity refers to the variety of all life forms: the plants, animals and micro-organisms, their genes, and the ecosystems of which they are a part. We depend on it for our survival and quality of life. Healthy ecosystems are necessary to maintain and regulate atmospheric quality, climate, fresh water, marine productivity, soil formation, cycling of nutrients, and waste disposal. Biodiversity is required for the recycling of essential elements, such as carbon, oxygen, and nitrogen. It is responsible for mitigating pollution, protecting watersheds, and combating soil erosion. Biodiversity is intrinsic to the qualities we value such as physical beauty and harmony. Plants and animals attract tourists and provide food, medicine, energy, and building materials. In recent years, entire species and natural areas have been lost at unprecedented rates, primarily due to human activity. The extinction of each additional species brings the irreversible loss of unique genetic codes, which provide many benefits, such as the development of medicines and food.

A meadow provides habitat for plants, birds, and mammals at the Army Creek Landfill site in Newcastle County, Delaware.

The ability of a wildlife species to thrive in a habitat is dependent upon the minimum necessary habitat area for the species, the minimum viable population of the species, and the species' tolerance for disturbance. A remediated Superfund site can help maintain or increase regional biodiversity by establishing connections between habitats or by enlarging nearby habitats. Birds and large mammals use habitat corridors for movement among different areas. Smaller areas of habitat that are connected by corridors typically receive greater wildlife use than isolated habitats. Corridors also prevent the isolation of plant and animal populations and reduce the danger of local extinction. Thus, for sites where adjacent areas are valuable habitats, planners can improve biodiversity by striving to create opportunities for the site ecology to support the existing regional landscape and habitat corridors.

2.1.2 Contaminant Bioaccumulation

At Superfund sites where contaminants will be left on site after the remedy is constructed, site managers and developers may need to address the potential for contaminant bioaccumulation in plants and animals as well as other residual risks associated with leaving contaminants in place. Certain contaminants (*e.g.*, toxic metals such as copper, cadmium, zinc, and lead; organochlorine pesticides; and a variety of chlorinated organic compounds) can become sequestered in the tissues of organisms. The sequestering results in the organism having a higher concentration of the substance than the concentration in the organism's surrounding environment.

Bioaccumulation can result in increasingly greater concentrations of contaminants in the tissues of organisms higher up in the food chain (biomagnification). These processes can result in an organism having higher concentrations of a substance than is present in the organism's food. The amount of bioaccumulation of a contaminant can vary widely among species.

The likelihood that contaminants of concern may bioaccumulate in food chains is one of the key parameters examined during the ecological risk assessment (ERA). The ERA, which is an integral part of the remedial investigation/feasibility study (RI/FS), is conducted to evaluate the likelihood that adverse ecological effects are occurring or may occur as a result of exposure to physical or chemical stressors at a site (1997a, 1999c). The information from the risk assessment, supplemented with additional ecological studies that may be necessary, can be used in the design of remedies and monitoring programs that can help avoid harmful bioaccumulation by preventing the exposure of plants and animals to the contaminated material. For example, at the West Page Swamp area of the Bunker Hill Superfund site in Kellogg, Idaho, root zone soil was amended to reduce or prevent the bioavailability of many heavy metals to plants (case history in Appendix A).

2.1.3 Threatened and Endangered Species

The goal of Superfund remedial actions is generally to protect local populations and communities of biota (*e.g.,* benthic species diversity), rather than to protect specific organisms (USEPA, 1999c). Study of specific organisms is done, with some exceptions, to extrapolate effects on these organisms to populations and communities. Thus, Superfund risk managers and assessors should select assessment endpoints and measures that are important to sustaining the ecological structure and function of local populations, communities, and habitats at or near the site, or likely to be at or near the site after remediation. In addition, if specific threatened, endangered, or commercially important species or critical habitats are present, additional evaluations may be required under the federal Endangered Species Act or a state endangered species act, since such laws may be ARARs. EPA's guidance on ecological risk assessment for Superfund provides information on these and other ARARs (USEPA, 1997a, and 1999c).

Where threatened or endangered species are present, or where the post-remediation habitat might be suitable for these species and promote their return, additional considerations should be included in the ecological risk assessment and subsequent cleanup and reuse plans, and coordinated with Trustees and other parties with knowledge of, and interest in, the local ecosystems. The development of remediation and reuse plans for areas that involve threatened or endangered species usually require the services of a professional biologist or ecologist. These professionals can help develop creative approaches, such as methods to measure the condition of the species without overusing destructive sampling, ways to delineate certain areas of the site to be excluded from specific remedial activities where a threatened or endangered species only affects part of a site, or increasing ecosystem scale by improving connectivity with other areas.

2.1.4 Potential for Unintended Consequences

Because of the diversity of factors that affect the behavior of wildlife and ecosystems, it may be difficult to anticipate all potential consequences of a newly created or altered ecosystem. For example, when farmland at Lake Apopka, Florida was converted to a marsh area designed to enhance wildlife habitat, the risk assessment anticipated no problems. However, flocks of migrating birds converged on the newly created marsh area and hundreds of birds died of pesticide poisoning. The birds, which were attracted by the lake, preyed on fish in nearby ditches and small pools that were contaminated with pesticides. Another example of an attractive nuisance is a plant that tends to attract burrowing animals, that could damage a containment system. Project managers should understand the contaminants present and types of exposures anticipated when developing plans to modify habitat to attract wildlife.

2.1.5 Scope of Ecological Reuse of Superfund Sites

In this report the term "ecological reuse" refers to a stable, self-sustaining ecosystem habitable by plants and animals, and where little or no human activity is expected. As described in Chapter 1, the term includes a variety of project types, ranging from establishing ecosystems at a site that replicate pre-disturbance conditions to simply revegetating the site with species that are compatible with the surrounding area. A given site may require more than one type of project—restoring some areas to relatively pristine conditions, while simply revegetating other parts of a site with compatible plants. Ecological reuse of a Superfund site may also involve the need to protect, improve, restore, or create on-site or off-site ecosystems, and to allow for low-impact or passive recreation, such as hiking or bird watching.

The scope of the reuse project is typically developed by local communities, Trustees, and other stakeholders in consultation with EPA and other local, state, and federal agencies. Communities and resource agencies responsible for managing lands within or near the site generally have knowledge and experience with regional soil, plant, and ecology issues. For example, determining which species are appropriate for local habitat conditions can be done with support from the Natural Resources Conservation Service (U.S. Department of Agriculture (http://www.nrcs.usda.gov), EPA's regional Biological Technical Assistance Groups (USEPA, 1991), EPA's Emergency Response Team (http://www.ert.org), and local native plant societies (http://michbotclub.org/links/native_plant_society.htm). With cooperation among these agencies and remedial project managers (RPMs), the planned remedy and reuse plans are likely to successfully address local and regional natural resource management objectives and concerns.

Some extensive efforts to restore or create ecosystems may entail additional actions beyond what is needed for a Superfund response. Although such actions may not be paid for with EPA funds, nor may EPA require others to pay for such actions, Trustees or other parties may undertake them and seek compensation from PRPs. It is EPA policy to coordinate EPA and Trustee investigations of risk and resource injuries to make more efficient use of federal and state funds.

2.2 Coordinating Ecological Reuse With the Superfund Process

As discussed in Chapter 1, the future use of a property can affect all aspects of the removal and cleanup processes. Likewise, the requirements of the remedy will generally affect many aspects of the design and function of the ecosystems to be protected, restored, or created. The objectives of the ecological reuse and those of the remediation are best accomplished if they are carefully coordinated. Thus, it is imperative that the cleanup team understand ecosystem development and operational needs, and that the reuse team work within the Superfund site management process. At most of the sites discussed in Appendix A (Case Studies), significant parts of the preparation of the sites for ecological reuse were integrated with the remediation work. It is EPA's policy to coordinate with all interested parties on establishing and implementing remediation goals that are compatible with reasonably anticipated land uses, and to share data needed for reuse planning, natural resource damage assessments (NRDAs), and recovery actions (U.S. EPA, 1997d, 1999c).

2.2.1 Establishing Remediation Goals

Establishing remediation goals for ecological receptors is considerably more difficult than establishing goals for the protection of human health because of (a) the paucity of broadly applicable and quantifiable toxicological and other necessary data; (b) the large variation in the kinds and numbers of receptor species present at sites; (c) the differences in their susceptibility to contaminants and recuperative potential following exposure; and (d) wide variations in environmental bioavailability of many contaminants in different media (USEPA, 1999c).

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. The NCP also states that ARARs shall be considered, along with other factors, in determining remediation goals (which establish acceptable exposure levels that are protective of human health and the environment–Section 300.430(e)(2)(i)). For example, water quality criteria/state standards established under Sections 303 and 304 of the Clean Water Act, that are based on risks to ecological receptors, may be an ARAR. For these reasons, the establishment of protective exposure levels is best done on a site-specific basis in coordination with Trustees and other stakeholders, such as communities and property owners. Involving all stakeholders will help to ensure that all relevant ecological resources are identified and considered in all phases of planning and implementing Superfund response actions.

Superfund response actions may not lead to the ecosystem contemplated by communities or Trustees and these parties may wish to undertake additional activities to protect or restore an ecosystem. Although such additional activities may not be EPA's responsibility, it is EPA's policy to coordinate its investigation of risk with the Trustees' investigation of resource injuries and reuse potential in order to most efficiently use federal and state funds and not duplicate efforts (USEPA, 1999c). Data collection efforts should be coordinated with other efforts to collect data for human health risk assessments or for NRDAs. Many data elements are common inputs to all these efforts.

It is not always necessary to completely remove contaminated material from a site to reduce ecological risk to acceptable levels. EPA may seek to develop remedies that reduce the contaminant's media exposure concentrations below ecotoxicity values, reduce the bioavailability of the contaminant to plants and animals, and interrupt the exposure pathways. For example, a protective cap may prevent exposure of certain species to subsurface contaminated materials or soil amendments may reduce the bioavailability of some contaminants to plants and animals. Sometimes the removal of contaminants could cause more harm than leaving them in place.

2.2.2 Ecological Risk Assessment and Natural Resource Damages

Ecological risk assessments, which are conducted as part of the RI/FS phase of the Superfund response process evaluate the likelihood that adverse ecological effects are occurring or may occur as a result of exposure to physical or chemical stressors. These assessments often contain detailed information regarding the interaction of these stressors with the current biological community at the site and the future biological community anticipated under the anticipated land use. Part of the assessment process includes creating exposure profiles which describe the sources and distribution of stressors and exposure pathways; estimate the intensity and extent of exposures at a site; evaluate toxicity, bioaccumulation, mortality, reproductive impairment, growth impairment, and loss of critical habitat; and identify sensitive organisms or populations. An ERA can be conducted quickly for a removal action, should there be an imminent threat to ecological receptors. However, these instances are rare and these risk assessments follow the same process outlined for long-term ecological risk assessments conducted during the RI/FS. EPA has published both Agency-wide guidance for ecological risk assessments (USEPA, 1998b) and Superfund Program-specific guidance (USEPA 1997a and 1999c).

Ecological risk information from the RI may be relevant in a NRDA and both EPA and Trustees generally benefit from sharing information and coordinating with each other during ecological risk assessments. EPA guidance requires coordination among EPA and all affected Trustees in site characterization, response actions, and settlement negotiations (USEPA, 1997d). The guidance also calls for Superfund site risk managers and Trustees to coordinate both EPA investigations of risk and Trustee investigations of resource injuries to make efficient use of federal and state funds.

An NRDA is used to identify additional actions, beyond the response, needed to address injuries to natural resources. Examples include actions needed to restore the productivity of habitats or the species diversity that were injured by the past releases or to replace them with substitute resources. A Trustee may also seek compensation for the loss of injured natural resources from the time of injury until the time they are fully restored. Regulations for assessing natural resource damages have been promulgated under both the Comprehensive Environmental Response, and Compensation and Liability Act (CERCLA) and the Oil Pollution Act (OPA).

2.2.3 Typical Ecological Reuse Development Process

EPA generally does not determine land use. Land use planning is generally conducted by communities with input from Trustees, and other stakeholders. Nevertheless, it is useful for EPA and others involved with the remediation to understand typical topics that are addressed when planning and implementing an ecological reuse project. It is best to develop a potential reuse plan early in the Superfund cleanup process. If the reuse option is identified early, planning for both the ecological reuse and remediation can be done concurrently. If the reuse option is not determined early enough, additional work may be needed to plan for and establish a viable ecosystem. In either situation, ecological reuse planning involves the following general steps.[1]

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[1] Adapted from U.S. Department of Interior 1998, National Research Council,1992, Federal Interagency Stream Corridor Restoration Working Group 1998, and Kent 1994.

- **Determine pre-disturbance and reference conditions.** Reuse planners can determine the pre-disturbance ecological characteristics and condition of a site by using historical records and maps and by studying nearby undisturbed areas with similar physical characteristics. This information can help develop reference conditions used for establishing reuse goals and objectives, and provide a model for creating ecological processes that will thrive at the site.
- **Conduct site inventory/characterization.** A site inventory and characterization should include mapping the site, documenting its condition, evaluating the type and degree of disturbance (type, concentration, and areal extent of waste and physical damage) and the degree to which pre-disturbance ecological processes were affected by the disturbances. It is important to develop a thorough understanding of the structure and function of the on-site and associated off-site ecosystems, and to determine the current condition of habitats, sensitive ecosystems, wildlife populations, drainage patterns, water bodies, roads, adjacent properties, and other factors that could be affected by the remediation and future land uses. Data will be needed on soil characteristics (compaction, tilth, carbon nitrogen ratio, nutrients), water quality and quantity, geomorphology, plant and animal communities, and threatened and endangered species. Much of the information may already be available from data collected as part of the RI. If the RI team has no plans to collect data on some critical parameters, reuse planners may coordinate with EPA to arrange for such data.
- **Establish reuse goals and objectives.** Reuse planners should develop a statement of goals for the ecological reuse project which describes the site conditions to be achieved (*e.g.*, restore a degraded wetland to its pre-disturbance species diversity). Reuse objectives are usually more specific measures to achieve those broader goals (*e.g.*, establish selected species at a desired frequency and density within a prescribed time frame).
- **Evaluate reuse alternatives.** One or more alternative approaches to site reuse should be evaluated, and a preferred alternative should be selected, in consultation with EPA.
- **Develop site-specific ecological design.** After the preferred reuse alternative is determined, reuse planners then proceed to develop a detailed plan for the reuse design.
- **Prepare specifications for construction contractors.** Based on the final approved reuse design, the specifications are used to solicit contractor support.
- **Construct the habitat features.** Oversight during construction of a reuse project is essential to ensure that the work is conducted according to the reuse design specifications and that any modifications are made appropriately. It is advisable, in many situations, to have an ecologist or biologist and remediation professionals available during construction to monitor progress and suggest modifications if unexpected conditions are encountered.
- **Maintain site.** After construction is complete, tasks such as periodic inspection of remedy components and habitat features and repair and replanting after flood damage are often needed to sustain the ecosystem. Generally, more intensive maintenance is needed for the first three to five years after the initial construction than in later years.
- **Monitor results.** A monitoring plan should be developed based on the initial sampling in the site inventory and characterization and the reuse design. Prior to beginning the reuse work, reuse planners may want to establish photopoints and permanent markers for monitoring sites that can be reestablished during and after the reuse project.

Many of the above reuse-related activities can be coordinated with the Superfund response. Section 2.2.4 indicates points in the Superfund process where Trustees are to be involved.

2.2.4 Superfund Site Management Process

The Superfund cleanup process begins with the discovery of hazardous waste or notification to EPA of possible releases of hazardous substances. Once discovered, EPA or another lead agency investigates the potential for a release and, if necessary, conducts or oversees a remedy. The following are the primary phases of the CERCLA remedial process and the ecological reuse considerations that accompany each phase.

- **Site Discovery.** After a site is reported, EPA conducts an initial screening to determine whether further assessment is warranted, and exchanges information with Trustees regarding PRPs and CERCLA §104 requests and invites them to be involved in the response.
- **Preliminary Assessment/Site Investigation (PA/SI).** The EPA Region performs a preliminary assessment (PA) and site inspection (SI), or an integrated or combined PA/SI to provide information on site conditions that typically allows a determination to be made of whether a site's preliminary score is sufficient for possible listing on the NPL. EPA coordinates assessments, evaluations, investigations, and planning with Trustees and provides them with an opportunity to participate in health and ecological risk screening.
- **Hazard Ranking System (HRS) Scoring.** This scoring is a screening mechanism used to decide whether a site is eligible to be considered for National Priorities List (NPL) listing.
- **NPL Site Listing Process.** This process allows for public comment prior to listing a site on the NPL, after which it is considered a Superfund site. EPA provides Trustees with national lists and site-specific information supporting the NPL listing.
- **Remedial Investigation/Feasibility Study.** In the RI/FS, EPA determines the nature and extent of contamination and its fate and transport, and identifies risks and cleanup alternatives. During this process, the lead agency or other party may conduct a reuse assessment to develop assumptions about reasonably anticipated future land uses (USEPA, 2001b). It is EPA's policy to coordinate the activities in this step with Trustees (NCP §300.430(b)(7)) and communities, and other interested or affected parties ((NCP §300.430(c)). EPA coordinates necessary assessments with Trustees and provides opportunity for Trustees to comment on work plans, RI/FS reports, remedial alternatives, ARARs, and the proposed plan and Record of Decision (USEPA, 1999c).
- **Record of Decision (ROD).** This document describes the selected remediation approach and the rationale that led to the decision. The remedy selection process involves a comparative analysis of alternatives with respect to the nine remedy-evaluation criteria specified in the NCP and the compatibility of a remedy with reasonably anticipated future land uses. The process is used to determine which alternative is most appropriate for the site and the anticipated land use(s). EPA provides Trustees the opportunity to review and comment on negotiated draft agreements, as well as a final copy of the ROD.
- **Remedial Design/Remedial Action (RD/RA).** When designing and implementing the remedy, RPMs should, to the extent practicable, strive to accommodate the anticipated future land uses consistent with the remedy, subject to regulations regarding enhancements (Section 1.4.3). When addressing ecological resources, RPMs should work with communities and local groups, Trustees (Section 2.4) and other organizations to develop remediation and reuse projects. It is EPA's policy to invite and encourage Trustee involvement in planning response actions, negotiate with PRPs, and review draft work plans and RD/RA documents.

- **Construction Completion.** After the construction of the remedy is completed, EPA and states can take steps to prepare for operation and maintenance, accommodate future uses, and help remove potential obstacles to reuse. If, during this phase of the remedial process, landowners or others propose to change the land use, RPMs and states play an important role in evaluating the implications of that proposed change on the original remedy, and determining whether or not modifications to the remedy are warranted.
- **Operation and Maintenance (O&M).** After construction is completed, O&M activities, which should be specified in the ROD, are undertaken to ensure that the remedy is effective and operating properly over time. EPA typically provides Trustees the opportunity for comment on O&M plans. At some sites, a Trustee may implement the O&M plan.
- **NPL Site Completion/Close-Out/Deletion.** When all cleanup activities at a site are completed, RPMs will need to document that the engineering and institutional controls are in place and that the site, or a portion of the site, is ready for the planned or anticipated use. The site may then be removed from the NPL. EPA provides Trustees the opportunity to participate in close-out activities and comment on the draft close-out report.
- **Five-Year Reviews.** Where waste remains on site at levels that do not allow for unrestricted use and unlimited exposure, EPA or other authorized organizations generally conduct formal reviews at least every five years to determine whether the remedies remain protective of human health and the environment. Copies of the five-year review are provided to Trustees.

2.3 Natural Resource Trustees and Other Organizations

The cleanup and successful ecological reuse of a Superfund site is facilitated by coordination among various EPA program offices, offices of other federal and state agencies, and other stakeholders. Many of these entities have information and technical expertise about local ecosystems and the biological effects of hazardous substances. Some entities, such as Trustees, have been authorized to act on behalf of the public as stewards of natural resources.

2.3.1 Natural Resource Trustees

CERCLA and the OPA authorize the United States, states, and Indian Tribes to act on behalf of the public as Trustees for natural resources under their respective trusteeship [CERCLA §107(f)(1); OPA §1006(c)]. Section 300.600 of the NCP designates the secretaries of the following agencies to act as Trustees for the natural resources, subject to their respective management or control: the Departments of Interior (DOI), Agriculture (USDA), Commerce (DOC), Defense (DOD), and Energy (DOE). State and tribal Trustees, which are usually the heads of agencies responsible for environmental protection or fish and wildlife management, are designated by their governors or tribal chairpersons. Links to specific information about each secretaries' responsibilities and state programs can be found on the EPA web site (http://www.epa.gov/superfund/programs/nrd/trust_r.htm#state).

CERCLA and OPA contain authorities to allow the assessment and restoration of natural resources that have been injured by a hazardous substance or oil release or response. EPA is not a Trustee, nor is it authorized to negotiate on behalf of Trustees. However, CERCLA requires coordination with all affected Trustees, and an even greater coordination with federal Trustees, in site characterization, response actions, and settlement negotiations. As part of its response responsibilities, EPA is required to notify Trustees of potential injuries to natural resources from releases under investigation, coordinate assessments, investigations, and planning with Trustees, notify trustees of compliance and enforcement actions affecting injuries to natural resources under their jurisdiction, and encourage the participation of federal Trustees in settlement negotiations (CERCLA §104(b)(2), §122((j)(1), and USEPA,1997d).

Trustees often conduct NRDAs for the purpose of determining the extent and value of injury or loss of natural resources. Some of the ecological studies that support NRDAs may also be useful to Superfund site managers who are conducting or directing RIs, including ecological risk assessments for the remediation process. However, the NRDA's may not be available until after the RD/RA is underway, and may not provide all the information needed by the RPM. Although many data elements will overlap, the objectives of the two efforts are different. Nevertheless, Superfund site managers are encouraged to consult and coordinate with the Trustees when conducting RIs. Often, the information from the RI is available prior to the NRDA, and it is EPA's policy to coordinate the activities in this step with Trustees (U.S. EPA, 1997d). Critical portions of the ecological information from these assessments may be useful to stakeholders in planning for the future use of a site and assessing and recovering damages. EPA typically coordinates necessary assessments with Trustees and provides opportunity for Trustees to comment on work plans, RI/FS reports, remedial alternatives, ARARs, and the proposed plan and ROD (USEPA, 1997d).

EPA has no authority or responsibility to negotiate on behalf of Trustees (USEPA, 1992). The Trustees and other stakeholders may request restoration, replacement, or acquisition of habitat as compensation for damaged resources. These restoration actions become the responsibility of the Trustees or other stakeholders. With proper coordination, however, it may be advantageous to all parties to combine the Trustees' restoration or other actions with remediation-related activities conducted by PRPs or EPA. Such coordination should be planned carefully because CERCLA, as amended by SARA Section 517, places restrictions on the use of Fund monies for NRDAs and subsequent implementation of restoration activities to compensate for damages (USEPA, 1992). In addition, EPA is prohibited from funding, and cannot legally require PRPs or others to incur extra costs beyond those necessary to ensure protection of human health and the environment, as explained in the discussion on "enhancements" in Section 1.4.3. Some extensive efforts to create or restore an ecosystem to exacting specifications may be considered enhancements, unless the need for the restoration is a result of the response actions, such as to repair damage done by excavation for the response action.

2.3.2 Biological Technical Assistance Groups and Other Agencies

A Regional Biological Technical Assistance Group (BTAG) can provide a useful mechanism to advance coordination among different EPA program offices, other federal agencies, and state programs. The BTAG is a group of scientists from EPA and other agencies that provide technical assistance and promote coordination on ecological issues at Superfund sites (USEPA, 1991). Each EPA Region has a BTAG coordinator. Some regions use a different name for the BTAG such as Ecological Technical Assistance Group or Superfund Ecological Assessment Team.

Valuable interagency partnerships have also been developed for coordinating planning efforts at individual Superfund sites. At Loring Air Force Base in northeastern Maine, for example, project managers recognized that large-scale RAs in Greenlaw Brook would severely disrupt sensitive and valuable habitat on the site. During the planning phase, the U.S. Air Force, in conjunction with EPA, U.S. Fish and Wildlife Service (USFWS), and the Maine Department of Environment, developed a Wetland Mitigation Process Plan. This plan outlined strategies for minimizing impacts to wetlands due to RIs and RAs. The plan drew upon the unique expertise and interests of each partner, and established an atmosphere of cooperation between interested parties.

Several government agencies and private interests are involved in cleaning up the Rocky Mountain Arsenal, near Denver, Colorado. Rocky Mountain Arsenal is a large and complex Superfund site covering 27 square miles. Shell Oil Company, the U.S. Army, EPA, the Colorado Department of Health and the Environment, and USFWS are all involved in planning site remediation. To balance the interests of these parties and ensure effective collaboration among them, an engineering group with representation from all five parties meets on a regular basis to coordinate the technical aspects of remedial activities. In addition, a revegetation group addresses planning activities relevant to ecological restoration at the site.

2.4 Site Characteristics That Affect Ecological Reuse

Information on a number of site characteristics is typically used to determine the condition of the site and the potential for ecological reuse. These variables should be considered during the process of planning, designing, and implementing the remediation and reuse projects. The most common variables are listed below.

- **Size of site:** Generally the larger the site, the greater the likelihood that it will contain the minimum acreage necessary to sustain healthy populations of desired species. However, even small spaces can provide valuable green space.
- **Existing habitat at the site:** The less disturbed the existing habitat at a site, the greater the potential for successful ecological reuse.
- **Proximity to existing undisturbed areas:** Natural areas that are adjacent to or near the site can effectively increase the habitat area available for some desired species and improve the ability of the remediated site to sustain healthy populations. Also, less initial planting is required as naturally occurring in-fill by adjacent plant species will tend to occur.
  Surrounding land uses: The impacts of surrounding land use activities (*e.g.*, crop agriculture, grazing, urbanized areas) can significantly affect the potential for restoring a functioning natural system at the site.
- **Topography:** It is often challenging to establish viable habitats on sites with very steep slopes or other extremes in topography.
- **Hydrology:** Sites where a natural water supply is available, or can be reestablished, tend to have greater potential to achieve a natural, self-sustaining system than sites where engineering structures will be needed to manage water flows.
- **Access to the site:** A site's potential to achieve the expected natural functions is improved where public access can be managed through institutional controls (ICs) or other measures (*e.g.*, to prevent future damage from off-road vehicle use).

- **Biodiversity:** An ecosystem's functions can be enhanced by incorporating features to ensure a minimum habitat size, such as habitat corridors. The importance of biodiversity to local and regional ecosystems is discussed above (Section 2.1.1).
- **Contaminant bioaccumulation:** The ecological impacts of the accumulation of certain contaminants in the tissues of organisms is discussed above (Section 2.1.2).
- **Indicators of health of species and ecosystems.** Measures, such as the baseline ecotoxicity levels and post-construction levels anticipated are used.
- **Threatened or endangered species.** These species will require special attention to ARARs, such as the Endangered Species Act or state endangered species acts.

Information on these variables can contribute to the evaluations of the availability of food, water, shelter, and living space, all of which vary by species. Some wildlife require running water, some require stagnant water, and some get their water from dew. Shelter is needed to provide protection from predators and the weather as well as areas for feeding, breeding, and resting.

A restoration ecologist may be needed to evaluate this information. The primary sources of data on these variables are the ecological risk assessments prepared as part of the Superfund process, NRDAs, and other studies prepared by Trustees and other parties. The ecological risk assessment typically identifies key contaminants and ecological receptors of concern including threatened and endangered species; critical habitats and wildlife migration corridors; and ecotoxicity values for the receptors of concern. Other assessments of natural resources at a site are often conducted by Trustees, such as the Department of Interior (DOI). These studies can be used to identify and describe environmental resources and constraints and to ensure that the remedy and the selected reuse minimize disturbance to ecological receptors, critical habitats, and historic resources.

Redevelopment of urban sites generally employs the same general considerations discussed above. Urban sites may also require special considerations in the selection of species and habitat design. Many urban waste sites are small, which calls for species that do not require large territories. Other urban and suburban sites, such as old landfills, shoreline, and riverside properties, may be the largest remaining tracts in the area. Urban areas may be subject to heavy runoff containing high concentrations of pollutants, because of an abundance of impervious surfaces, such as roads and parking lots. Furthermore, ecologists must consider that ambient air temperatures in urban areas are often warmer than in rural areas. A number of ecologists have examined the types of species and habitat design considerations for urban areas, and sources for further information are included in the References, which begin on page 61 (Clemants, 2002; Robinson and Handel, 1993; Handel, 1997 and 2003).

2.5 Site Configurations

Remediation approaches and the potential for ecological reuse differ according to whether the contaminated materials are left in place, placed in a new containment system created as part of the RA, or treated over time with special structures or equipment that remain on site after the initial remedy construction is completed.

2.5.1 Closed-in-Place Sites

Sites where the materials are left in place, primarily include municipal or industrial landfills, some large surface impoundments, and mine tailings accumulations. Site managers and developers for many of these sites have to deal with conditions such as the potential for substantial subsidence or differential settlement, gas production, and very hazardous materials remaining on site. These facilities frequently lack bottom liners and, if covered, the covers may be poorly designed. There are generally few remedial options for old landfills and other existing waste depositories that are to be closed in place. The presumptive remedy for these sites involves containing the waste, installing a protective cover, treating or controlling contaminated groundwater, leachate, and gas, and implementing institutional controls (U.S. EPA, 1993c). Key ecological issues at these types of sites include the types of vegetation over and near areas containing waste, the management of groundwater and surface water, the presence of gases, and settlement. These issues, and other concerns are discussed in Section 3.

Many closed-in-place sites have been developed into ecological reuse areas. For example, the Bowers Landfill in Pickaway, Ohio now contains meadows and a wetland that are habitats for waterfowl and other species. At the Fresh Kills Landfill in Staten Island, New York, the largest municipal landfill in the world, grass, shrubs and trees with shallow root systems have been planted in about two feet of fill placed above the landfill cover. The trees are attracting birds, which are expected to carry seeds from the surrounding area, thereby increasing the biodiversity of the area's flora. Once the vegetation is established, hiking and biking trails are planned.

There are a number of mining sites, especially in the West, where extensive tailings deposits have not been removed or fully treated in place. These tailings often contain levels of metals that are sufficiently high to be toxic to both flora and fauna, leaving the area a virtual wasteland. By covering and/or amending the surficial tailings with a mixture of biosolids, lime, or other materials that will increase the pH, EPA and its partners have been successful in providing a root zone that will support native plants as well as greatly reduce the bioavailability of the metals. At Leadville, Colorado large tracts of tailings that previously did not support plant life have now been turned into meadows using composted biosolids and lime, which allow for a more hospitable growing environment. The soil amendments reduced toxicity by immobilizing the metals, increasing fertility, and raising the pH. While the materials beneath the cover layer remain toxic and should not be disturbed, the meadowland plants provide cover and safe food for a variety of animals.

2.5.2 New Containment Systems

New containment systems generally are those that are created as part of the remediation. These systems range from simple unlined pits with covers to highly engineered depositories into which waste from the site or other sites are consolidated. A new containment system may also include material that has been solidified or stabilized ex situ. High-hazard wastes are generally treated or sent to an off-site commercial disposal facility and not placed into new containment systems.

Engineered containment systems generally do not have serious differential or general settlement, subsidence, or gas production problems. As part of good construction practice, the materials should be compacted as they are placed into this type of containment system. A minimum amount of compaction may be necessary to minimize settling of the cover. A 2002 EPA report, *Reusing Superfund Sites: Commercial Use When Waste is Left On Site* (EPA, 2002), discusses factors to consider if additional compaction is required to accommodate structures.

When addressing new containment systems, EPA site managers generally have more flexibility in deciding which materials will remain on site and in designing and locating containment areas than they do with existing waste depositories. This flexibility generally allows for a greater range of development options. In designing cleanups, the site manager generally considers factors such as the types of contaminants, their stability, the media through which they travel (*i.e.*, air, soil, groundwater), and the anticipated future land use. For example, engineered containment areas could be located where they will not interfere with ecological functions and structure. At the Cherokee County Galena Subsite in Cherokee County, Kansas the remedy included consolidating surface mine wastes in abandoned mine pits, mine shafts, and subsidence areas where they could be covered with clean soil and the surface could be recontoured and planted with specially selected mixtures of native prairie grasses. The tall, wavy grass now harbors birds and small mammals, has improved the aesthetics of the area, and controls run off and erosion.

Native Grasses thrive in clean soil placed above consolidated mine wastes at the Cherokee County, Kansas site

Another approach to protecting the contaminated material from periodic events such as flooding is to place clean fill above it so that flood waters will not pool on top of the cover, and use vegetation, riprap or other appropriate surface material to hold the fill in place. At the Ohio River Park Superfund site in Neville Island, Pennsylvania, an average of eight feet of fill was placed on parts of the site to raise the elevation above the 100-year flood plain. This fill is designed to protect subsurface materials from erosion and to provide a clearance of clean soil in which to place utilities. When these types of approaches are used, a good safety measure is to place visible barriers, such as colored soil or brightly colored synthetic geotextile material, between the contaminated material and the clean fill to act as markers for future workers.

Building new containment systems usually effectively removes existing biota. Revegetation over containment areas or treatment systems must not detract from the effectiveness of the remedy. Features that could damage the containment system or attract nuisances, should be avoided. For example, some deep-rooting plants can damage a protective cap and some plants can attract burrowing animals. There should also be enough soil above the protective cover to allow for the intended vegetation. The containment system can be designed to discourage wildlife from coming into contact with the contaminated material or from damaging a containment area. At Rocky Mountain Arsenal, project managers are designing biota barriers to keep burrowing animals, such as badgers and prairie dogs, away from the containment areas. These concrete cobble barriers are installed around landfills and other containment areas on the site.

Section 3. Remediation Considerations for Ecological Reuse

There are numerous site remediation approaches that can be used to ensure that contaminated material left on site is managed and contained in a manner that protects human health and the environment, complies with federal, state, and local cleanup requirements, and allow for safe ecological reuse. The most common methods are cover systems, gas collection and treatment systems, groundwater collection and treatment systems, permeable reactive barrier walls, and diversion walls. Each of these methods can impact ecosystems such as wetlands, streams, and other areas to be vegetated.

Key remediation issues for ecological reuse sites:

- Common containment system components
- Remediation technologies
- Remedy planning and design
- On-site waste treatment and monitoring
- Minimizing damage from construction
- Ensuring the short-term and long-term effectiveness of the remedy

3.1 Containment System Covers

Cover systems at containment sites are generally used to minimize the infiltration of water into the contaminated material and to serve as protective barriers to isolate contaminants from the public and the environment. CERCLA requires that cover systems at Superfund sites attain, at a minimum, applicable or relevant and appropriate requirements (ARARs). Common ARARs for containment systems are regulations promulgated under Subtitles C and D of the Resource Conservation and Recovery Act (RCRA) and state regulations when they are more stringent. Although cover systems at Superfund sites are not necessarily based on RCRA closure regulations, RCRA requirements are the prevalent basis for cover system design. RCRA and state regulations generally require that the cover be built to:

- minimize the migration of liquids over the long term,
- function with minimum maintenance,
- promote drainage and minimize erosion, and
- accommodate settling and subsidence.

EPA encourages flexibility in the design of waste site covers. They can range from a simple soil or asphalt layer to protect people from contact with the contaminants, to multi-layered composite caps often used for more demanding situations. General design requirements are based on federal and state criteria.[2] Cover systems can utilize one or more of the following types of barriers:

[2] For example, the RCRA Subtitle C closure requirements for hazardous waste management facilities (40 CFR 264.10).

Hydraulic barriers, the most common of the five cover types, use low-permeability material to impede the downward migration of water. They are usually multi-layered systems that typically incorporate geomembranes, geosynthetic clay liners, compacted clay liners, or a combination of these. These systems may also include features such as a gas venting layer, biota layer to prevent damage from burrowing animals or plant roots, drainage layer, and a soil and vegetative or other top layer. Multi-layered hydraulic barriers are used at many RCRA Subtitle C and D facilities.

Placement of a geotextile layer at the Loring Air Force Base site

Capillary barriers are intended for use in arid to semi-arid climates where unsaturated soil conditions prevail. This type of cover exploits the difference in pore water pressure potential between fine and coarse grained soils to limit the downward movement of water. A simple configuration of this type of cover system consists of a fine-grained soil (clay) layer located over a coarser-grained soil (sand) layer. Under unsaturated conditions the fine-grained clay holds water, preventing its downward movement. As the top layer becomes saturated, it releases water to the lower layer.

Evapotranspiration barriers are also used predominantly in arid and semi-arid areas. This type of cover generally consists of a thick layer of relatively fine-grained soil which is capable of supporting vegetation. It provides sufficient water storage capacity to prevent water from moving into the waste area and contains the water until it is removed by evapotranspiration.

Direct contact barriers provide a physical barrier over contaminants that are contact or ingestion hazards. They are typically up to three feet thick, but can be thicker. They also provide protection against erosion and shallow digging. Soil covers are often economical because they typically consist of low-cost fill materials covered with a few inches of topsoil to support vegetation. These types of covers are commonly used with contaminated soil that has been stabilized or material that is unlikely to migrate to groundwater, such as low-solubility metal or asbestos.

Amended waste covers are used when the contaminant mass is too large to move and when it would be impractical or ecologically damaging to provide a sufficient quantity of borrow soil to cover the contaminated material, such as on some areas containing mine tailings. The amendments may include mixtures of biosolids, wood chips, other organic matter, and lime or other material that will raise the pH. These mixtures will support plants which, in turn, reduces water and wind erosion and decreases the bioavailability of the metals. Amended covers are not a barrier against burrowing animals, but they do reduce contact exposure for larger animals and birds while providing them with a stable ecosystem.

Depending on site-specific conditions, cover systems may be composed of multiple layers of natural and/or synthetic materials, each designed for one or more specific purposes, such as gas control, internal drainage, and vegetative support. In addition, the impact of cover systems on the local stream flows should also be considered. The References (page 61) lists a number of EPA documents that address cover system function and design.

3.2 Other Containment System Components

Liner systems are barriers that are typically constructed at the bottom of containment cells to prevent the migration of contaminants to the environment. Liner systems prevent leachate and gases produced in the subsurface from contaminating adjacent soil and groundwater. Liners usually consist of hydraulic barriers fabricated with clay or geomembranes, depending on local geology and environmental requirements. Most waste depositories in the Superfund program, such as old landfills, do not have liners.

Leachate collection systems control the movement and prevent the buildup of leachate within a containment system. Leachate is produced when water percolates through contaminated material and carries biological and chemical constituents into the bottom of the containment system. These containment systems typically consist of high hydraulically conductive soil (*e.g.*, sands and gravels) and perforated pipes located between the contaminated material and the bottom liner. Leachate collection systems are typically sloped one to five percent toward a sump. A pump is used to extract the leachate from the sump. Most old containment systems at Superfund sites do not have leachate collection systems.

Gas collection systems are incorporated into the cover system to control the movement and prevent the buildup of harmful gases within the containment system. Gas collection and treatment systems are generally associated with sites that have decaying organic matter, such as municipal landfills. Two common types of systems are passive and active. Whether these systems are complex or simple, the location of vents, discharge points, and treatment systems can generally be chosen so that they do not interfere with the ecological use of the property.

3.3 Associated Remedial Technologies

Several remedial technologies can be used at a site alone, or in conjunction with a cover system remedy. Because groundwater contamination is present at most Superfund sites, the majority of these technologies are for groundwater remediation. The following are some of the more common types of technologies associated with containment systems.

Groundwater Extraction and Treatment Systems. Groundwater extraction and treatment systems, also referred to as pump-and-treat systems (P&T), are used to remove contaminated groundwater to above-ground facilities for treatment. P&T systems typically consist of extraction wells or french drains. Extraction wells can be deployed in most hydrogeologic situations, while french drains are generally limited to shallow, low hydraulic conductivity aquifers. There are a number of additions and variations to a typical P&T system that can enhance performance or target other media such as soil. They include in-situ technologies, such as dual phase extraction, soil vapor extraction, and air sparging; and ex-situ technologies, such as air stripping, carbon adsorption, metals removal, and biological treatment.

P&T systems cause less surface disruption than excavation. However, if not designed carefully, overpumping can cause adverse effects on existing and anticipated habitat. Overpumping occurs when groundwater is extracted at a greater rate than it can be replenished or naturally recharged. Some important design considerations for P&T remedies in ecological reuse areas are preventing the dewatering of wetlands (*i.e.*, resulting from lowering of the water table), avoiding alterations in site hydrology (*e.g.*, stream flow reduction which can also result from a lowering of the water table), preventing land subsidence, and managing the discharge or disposal of treated water (USEPA, 1993b). In cases where process water is discharged to surface waters, site managers should consider the ecological impacts of the discharge. Compliance with discharge permit provisions, where they are required, does not guarantee that there will not be any adverse impacts on sensitive species in wetlands or streams. The discharge of large quantities of water may result in changes in water depth, turbidity, circulation, and temperature. Species that cannot adapt to these changes may disappear. To mitigate these potential effects, measures, such as the use of settling basins, can be employed to moderate discharges to wetlands and streams.

Although subsidence is more often associated with large well fields than with P&T systems, it is potentially an issue with larger P&T projects. Subsidence typically occurs slowly and often can affect a large area around a P&T system. It can alter site hydrology by increasing or decreasing stream gradients and changing stream flow. Such alterations in hydrology can result in loss of in-stream or riparian habitat, and alter the water flow into wetlands, thereby impairing their function. To avoid overpumping, RPMs should design a pump-and-treat remedy so that the aquifer's recharge rate at least equals the rate of groundwater withdrawal. Methods are available to estimate the extent of water table drawdown and land subsidence that will result from the groundwater extraction. Additional information on characterizing aquifer hydraulic properties and pump-and-treat guidance is available in EPA's *Presumptive Response Strategy and Ex-Situ Treatment Technologies for Contaminated Groundwater at CERCLA Sites* (USEPA, 1996a).

In addition to wells and drains, collection and treatment systems require piping, utilities, and on-site or off-site treatment facilities. Access for operation and maintenance (O&M) may be needed throughout the life of the systems, which may be in place for many years. Careful consideration of the location of treatment wells and equipment can help maximize the potential for habitat formation and biodiversity, and minimize the disruption from future maintenance activities. To the extent that the site manager has flexibility in placing this equipment, he/she may consider potential ecological reuse scenarios or land use plans, if any are available. For example, based solely on engineering criteria, the optimal location for an on-site water treatment plant at the Petro-Chemical Systems, Inc. (Turtle Bayou) Superfund site in Liberty County, Texas, was in a grove of live oaks. These 150-year-old live oaks, which form the backbone of a unique ecosystem that provide habitat for plants and animals on site, are sensitive to physical disruption around the root zone. To prevent damage to the live oaks and the unique ecosystem they support, the water treatment plant was located in an abandoned rice field about 1,000 feet away, where the ecological impacts would be comparatively minimal. The ecological benefits were significant enough to justify the additional expense.

In-Situ Treatment. In-situ treatments use biological, thermal, and physical/chemical processes to treat contaminated material in place, without excavation. Because in-situ treatments require less surface disruption, they allow the preservation of critical ecosystem components, such as vegetation and topsoil. For example, at the French Limited Superfund Site in Harris County, Texas, the use of in-situ bioremediation enabled the project manager to minimize disturbance to the surface, thereby preserving site topography, existing vegetation, and natural drainage patterns. This approach allowed the site to be used as a freshwater wetland.

Some in-situ treatments require the addition of amendments, such as aqueous extracting solutions, nutrients, or chemicals to the contaminated media. Project managers should evaluate their effects in the subsurface, their potential for eventual transport to surface waters, and their possible subsequent adverse effects on plant and animal communities.

Diversion Walls. Diversion walls are below-grade vertical structures designed to divert groundwater flow away from contaminated material or to contain contaminated groundwater. Diversion walls can be grouped into three types: sheet pile, grout, and slurry. Of the three types, slurry walls are the most common. These structures are also used in conjunction with covers to fully confine a waste area and to prevent clean water from leaching through the material. Diversion walls are generally, but not always, associated with groundwater pump-and-treat systems and wells used to monitor the continued effectiveness of the remedy.

While the walls themselves leave a relatively small footprint and are low maintenance, the pump-and-treat system will have to be designed carefully for an ecological setting. To avoid permanent damage to the flora, fauna, and water resources, the project manager should consider the potential impact of the location of these walls. For example, barrier walls can be placed near the edge, rather than through, a valuable habitat. Also, to allow for access to a well or wall for maintenance, it is important to not allow deep rooted vegetation to establish itself near the wall.

Solidification/Stabilization. Solidification and stabilization (S/S) involve modifying the physical and/or chemical properties of the contaminated material to improve its engineering or leaching characteristics, or to decrease its toxicity. Solidification encapsulates contaminants into a solid material of high structural integrity. Stabilization converts waste contaminants into a less soluble, mobile, or toxic form. S/S can be done either in situ or ex situ. Ex-situ processing involves (1) excavation to remove the contaminated material from the subsurface, (2) sorting to remove large pieces of debris, (3) mixing with an S/S agent, and (4) delivering the treated material to molds or trenches, or for subsurface injection. In-situ processing entails merely mixing the material with an S/S agent. Some types of waste require solidification or stabilization prior to being placed into a containment system or covered by an engineered cover system. If ex-situ S/S is used, the RPM has the choice of returning the treated material to the original excavation or placing it in another excavation at a different part of the site. The location of this material may significantly affect the type and amount of habitats that can succeed on the site.

Permeable Reactive Barrier Walls. Permeable reactive barrier (PRBs) walls are used to treat contaminated groundwater. Reactive material is placed in the subsurface in the path of the plume. As the groundwater flows through the material, contaminants are destroyed or made insoluble, and treated water flows out the other side of the barrier. Compliance monitoring wells are usually installed downgradient from PRBs to ensure they are meeting cleanup goals. They may also have performance monitoring wells placed within them to evaluate changes in physical and chemical characteristics over time. To allow for these sampling activities and the potential need to replace or repair the reactive materials, access to the wall and monitoring wells is required until the cleanup is complete.

Phytoremediation. Phytoremediation is an emerging group of technologies that uses the natural processes of plants to remediate or stabilize hazardous materials in soil, sediment, sludge, and groundwater in situ. This technology makes use of plant biochemistry to contain, degrade, destroy, or remove contaminants. Phytoremediation is a broad term that refers to several physical and biological processes. Phytoremediation treatment systems can be an integral part of the ecosystem only under very specific conditions. For example, phytoextraction and rhizofiltration involve the uptake and capture of contaminants (mainly metals and radionuclides) by roots, limbs, and leaves. Unless these plants are harvested, they may become an attractive hazard to some species, since the contaminants can become bioavailable to herbivores. Harvesting of plant materials typically will result in habitats of low or impaired ecological function. On the other hand, phytodegradation and rhizodegradation, such as occur with poplars and trichloroethylene (TCE), minimize the bioavailability of the contaminant and eventually transport it through the plant into the atmosphere where it has a short half-life. Thus, not all of the phytoremediation processes are appropriate for ecological reuse.

Phytoremediation has been undertaken on a demonstration- or full-scale basis at more than 200 sites nationwide (EPA, 2001g). Although the use of this technology, which was first tested actively at waste sites in the early 1990s, has been growing, it is still limited to a minority of sites. It is most effective for sites that have relatively low concentrations of contaminants at shallow depths over a large area. Plant species, which are selected on a site-by-site basis, can include hybrid poplars, willow, and cottonwood trees; grasses, such as rye, Bermuda, sorghum, and fescue; legumes, such as clover, alfalfa, and cowpeas; aquatic and wetland plants, such as water hyacinth, reed, bullrush, and parrot feather; and hyperaccumulators for metals, such as alpine pennycress for zinc or alyssum for nickel.

> At the Aberdeen Proving Ground Superfund site in Aberdeen, Maryland, hybrid poplar trees were planted on a one-acre area to remediate plumes of chlorinated hydrocarbons in groundwater. TCE is the principal contaminant and an examination of tree tissue shows the metabolic degradation products of TCE (chloral hydrate, trichloroethanol, and di- and trichloroacetic acid). There is also evidence of minor transpiration of the TCE into the atmosphere. Since the planting, TCE concentrations in the groundwater downgradient of the trees have fallen since they were planted.

Phytoremediation, where it is viable, offers several advantages. It does not require excavation of soil and its application may require only minimum materials handling. In some cases, the technology can destroy most or all of the pollutants, and require no or few institutional controls (ICs). Phytoremediation may also be used as an interim measure to contain contaminants and begin treatment, while a permanent remedy is being planned. Phytoremediation systems, which are placed and maintained using traditional agricultural or landscaping equipment and practices, are typically less expensive to install and operate than many other remediation alternatives. The plants can be integrated into natural environments, such as wetlands, forests, and grasslands, and arranged to be unobtrusive and aesthetically pleasing. Plants used in phytoremediation may also provide other ecologically beneficial functions, such as riparian buffers which can protect streams from non-point source pollution, stabilize the stream banks, and provide a wildlife habitat.

There are a number of technical and practical considerations that may limit the viability of phytoremediation at many sites. It is an emerging technology, and more information from treatability studies and long-term field applications is needed to support its use at some sites. It is advisable to consult with technical experts to determine its applicability on a site-by-site basis. Several EPA publications provide information about the application and limitations of these processes and sources for technical support (USEPA, 2001g; USEPA, 2003; RTDF, 2004).

3.4 Remedy Planning and Design Issues

A number of factors considered during the application of any cleanup technology can affect the effectiveness of the remedy and the redevelopment of a property. These factors include settlement, subsurface gases, utilities, surface vegetation, surface water, and institutional controls (ICs). By carefully accounting for these factors, site managers can ensure that implementation of any remedy minimizes potential damage to the future use of the site.

Settlement. Settlement may cause damage to containment systems, alter slopes, cause gullies to form, and disturb other site features. It is primarily an issue at closed-in-place sites, such as old landfills. Studies show that municipal landfill sites generally settle from 5 to 20 percent of the landfill depth over a 15 to 30 year period, and some have settled as much as 30 percent. Settlement is primarily attributed to consolidation of subsurface materials under the weight of the materials, and cover system above it, and chemical and biological degradation of subsurface material. The magnitude, distribution, and rate of settlement are governed by several factors such as material and soil type, age, density, thickness, manner of placement, and moisture content.

The first step in addressing settlement is to consult with a geotechnical engineer to estimate its magnitude, distribution, and rate. CERCLA guidance recommends that the remedial design consider estimates of the rate of settlement (USEPA, 1995c). These estimates can be used to determine if any special design features are needed for the cover or other remedy components. The rate and magnitude of settlement may also affect the type of habitats that will be successful at the site. Regular inspections and repair of settlement damage may require human intrusion into ecologically sensitive areas. The ecological reuse plan should allow for such access.

Several methods are available to reduce the potential for damage due to settlement. When severe settlement is expected, the construction or reuse project can be delayed until settlement has largely ceased. A variation on this approach is to install an interim cover that protects human health and the environment or arrange for temporary uses of the area, such as a nurse crop like annual rye grass, to control erosion and provide green space. Then, when settlement is essentially complete, the interim cover could be replaced or incorporated into the final cover.

Several construction techniques, such as accelerating the consolidation of the subsurface materials through various forms of preloading, vibrocompaction, and dynamic compaction are available to allow acceleration of remedy construction. Although these techniques are primarily used at sites designated for commercial or recreational reuse, they may be useful at some ecological reuse sites. These approaches, however, will not sufficiently affect settlement caused by biodegradation.

Managing Gases. Depending on the waste composition, some containment sites, primarily but not exclusively landfills, have the potential to generate gas. If not properly controlled, gas could damage the cover system, infiltrate buildings, provide fuel for fire or explosion, stress vegetation, and pose other health or safety hazards. In planning for reuse, it is important to determine the ability of subsurface materials to generate gas and the rate of generation. The quantity, rate, and type of gas generated at a site are primarily dependent on the composition, age, and volume of the waste, and moisture conditions. Gases can contain methane, carbon monoxide, nitrogen, sulfur, volatile organic compounds, and other compounds (USEPA, 1991c).

Control systems can be developed to minimize any adverse affects on the planned vegetation and wildlife. Gas collection systems can be built into the containment system and gas protection incorporated into structures placed on or near the containment system. Examples of gas protection techniques for buildings are provided in the EPA report *Reusing Cleaned Up Superfund Sites: Commercial Use Where Waste is Left On Site* (USEPA, 2002). Gas collection systems can include subsurface piping, and wells and vents that extend through the cover system to discharge gases to the atmosphere or a treatment system. These components can be placed where they will not interfere with planned uses, minimize noise, odors, and other disamenities, and where they are less likely to be accessible to potential trespassers, vandals, or wildlife.

Utilities. Some sites being used for ecological purposes may need to contain underground or above ground utilities, such sanitary sewers, water, telecommunications, natural gas, and electricity. Utilities can impact the effectiveness of the containment system in the following ways:

- A utility line can become a conduit for gas migration.
- A utility structure that penetrates the cover system can serve as a conduit for water infiltration into the waste.
- If the utility is located within or below the cover system, repair or upgrade work would also require excavation into the cover and contaminated material.
- If the utility is located within or below the cover system, liquids leaked from a sewer or water lines can increase the quantity of leachate generated. Leakage from a sanitary sewer located above a cover’s hydraulic barrier layer might cause excessive bio-fouling of drainage media.
- Differential settlement of the waste can result in damage to the utility.

Should utilities be included on the site, special provisions will likely be needed to ensure that they do not hinder the effectiveness of the remedy or ecosystem functions. For example, burying a utility line in a protective cap or placing it in an area to contain woody trees should generally be avoided. A number of other approaches are enumerated in an EPA report *Reusing Cleaned Up Superfund Sites: Commercial Use Where Waste is Left On Site* (USEPA, 2002).

Surface Vegetation. Vegetation is usually important to both the operation of the cover system and to the structure, function, and aesthetics of the post-cleanup ecosystem. The vegetation used on the cover system can serve several purposes, including limiting soil erosion, promoting evapotranspiration and surface water management and, in some cases, phytoremediation.

The type of vegetation that will thrive at a site depends on the local climate, soil, and native plants and animals, and types of containment system. It is usually preferable to use mixtures of native plant species, since they are acclimated to the area, usually grow well and, once established, require little or no irrigation, fertilization, or other maintenance. Executive Order 13112 promotes the use of native species for federally funded projects that involve revegetation and landscaping.[3] The selection of vegetation should also consider potential unintended consequences of some species. For example, deep-rooted plants, such as some trees and shrubs, typically have not been used on cover systems because of the potential that roots would damage the cover or grow into the contaminated material. However, if properly accounted for in the design, a containment system can support a variety of vegetation including woody species. Such species may require modifications to ensure the integrity of the cover, such as thicker soil layers, biota barriers, and drainage features. Some plant species may attract wildlife species that are particularly sensitive to the pollutants or that may overpopulate an area.

Channel for draining surface water away from containment areas at the Cherokee, Kansas site

Construction activities can also significantly affect vegetation. Excavations and the placement of staging areas, access roads, and treatment systems can be conducted so that they minimize disturbance to existing plant life and allow for the planting of additional vegetation.

Surface Water Management. Surface water runon and runoff can erode the top layer of a cover system, percolate into a cap, and impact nearby vegetation, streams, lakes, and wildlife migration routes. To manage surface water on cover systems, engineers typically grade the cap to establish an effective slope (usually 3-5

3 Chapter 6, Terrestrial Ecosystems and Superfund Remediations, provides more detail on selecting grass seeds and other plants for the revegetation of disturbed areas.

percent), and/or build drainage channels and swales to prevent runon and direct the path of runoff. Surface water controls also typically include provisions for periodic inspections of flat areas to detect pooling of water.

Another key design consideration is the impact of the containment system on area hydrology. Protective caps designed to prevent precipitation from infiltrating into the subsurface can cause additional surface water run off from the containment area. Run-off controls and water diversions implemented as part of a remedy can influence water tables and the rate of flow into streams or wetlands. Depending on the site, reduced flows can result in water losses to adjacent wetlands. Increased flows can magnify flooding, and cause sedimentation in wetlands and streams.

Measures to reduce adverse impacts on site hydrology include routing runoff through settling basins to collect sediment, and constructing runoff controls to reduce the volume and rate of runoff to low-lying areas, wetlands, or streams. Where possible, diversions can be designed to minimize changes to natural drainage patterns or the quantity of surface water flows to wetlands or streams (USEPA, 1993b). Similar considerations may be necessary to mitigate the impacts of temporary disruptions to the ecology created by remedy construction.

Other Design Considerations. In addition to utilities discussed above, some ecological reuse sites will contain structures needed for maintenance, restrooms, utilities, or other purposes and paved surfaces such as parking lots and roads. For the most part, structures in ecological reuse areas are small and light. If a structure is to be placed over an area containing hazardous materials, several considerations become important. Differential settlement can cause structural damage. Gases from subsurface materials can penetrate a building and present health hazards for building occupants, and a structure can alter surface water flow and habitat migration patterns. Additional detail on the placement of structures on containment areas can be found in the EPA report on commercial reuse of Superfund sites (USEPA, 2002).

3.5 Minimizing Ecological Damage During Remedy Construction

Remedial actions that include excavation of soil and wastes often require earthmoving equipment and large staging areas. Because construction activities often disrupt the surface area of a site, they can cause considerable loss of existing habitat. Surface disruptions can create conditions conducive to erosion and sedimentation as well as colonization by undesirable invasive and exotic plant species. These disruptions may also affect groundwater and nearby surface waters. Although the depth of excavation differs from site to site, excavation usually removes the productive layer of topsoil, which contains seeds, roots, and organic material, essentially sterilizing the site. Site managers could take steps to minimize excavation and other surface disruptions, avoid erosion and sedimentation, and protect the existing flora and fauna. A number of considerations for ensuring that construction activities minimize adverse ecological impacts and contribute to the protection or creation of habitats are discussed below (USEPA, 1993b; NRC, 1992; Kent, 1994).

Design a Site-Wide Work Zone and Traffic Plan. Construction staging areas, work zones, and traffic patterns should be delineated to minimize unnecessary disruption of sensitive areas and existing habitat on or near a site. Areas not requiring surface disruption and areas off-limits to disturbance, such as steep slopes, sensitive habitats, and clean stream corridors, should be clearly delineated with fences, tape, or signs to avoid disturbance by site workers and equipment. At the Rocky Mountain Arsenal, project managers recognized that remediation-related traffic and road building could have major impacts on the existing habitat at the 27-square-mile site. To facilitate reuse of the site as a wildlife refuge, they developed a site-wide traffic plan that routed traffic around valuable habitat and sensitive areas, minimized the potential for erosion and sedimentation, and used existing roads wherever possible.

Minimize Excavation and Retain Existing Vegetation. Earthmoving can destroy the roots of trees and other plants as well as disturb vegetation in uncontaminated areas. These activities can be restricted to areas essential for remedy construction and avoided in all other areas. Some areas with low contamination levels or immobile contaminants may be better off if left undisturbed, if the disruptive impacts of excavation outweighs the benefits of further cleanup, especially in valuable habitats (USEPA, 1997a).

Common Measures to Minimize Damage to Vegetation During Excavation:

- Confine road building, grading, and other activities that require earthmoving to areas essential for remedy construction.
- Protect existing vegetation from construction activities with fencing, tree armoring, or retaining walls. Route construction traffic to avoid existing vegetation.
- Avoid disturbing vegetation on steep slopes or other sensitive areas where revegetation tends to be difficult.
- Create buffer zones of existing or additional plants to help control erosion and other impacts from surface disruption.
- In some cases, hand digging may be warranted around especially valuable, mature trees.

RPMs at the Rocky Mountain Arsenal site, after conferring with USFWS biologists, left areas within the drip line of trees bordering contaminated areas undisturbed. At the Myers Property Superfund site in Hunterdon County, New Jersey, RPMs are saving existing trees above a certain size in areas with low levels of contamination by hand digging around the roots to a level of six inches. Excavated soil will be replaced with clean topsoil from off site. The site will be monitored in case large trees fall and expose soils deeper than six inches.

Phase Site Work. Sometimes construction can be phased so that one area of the site can be stabilized before another is disturbed. In addition to limiting the amount of disturbed area at any one time, this approach may also reduce the total soil erosion for the entire site. It also allows for revegetation or redevelopment of some areas as soon as they are cleaned up, while remedial construction is proceeding in other areas. The construction can be scheduled to minimize the area of soil exposed during periods of heavy or frequent rains. Project managers at the Rocky Mountain Arsenal site, suspended remedial activities during certain seasons to avoid disturbing the nesting and breeding of sensitive species, such as the bald eagle.

Protect On-Site Fauna. In some cases, on-site fauna are temporarily relocated during site remediation. Relocation may require humane trapping and release, but can also be accomplished through less disruptive techniques. To relocate beavers and alligators at the French Limited site in Harris County, Texas, for example, project managers reduced their food supply in areas to be treated and increased the food supply in other suitable areas of the site.

Locate and Manage Waste and Soil Piles to Minimize Erosion. Waste or soil piles may be created to temporarily store contaminated soil for treatment or to store treated soil that will be re-deposited. To minimize disruption of the local habitat, stockpiles should be structured to minimize runoff, located away from steep slopes, wetlands, streams, or other sensitive areas, and covered or stabilized to control erosion and dust.

Reuse Indigenous Materials Whenever Practical. Reusing logs, rocks, brush, or other materials found on site can provide logistic, cost, and ecological advantages. Topsoil from on-site sources is usually well suited for supporting native vegetation. Treated soil and other materials can also be used as backfill, thereby reducing the need for borrow areas. At Loring Air Force Base, in Northeastern Maine, for example, boulders and cobbles from the streambed and nearby trees larger than 15 centimeters in diameter that were removed during remediation were later used in stream reconstruction, after completion of RA. Reuse of native materials at Loring significantly reduced both the cost of materials and impacts from heavy trucks.

At the Loring Air Force Base site, workers used on-site materials to build a log bank

Control Erosion and Sedimentation. Erosion and sedimentation control measures are usually needed to avoid disruption of sensitive areas, even when they are not required by state or local regulation. These measures can include retaining sediment on site, and managing runoff.

Ensure that Borrow Areas Minimize Habitat Impacts. Borrow sites should be located and used with ecological reuse objectives in mind. Borrow sites can be located in low-value areas and designed, contoured, and vegetated to meet aesthetic and habitat considerations. Based on consultations with the USFWS, project managers at the Rocky Mountain Arsenal designed borrow sites to establish the future habitat of a planned wildlife refuge.

Avoid Introducing New Sources of Contamination. If not properly managed, remediation activities can introduce new sources of contamination. Contamination can result from materials used on site, fugitive dust emissions, and operations of equipment and sanitation facilities. Materials that can cause contamination include pesticides, herbicides, fertilizers, petroleum products, treatment agents, and solid wastes. Storage areas should be sheltered from the elements, lined with plastic sheeting, surrounded by berms, and regularly inspected for releases. Equipment maintenance should be done in suitable staging areas and adequate sanitation facilities for site workers should be provided and not located near streams, wetlands, and other sensitive areas.

Prevent the Introduction of Undesirable Species. Non-native plant species can invade and destroy native species. Barren and disturbed, which are susceptible to colonization by undesirable plants, should be monitored and undesirable species removed where necessary.

Develop and Communicate Ecology Awareness and Procedures. Contractors and construction engineers are often not cognizant of sensitive ecological areas nor aware that they should minimize site disturbance and protect site ecology. A site preservation policy should be articulated and distributed to everyone involved with on-site activities.

3.6 Operation and Maintenance

Operation and maintenance (O&M) protect the integrity of the remedy and the functioning of the associated ecosystems after the construction of the remedy is complete. O&M related to the reuse project is usually the responsibility of Trustees or other stakeholders. The responsibility for O&M related to the remedy usually falls to the PRPs, federal facility, state, or EPA, depending on which is the lead agency for the RA. There are four major areas of consideration for a successful O&M program: planning and designing for future O&M needs; specification of which remedy components require O&M; monitoring of ecosystems and remedy features; and ICs.

3.6.1 Planning and Designing for Stewardship

Preparation for safeguarding the effectiveness of the remedy should begin as early in the remedy planning process as possible to allow time for EPA, Trustees, and other stakeholders to coordinate and plan the specifics of the institutional controls and O&M. O&M measures related to waste containment and control are generally initiated after the remedy has been constructed and is determined to be operational and functional (O&F) based on state and federal agreement. For Fund-lead sites, remedies are considered O&F either one year after construction is complete or when the remedy is functioning properly and performing as designed, whichever is earlier.

PRPs or federal facilities are responsible for O&M for sites for which they have the cleanup lead. For a Fund-financed site, the state becomes responsible for O&M, once the site becomes Operational and Functional. Fund-financed remedies that involve long-term treatment or other measures to restore groundwater or surface water quality are a special case in which EPA will fund the costs for the first 10 years, and CERCLA requires that states assume the costs after that period. Additional information on O&M is available in OSWER Directive 9200.1-37FS, EPA 540-F-01-004, "Operation and Maintenance in the Superfund Program," May 2001.

Regardless of who is responsible for O&M, agreements can be made to have many maintenance tasks implemented by site owners, a local government agency, Trustees or others. It is sometimes practical to have the same entity undertake O&M activities relating to the ecosystem. (Although, an appropriately designed ecosystem may be self-sustaining and require little or no maintenance after an initial establishment period). For example, at the Silver Bow Creek/Warm Springs Ponds

Superfund site, many monitoring and maintenance tasks are conducted by a Trustee, the Montana Department of Fish, Wildlife, and Parks. It is often less costly and more effective to have a Trustee or other stakeholder perform O&M than to have the PRP do it. Such groups tend to be very committed to follow through in the long run and have knowledge of local conditions.

At some redeveloped sites, O&M tasks may be split among various parties. Generally, an agreement can be reached between the state or federal regulatory authorities, developer, PRP, and Trustees to establish procedures for the critical O&M needs. It is important that the roles and responsibilities are clearly delineated in enforceable agreements and specified in an O&M plan. Although O&M activities related to the hazardous waste site may be conducted by a Trustee or other party, the PRP or state (whether or not it is a Trustee) will always be responsible for ensuring that the site remains protective of human health and the environment.

3.6.2 O&M of Remedy Components

Typical remedy components requiring long-term O&M include protective covers and liners; gas management and monitoring systems; water collection, treatment, and monitoring systems; and permeable reactive barriers. O&M monitoring includes four activities (USEPA, 2001a).

Inspection. Routine inspections of covers and other remedy components should be performed on a regular basis, with the frequency of inspections dependent on the complexity of the remedial measures. Non-routine inspections should be performed after unusual events such as earthquakes or large storms. Typically, inspectors check for pooling water, erosion, settling, burrowing animals, and dead or dying vegetation (which may be caused by methane), among other items.

Sampling and analysis. Sampling and analysis is often conducted to monitor groundwater and surface water quality, leachate formation, and gas release concentrations. Sampling and analysis typically includes the collection and chemical analysis of gas, air, and water samples from wells, probes, and other means. The frequency of sample collection may vary widely.

Routine maintenance and small repairs. Routine maintenance may consist of simple activities such as mowing and maintenance of a cover or repair of perimeter fencing. On sites that have operating treatment plants, routine maintenance may be more complex and may require a full- or part-time plant operator. Typical activities include operating groundwater and gas treatment systems and repair of erosion damage and of rainwater collection and diversion systems.

Reporting. O&M reports are typically written and submitted to regulatory authorities after both routine and non-routine inspections. The reports typically include information on the general condition of the remedial measures, test results from samples collected, and operational data from treatment processes (*e.g.*, groundwater extraction rate, gas flow rate).

In addition to the annual and special inspections specified in the O&M plan, EPA conducts an in-depth review of the remedy at least every five years for any site where the remedial action results in hazardous substances, pollutants, or contaminants remaining on site above action levels that would allow for unlimited use and unrestricted exposure. The five-year review consists of an analysis of whether the remedy is still protecting human health and the environment, and a list of additional follow-up actions that need to be performed to ensure continued protectiveness, including the identity of the parties responsible for those activities. Although these reviews can be performed by EPA or the lead agency for a site, EPA remains responsible for determining if the remedy is protective. For additional information concerning five-year reviews, see OSWER Directive 9200.1-37FS, *Comprehensive Five-year Review Guidance* (USEPA, 2001f).

3.6.3 Monitoring Ecological Risks

A monitoring program should be established as part of the post-construction activities to evaluate the effectiveness of the remedy in restoring ecological function and reducing ecological risks (USEPA, 1997a, 1999c). Information from the ecological risk assessments prepared during the RI can be the starting point for developing the monitoring program. The ecological evaluations prepared by Trustees and other parties can provide additional information useful for monitoring the ecosystem's function and health during and after remediation. For example, periodic monitoring of sediment contamination and benthic communities following the removal of contaminated sediment in a stream can provide indications of the protectiveness of the remedy as well as the ecosystem's recovery to a more natural condition. At the Revere Chemical Company Superfund site in Pennsylvania, groundwater and stream monitoring are used in the evaluation of the risks of heavy metals getting into the groundwater and migrating off site. The monitoring program is also expected to help evaluate the recovery of important aquatic species.

At Loring Air Force Base, in Maine, site managers consulted with USFWS to identify useful indicator species such as dragon fly nymphs, midge flies, dace minnow, and brook trout to monitor the recovery of the stream system after remedial activities. These species were selected because they are sensitive to contaminants and are quick to manifest symptoms of exposure.

Monitoring programs can be designed to be compatible with ecological reuse. At the Bowers Landfill Superfund site in Ohio, a seven-acre wetland was created to protect the landfill cap from flood damage from the Scioto River. Since the wetland was expected to experience periodic flooding, groundwater monitoring wells in the wetland area could become inaccessible or experience water intrusion during flooding. To ensure access and prevent the potential water intrusion, the wells were fitted with risers and surrounded with earth mounds. The use of a portion of the site as a wetland does not preclude the use of monitoring wells to ensure that leachate from the landfill does not migrate to the underlying groundwater.

Monitoring wells were installed in the wetland created at the Bowers Landfill in Pickaway, Ohio

3.6.4 Institutional Controls

EPA defines institutional controls (ICs) as non-engineered instruments, such as administrative and legal controls, that help to minimize the potential for human exposure to contamination and protect the integrity of a remedy (USEPA, 2000b). ICs are designed to work in two general ways: by limiting land or resource use, and by providing information that helps modify or guide human behavior. They may be used for a variety of goals at ecological reuse sites, such as to restrict public access to parts of a site that are particularly sensitive to erosion, or that contain sensitive or establishing habitats.

An important key to success is to identify and evaluate as much information as possible about the needed ICs early in the remedy selection process. "Adding ICs on as an afterthought without carefully thinking about their objectives, how ICs fit into the overall remedy, and whether the ICs can be realistically implemented in a reliable and enforceable manner, could jeopardize the effectiveness of the entire remedy (USEPA, 2000b)." Generally, there are three major considerations with IC use at ecological reuse sites:

Developing IC Objectives. A useful first step is to think broadly about what the IC is intended to accomplish and establish clear objectives. Common IC objectives for ecological purposes involve controlling activities in a particular area that could potentially interfere with sensitive habitats or the ecosystem balance that support the remedy.

Selecting appropriate IC mechanism(s). ICs can be grouped into four general categories: (1) governmental controls, such as zoning, building codes, and groundwater use restrictions; (2) proprietary controls, such as common law easements, covenants, and conservation trusts; (3) enforcement tools with IC components, such as consent decrees and administrative orders; and (4) informational devices, such as fishing advisories, deed notices, and state registries of contaminated properties. Since each of these mechanisms has strengths and weaknesses, it may be prudent to use them in layers. Layering refers to using different types of ICs at the same time or in sequence. For example, both a conservation easement for catch and release fishing and a local health department fishing advisory may be used for the same IC objective. The different types of ICs and the layering concept is described in an EPA guide (USEPA, 2000b).

Ensuring Durability. The third considerations is how to ensure that the specified controls are effective and remain in place over the long term. Because the implementation, monitoring, and enforcement of ICs may be carried out by more than one party, it is important to consider the capabilities and willingness of local authorities and private sector interests to fully implement, monitor, and enforce the ICs. For example, at the Silver Bow Creek site in Butte, Montana, the Montana Department of Fish, Wildlife and Parks enforces a fish consumption prohibition. Another example is at the Bunker Hill Superfund site in Kellogg Idaho, where the Idaho legislature amended the Environmental Health Code to give the local jurisdictions the authority to govern all excavation, building, development, grading, and renovation at the site.

Many factors may influence the design and implementation of ICs, such as state policies, whether the site is a federal facility or whether other regulatory authorities, such as RCRA, are involved. A useful EPA guide addresses many of these considerations (USEPA, 2000b).

Section 4. Wetlands and Superfund Remediation

The need to consider wetlands at a Superfund site may arise for a number of reasons. An existing wetland may be affected by the site contamination or cleanup activities. Local and regional planners may have determined that a wetland is a worthwhile use for the land, even if the property did not previously contain one. A response action, whether directed at a wetland or not, may still have adverse impacts if the wetland is not part of the planning process.[4]

Generally, activities related to the cleanup of contaminants or repairing damage to wetlands resulting from releases of hazardous substances or cleanup activities may be paid for with Superfund Trust Fund monies. However, efforts to create new wetlands, where none existed prior to the disturbance, or to undertake extensive efforts to restore a wetland, where other practical alternatives exist, may be considered "enhancements." As described in Section 1.4.3, EPA cannot fund, nor require PRPs or others to fund, enhancements of a remedy. Nevertheless, there may be situations in which extensive restoration efforts are not considered enhancements. The determination of whether or not an action or facility is considered an enhancement is determined on a site-by-site basis and involves coordination with Trustees and other parties with knowledge and interest in local ecologies. Even if EPA does not pay for activities related to the restoration or creation of a wetland, it may coordinate remedial activities with such efforts.

Developing and implementing cleanups involving wetlands can involve very complex trade-offs. For example, removing contaminated materials from a wetland may involve excavation of all vegetation and growing media, effectively destroying all ecosystem function and structure. Sometimes, less damage is done by leaving the contamination in place and using other techniques, such as covering or amending soil.

Whether a remediation involves an existing wetland or the creation of a new wetland, the following steps are typically taken: (a) evaluation of the characteristics, function, and condition of wetlands related to the site; (b) determination of the type of wetland functions and structure that would be beneficial in the area after the remediation; (c) development of a wetland design that will achieve the stated ecological functions; (d) construction of the remedy and wetland features while ensuring that remediation activities have minimum impacts on existing wetlands and other ecosystems; and (e) specification and implementation of explicit maintenance requirements. Although this section is based primarily on experiences from sites where a wetland ecosystem was the primary reuse goal, these steps would also apply to sites being developed for commercial or other uses, when these sites also have wetland issues.

Once it has been determined that wetlands are to be affected by a remediation, a number of key factors that will influence the success of the wetland habitat should be considered. Some of these factors are discussed below.

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[4] A wetland outside a site's boundaries may be hydrologically connected through surface water or groundwater.

4.1 Wetland Regulatory Requirements

Several regulatory requirements generally apply when a remediation or reuse project affect wetlands. The Clean Water Act (CWA) provides authority for regulating discharges of pollutants to waters of the United States. Section 404 of the Clean Water Act establishes a program to regulate the discharge of dredged and fill material into waters of the United States, including wetlands. Wetlands are defined as "those areas that are inundated or saturated by surface or groundwater at a frequency and 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 Part 232.2 (r)). Activities in waters of the United States that are regulated under this program include fill for development, water resource projects (such as dams and levees), infrastructure development (such as highways and airports), and conversion of wetlands for other purposes, such as farming and forestry.

Typically, an actual §404 permit is not required for on-site Superfund response actions, however any off-site activity affecting wetlands must meet all §404 requirements, including a permit. Even though §404 permits are not required for on-site Superfund actions, the substantive guidelines of §404(b)(1), which are environmental criteria that must be satisfied before a §404 permit can be issued. Any off-site activity affecting wetlands must meet all requirements of §404, including obtaining permits. EPA guidance provides information for considering laws other than CERCLA and for fostering Agency coordination when carrying out remediations affecting wetlands at Superfund sites.[5] Actions at Superfund sites affecting wetlands must comply with Executive Order 11990 relating to the protection of wetlands, which directs federal agencies to avoid the long- and short-term adverse impacts associated with the destruction or modification of wetlands and avoid direct or indirect support of new construction in wetlands whenever a practicable alternative exists.[6] Thus, unavoidable impacts to wetlands from CERCLA response actions should be mitigated to comply with pertinent regulations and executive orders.[7]

Under §401 of the CWA, states and tribes can review and approve, set conditions for, or deny all federal permits or licenses (such as those that might be issued under §404) that might result in a discharge to state or tribal waters, including wetlands. States and tribes make their decisions to deny, certify, or condition permits or licenses primarily by ensuring the activity will comply with state water quality standards. In addition, states and tribes look at whether the activity will

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[5] U.S. EPA, 1994, Office of Solid Waste and Emergency Response, *Considering Wetlands at CERCLA Sites*, EPA 540/R-94/019. This guidance document also discusses how wetlands should be considered in compliance with applicable or relevant and appropriate requirements (ARARs) under § 121(d) of CERCLA. It discusses CWA Section 404 as a potential ARAR and mitigation in accordance with the CWA Section 404(b)(1) Guidelines, which were promulgated as regulations in 40 CFR 230.10, as important environmental criteria to be considered.

[6] OSWER Directive 9280.0-02 of August 1985, *Policy on Flood Plain and Wetlands Assessments for CERCLA Actions*, states: "Under this policy, Superfund actions must meet the substantive requirements of Executive Order E.O. 11988 (Floodplain Management), and E.O. 11990 (Protection of Wetlands).

[7] Examples of mitigation actions are discussed in U.S. EPA, 1994, Office of Solid Waste and Emergency Response, *Considering Wetlands at CERCLA Sites*, EPA 540/R-94/019.

violate effluent limitations, new source performance standards, toxic pollutants, and other water resource requirements, including those under watershed and wetland protection programs under state and tribal law or regulation.

The provisions of other CWA sections and other federal laws and executive orders may also apply to actions affecting wetlands. For example, §402 mandates the National Pollutant Discharge Elimination System and §403 addresses Ocean Discharge Criteria. Section 10 of the Rivers & Harbors Appropriation Act of 1899 establishes a program to regulate activities affecting navigation in United States waters, including wetlands. The Federal Agriculture Improvement and Reform Act of 1996, commonly known as the Farm Bill, included modifications to four programs related to the conservation of wetlands on agricultural land. The Endangered Species Act provides a program for the conservation of threatened and endangered plants and animals and the habitats in which they are found. In addition, several executive orders may also apply to wetland-related projects, including Executive Order 12630 (Government Actions and Interference with Constitutionally Protected Property Rights, 1988); Executive Order 12962 (Recreational Fisheries, 1995); and Executive Order 13186 (Responsibilities of Federal Agencies to Protect Migratory Birds, 2001). EPA directives provide useful information for coordinating requirements (USEPA, 1990c, 1990d, 1993b, and 1994a).

One approach sometimes employed in restoring or protecting wetlands is the use of "wetland credits," which are issued by "mitigation banks." A wetlands mitigation bank is a wetland area that has been restored, created, enhanced, or (in exceptional circumstances) preserved, and is then set aside to compensate for future conversions of wetlands for development activities elsewhere. Credits are issued to organizations or individuals that establish or own the bank. They can be used or sold to third parties who convert wetlands for development elsewhere. A wetland bank is developed under a formal agreement with a regulatory agency. A benefit of this arrangement is that in addition to removing contaminants and protecting or restoring a wetland, an individual land owner or organization can sell credits. Furthermore, if the site is in a state where conservation areas are not taxed, the land owner can save on property taxes. Use of this approach requires that an ecologist examine the proposed project and confirm that there are environmental benefits. Several sources are available for information on mitigation credits and banking, including an EPA web site, http://www.epa.gov/OWOW/wetlands/facts/fact16.html and the National Wetland Mitigation Plan, http://www.mitigationactionplan.gov. According to the National Mitigation Banking Association, there are about 100 banks in the U.S. in almost three dozen states (NWMBA, 2004). http://www.mitigationbanking.org/

4.2 Wetland Characteristics

A recommended first step in designing a remedy that involves a wetland is to develop a thorough understanding of the role of the wetland in the overall ecosystem and the relationships between the various plant and animal species within the wetland. It is also important to determine if any endangered, sensitive, or commercially important species are present. Understanding the wetland will help evaluate which wetland functions and structural characteristics to protect, restore, or create. Similar evaluations should be conducted in anticipation of potentially new wetlands to be created on or near the site. This evaluation should begin early in the RI/FS stage, because information and analyses on the function and condition of the wetlands are important to the remedy selection and design process.

A wetlands characterization should include, at a minimum, an evaluation of the size, location, ecological structure, hydrology, soil, vegetation, and function of the wetlands.[8] A wetlands delineation may be conducted to identify the limits of jurisdiction under the CWA Section 404 regulatory program.[9] During the RI, it is also important to determine if wetlands on or adjacent to Superfund sites have become contaminated. The determination of whether the wetlands have been or will be affected by the contamination is usually made in the ecological risk assessment, which contributes to the evaluation of remedial alternatives for the site. Assessment of the impacts of the contamination on wetlands and evaluation of potential wetlands disturbance from remedial alternatives is generally done as part of the RI/FS.

4.3 Wetland Vegetation and Hydrology

Analyses of hydrological conditions (*e.g.*, hydroperiod, or the period of time during which a wetland is inundated with water, and water depth) help define the site's wetland vegetation associations (a plant community type of definite floristic composition, uniform habitat conditions, and uniform appearance). Analyses of soil conditions (*e.g.*, field observations supplemented by soil maps) help define the historic native vegetation associations, the appropriate wetland species for the site, and any constraints on the wetland posed by soil characteristics. Generally, reestablishment of an historic vegetation association tends to lead to a successful wetland ecosystem. For sites where the historical native vegetation association cannot be determined, analyses of nearby wetlands with soil and hydrology similar to the project site can help determine the types of vegetation that are likely to be successful.

Tree planting in wetlands at the Loring Air Force Base site in Limestone, Maine

A good wetland design attempts to achieve ecological function, as defined above. Usually, after an initial establishment period following construction, the wetland will undergo a succession of changes in vegetation, ultimately achieving a more

8 Wetland functions may include wildlife and waterfowl habitat, water quality improvement, groundwater recharge and discharge, flood water storage and conveyance, and shoreline and erosion control.

9 The 1987 *U.S. Army Corps of Engineers Wetlands Delineation Manual* is the EPA and Corps of Engineers standard for delineation of wetlands. A wetlands delineation is an on-the-ground determination of the boundary between wetland and upland using the three criteria of hydrophilic (wetlands) vegetation, hydric (wet) soils, and hydrology, in the form of flooding or soil saturation.

natural wetland that requires little or no maintenance.[10] To achieve a natural wetland vegetation association, the site will require a reliable natural water supply and the appropriate hydroperiod and water depth. Where a wetland is designed specifically for waterfowl habitat, artificial water supply systems (*e.g.*, pumps and gated culverts) may be used. However, these systems will usually increase maintenance costs and reduce the ability of the wetland to sustain itself. These factors are generally evaluated thoroughly in the design stage.

It is important to consider water availability and soil type when selecting and placing the vegetation. Wetter vegetation associations (*e.g.*, perennial marshes) can be established on nearly any soil type. Drier vegetation associations (*e.g.*, seasonal marshes or wet meadows) require more careful consideration of soil type. Because inundation is less frequent, soil saturation is the primary source of water. It is also important to consider the successional status of the various species. Where appropriate, seeded species that can quickly establish may be planted first and species that are more difficult to establish can be planted later (*e.g.*, rooted wetland plants salvaged from nearby areas or purchased from nurseries). Where available, a natural seed bank in existing wetland soils is often adequate for establishing wetland vegetation.

4.4 Wetland Wildlife

Wetlands provide valuable wildlife habitat. The ability of a wildlife species to thrive in a wetland is dependent upon a number of factors, including the minimum habitat area necessary for the species, the minimum viable population of the species, the species' tolerance for disturbance, and the wetland ecosystem's functional relationship to adjacent water resources and ecosystems. Thus, three factors will play a major role in determining the effectiveness of a wetland for long-term wildlife use: 1) the size of the wetland, 2) the relationship of the wetland to other wetlands, and 3) the level and type of disturbance (Kent, 1994; National Research Council, 1992; USEPA, 1994a).

The Northwest 58th Street Landfill in Miami, Florida provides a vibrant habitat for waterfowl

Wetland size is perhaps the most important factor in designing for wildlife. Designers should determine which wildlife species can be supported at a planned wetland. The area necessary to support minimum viable populations of species varies widely among the species. Few Superfund-related wetland projects will be large enough to support the minimum viable populations for many species. Consequently, a wetland designed for wildlife use should consider the connectivity of the site, through habitat corridors, to other habitats. Habitat corridors that connect smaller wetlands can provide a mechanism for interpopulation movement, effectively increasing the habitat size

10 Succession refers to the changes in a vegetation association over time to a more mature phase.

and creating a more sustainable population base. Usually, this arrangement also results in a reduction of the risk of local extinction as a result of localized disturbances. Species can disperse through the habitat corridors and colonize other areas. Because species have different dispersal abilities and different habitat tolerances, it is important to evaluate the habitat needs of each of the anticipated species.[11] For migratory birds, the design typically would focus on providing breeding or wintering habitat, or resting or feeding places within their large migratory corridors.

The effective size of a wildlife habitat area can also be increased by establishing or increasing upland buffers. In addition to reducing direct disturbances to wetland wildlife from surface runoff, buffers can help support part of the life requirements for some species. For example, buffers can provide additional areas for cover and forage.

Wetland wildlife management has historically focused on waterfowl management, especially game species. More recently, it has increasingly focused on maintaining species diversity. Management techniques range from simply installing nest boxes, to actively managing a wetland's hydrology, to enhancing habitat for some species. For example, bird boxes were installed along the riparian wetlands at the Army Creek Landfill Superfund site, in New Castle County, Delaware, to encourage nesting.

Wetland protection or creation measures can sometimes have unintended consequences. For example, efforts to attract wildlife can sometimes cause one species to thrive so well that it throws the wetlands ecological functions out of balance or interferes with anthropomorphic activities in the area. For example, an overabundance of Canada geese have consumed too many wetland plants at a number of wetlands. Sometimes, geese attracted to an area by a wetland also consume desirable plants at nearby residences and businesses. The later point is especially important for Superfund sites, many of which are located in or near urban and suburban areas. Wetland managers in some areas have attempted actions to make the area less hospitable to this species, such as using plants that are not palatable to geese or installing fences. Such measures may also have drawbacks. For example, eliminating plants that geese dislike reduces the biodiversity of the wetland, which could affect its stability.

The nature and condition of the vegetation is likely to affect a wetland's overall wildlife species composition. It is recommended that remedy and wetland designers and planners consult with wildlife agencies for assistance in evaluating and selecting the wildlife management goals and techniques appropriate for a site.

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[11] For example, large mammals and some resident bird species have greater dispersal abilities and greater tolerances for movement through different types of habitats. Amphibians, reptiles, some bird species, and small mammals often have poor dispersal abilities, narrow habitat tolerances, and are more seriously affected by the distances between habitats and the suitability of the habitats used as corridors.

4.5 Remedy Design and Construction Involving Wetlands

Wetland reuse can involve restoration of remediated wetlands or creation of new wetlands in areas that have been contaminated. Restoration involves modifying a disturbed or altered wetland to provide greater acreage or improved wetland functions (*e.g.*, habitat, flood storage, water quality improvement). Wetland creation involves building a new wetland where none currently exists. Unless severely degraded, a natural wetland will usually provide more functions to the ecosystem than a created wetland because of uncertainties in the successful creation of new wetlands. While a created wetland may be suitable for some species, such as waterfowl, other species are usually less likely to colonize them than they are to adapt to restored natural wetlands.

Consequently, where natural wetlands exist at a Superfund site, it is important to carefully consider remedial design and construction methods that will avoid or minimize any adverse wetland impacts. RPMs may need to avoid or limit certain remedial activities to minimize the extent of wetland disturbance. To ensure that wetland projects are built as designed and to minimize the potential for adverse impacts from remedy construction, careful coordination between wetland and remedy designers and construction contractors is important.

Many aspects of remedy and wetland protection, restoration, or creation are site-specific and designed to address local conditions. Nevertheless, the following techniques are often applicable and, where appropriate, may be considered in remedy and wetland construction (Kent, 1994; National Research Council, 1992; USEPA, 1994a).

Wetland Design and Construction Considerations

- Use flags or temporary fencing to prevent disturbance of existing on-site habitats.
- Carefully manage grading during construction to meet design specifications, since proper grading is often essential to developing a site hydrology that will support successful wetland vegetation associations.
- Remove invasive exotic plants from a site prior to construction, to the extent possible.
- Whenever practicable, salvage existing plants or wetland soil that could provide a seed bank and use these to reestablish native species.
- Where possible, collect plant material from within the immediate region and ensure that it is also free from disease, insects, and weeds.
- When nursery-grown plants are used, select species from local sources that are genetically similar to native plant species, whenever possible.
- Ensure that all seed used in a wetland project is certified, and free of weeds and disease.
- Check all water control structures during daily, seasonal, and peak flows for maintenance needs and to ensure that they are achieving the planned site hydrology.

Remedy Design and Construction Considerations

- Consider alternative locations for remedy components to minimize impacts to wetlands.
- Consider alternative access routes and staging areas for construction that minimize impacts.
- Design the site layout to minimize the area required for construction of the remedy.

- Minimize grading and backfilling, to reduce the potential for sedimentation and minimize the need for special erosion control measures during construction.
- Use sedimentation and erosion controls (*e.g.*, hay bales, siltation fences, geotextile and filter fabrics) to contain sediment-laden runoff generated by upland construction activities.
- Install erosion controls (*e.g.*, geotextiles and filter fabrics) on newly graded slopes in conjunction with seeding efforts to hold soil in place until the vegetation is established.
- Promptly reseed or replant to stabilize newly graded slopes.
- Design adequate drainage and minimize the adverse hydrologic impacts of drainage channels.
- Minimize the clearing of trees, ground cover, and other valuable vegetation to maintain existing vegetative buffers and to reduce runoff from construction areas and erosion.
- Minimize land clearing and alteration of existing slopes and grades along shorelines, to reduce erosion potential and wave impacts.
- Minimize compaction of wetland soils by construction equipment (*e.g.*, through the use of wide, low pressure tires on vehicles to distribute the loads on wetland soils).
- Locate staging areas for equipment outside of wetlands and their buffer zones and provide for adequate systems to control sedimentation from construction equipment, accidental releases of fuel, oil, and other potentially hazardous materials from equipment.
- In wetlands and other sensitive habitats, use pilings where practicable to support foot or equipment traffic and reduce the impacts from construction equipment.
- Schedule construction to avoid impacts to any sensitive or commercially or recreationally important species present by avoiding peak growing seasons, fish spawning and migration periods, and peak waterfowl migratory periods.
- Schedule construction to minimize the time between the disturbance and revegetation.

4.6 Wetland Maintenance

Many wetlands require monitoring and maintenance to ensure that the habitat is functioning as planned and that pollution sources are being controlled, especially when the vegetation is being established. The maintenance of remedy components were discussed in Section 3. This section addresses activities needed to maintain the function and structure of wetlands. Although maintenance needs are site-specific, the following are some typical issues to be addressed.

- Weed control is important because invasive species can quickly replace native or planned species. Weed control generally entails identifying and addressing conditions that encourage the establishment of exotics, removing those that are established, and replacing them with appropriate plants.[12]
- Disturbed areas are especially vulnerable to aggressive exotic species, such as purple loosestrife (*Lythrum salicaria*), water hyacinth (*Eichornia crassipes*), and salvinia (*Salvinia molesta*). It is important to take timely action to control exotics.

[12] For example, quick establishment of a dense ground cover or other measures to reduce soil disturbance is often effective for limiting the spread of exotics. Annual exotics or weeds can be removed manually by pulling the plants or cutting them above ground. Perennial weeds can be eradicated or reduced through chemical controls. Woody plants usually can be removed once a year either manually or by cutting and subsequent herbicide application to the stump. For some drier wetlands vegetation associations, mechanical mowing may be effective.

- Deer, rabbit, or beaver grazing can damage young plants. This problem can be controlled by installing wire screens around the plants or the planted area to help protect vegetation until the ecosystem becomes established.
- Where opportunistic native species begin to dominate a wetland and crowd out other species, measures to increase species diversity should be implemented.[13]
- When important plants are lost, wetland areas often must be replanted. Plant losses can result from unexpected conditions such as erosion from a heavy storm, inadequate root penetration prior to the storm, and inadequate water supply due to lower than normal precipitation.
- Scouring can be caused by increased flow velocities through the site or reoriented high velocity flows. To minimize additional scouring apply new erosion controls as soon as possible after the storm or other events that caused the erosion.
- It may be necessary to monitor for insect or disease infestations, and quickly treat them.
- Any litter or debris that collects at the site should be removed at least annually.
- For sites near populated areas, public education efforts can help reduce maintenance issues associated with litter or debris dumping, off-road vehicle use, or other human activities that may threaten the long-term success of a wetland project.

Wetlands that are actively managed will usually require more maintenance for components such as pumps, culverts, and piping.

4.7 Sources for Technical Assistance on Wetlands

The following are selected sources for technical assistance for wetland reuse. Other sources of information are provided in the References beginning on page 61.

Society of Wetland Scientists (SWS), publishes *Wetlands* Journal – http://www.sws.org/wetlands

U.S. Army Corps of Engineers, Waterways Experiment Station. Wetlands Research Program and Wetlands Research Technology Center. http://www.wes.army.mil/el/wetlands/wetlands.html

U.S. Department of Agriculture, Natural Resources Conservation Service, Wetland Science Institute. http://www.pwrc.usgs.gov/wli

U.S. Department of Interior (DOI), U.S. Fish and Wildlife Service. National Wetlands Inventory. http://www.nwi.fws.gov

U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. Environmental Fact Sheet: Controlling the Impacts of Remediation Activities in or Around Wetlands. EPA 530-F-93-020, EPA1993.

13 Examples include cattails (*Typha* spp.) and common reed (*Phragmites* spp.).

U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response.. Considering Wetlands at CERCLA Sites, EPA 540/R-94/019, 1994. http://www.epa.gov/superfund/resources/remedy/pdf/540r-94019-s.pdf

U.S. Environmental Protection Agency, Office of Water, Office of Wetlands, Oceans and Watersheds. http://www.epa.gov/OWOW/wetlands
(And River Corridor and Wetland Restoration link– http://www.epa.gov/owow/wetlands/restore/

U.S. Geological Survey (DOI), National Wetlands Research Center – http://www.nwrc.gov

Section 5. Stream Restoration and Superfund Remediation

At some Superfund sites, contamination has degraded stream corridors to the point that in-stream or riparian habitats are biologically dead or dying. Cleaning up this contamination is complicated by the fact that cleanup remedies can physically disrupt stream habitats. For example, removing contaminated sediment from streambeds or contaminated soil from streambanks will usually entail alteration of the channel, and leave the streambanks barren and erodible after cleanup.

Restoring these resources after cleanup can be a major undertaking with no guarantee that a viable ecosystem will successfully establish as anticipated. Ecosystems are complex and may take years to reach equilibrium or fully establish. A major natural event such as a flood or heavy rainfall can seriously damage or destroy vegetation that has not yet fully established. Restoration must address questions concerning practicality, predictability of outcomes, and overall effectiveness of specific techniques. Because ecological restoration is an imprecise discipline, our ability to predict outcomes is limited. For some stream corridors, we cannot be sure that physical reconstruction of the stream will not do more harm than to eliminate sources of stress (such as upland point or nonpoint sources of pollution) and allow the stream to recover through natural processes.

This section provides an overview of considerations for designing and implementing remedies that facilitate ecological reuse of stream corridors and mitigating adverse ecological impacts of constructing remedies. A successful stream cleanup, combined with appropriate restoration strategies can hasten the recovery of degraded stream corridors and begin the natural process of restoring their ecological functions. Healthy stream corridors can provide important habitat for fish populations; erosion and sedimentation control; high-quality water for wildlife, livestock, flora, and human consumption; opportunities for recreationists to fish, camp, picnic, and enjoy other activities; and support a diversity of plant and wildlife species.

5.1 Evaluating Stream Corridor Conditions

Restoration of degraded streams generally begins with an assessment of the cause of disturbances and a characterization of the degradation. These assessments, along with other information, can help remedial project managers (RPMs), communities, and other stakeholders establish remediation and reuse goals. A useful first step in assessing a stream system is to collect and analyze baseline data on existing species, in-stream

Excavating streambed at Loring Air Force Base, Limestone, Maine and riparian habitat, soil characteristics, and stream function. Both the remediation and reuse teams will typically seek to identify and inventory existing animal species and vegetation and evaluate key ecological stressors to the existing riparian and aquatic life in the stream corridor. In addition to evaluating site contamination in the RI, other common disturbances to stream ecology should be evaluated and prioritized. These disturbances can include stream channel alteration, water quality impairment, invasion by exotic species, loss of riparian vegetation, and compaction or undercutting of streambanks.

Another important, but often difficult, step is to define the conditions of the stream corridor prior to the disturbance. Knowledge of the pre-disturbance condition can help evaluate the cause of the disturbances and to develop a model for reestablishing a viable habitat with similar ecological processes that thrive over time. When historical records are unavailable, information on undisturbed, nearby stream corridors that have physical characteristics similar to that of the disturbed area can help to depict reference conditions for determining the type of ecosystem that will likely be successful at the site.

At Loring Air Force Base in Northeastern Maine, RPMs realized that removal of contaminated wetland and stream soil and sediment would severely disrupt the stream and wetland areas. They decided to create a thorough record of the pre-remediation conditions of these areas by carefully mapping stream channels, streambanks, in-stream structures, and wetland areas. For each stream segment, workers mapped boulders, submerged logs, riffles, pools, water depths, substrate textures, plant communities, and topography. They photographed the streambed every 30 meters, entered the exact locations of these photographs onto topographic maps, videotaped the area, conducted extensive sampling, staked out these locations, and developed maps using Global Positioning System (GPS) equipment. Project managers used the information to restore plant communities according to their prevalence prior to the site's disturbance, reconstruct wetland topography, and restore stream channels and in-stream structures.

5.2 Stream Corridor Restoration Considerations

After characterizing the stream corridor, it is important to establish detailed reuse goals, and identify alternative approaches to remediation and to achieving the ecosystem conditions specified in the goals. For stream corridors at Superfund sites, reuse planning can be grouped into four areas: stream channel restoration, streambank stabilization, streambank revegetation, and watershed management.

Streambed layout at Loring Air Force Base, Limestone, Maine

Stream Channel Restoration. Removal of contaminated sediment and soil from stream channels and banks during a remedial action usually severely disrupts stream flow. In such instances, reconstruction of stream channels and banks is usually necessary. Decisions about stream channel width, depth, cross-section, slope, and alignment profoundly affect future hydrology (and the resulting ecology) of the stream system. Restoration design typically considers factors such as the physical aspects of the watershed hydrology, sediment size distribution, average flood flows, and flood frequency. When designing a stream channel restoration, it is important to try to anticipate the impacts of future land uses on the watershed. Ideally, the restoration team will have sufficient knowledge of the types of habitats that will be compatible with the area from the evaluations discussed above.

Streambank Stabilization. Disturbed or reconstructed streambanks often require temporary stabilization to prevent accelerated erosion. Temporary stabilization may consist of natural materials such as logs, brush, and rocks and can be designed so as to not hinder permanent revegetation. In some cases, geotextiles, natural fabrics, and bioengineering techniques (see below) may be necessary. Revegetating streambanks using seeding or bare root planting techniques will often fail if the stream is subjected to flooding before vegetation is fully established. Consequently, temporary vegetation for stabilizing streambanks may be more successful using anchored cuttings or pole plantings (*e.g.*, woody cuttings or poles inserted and anchored into the streambank) taken from species that sprout readily, such as willows.

Potential Stream Corridor Restoration Approaches:

- Restore the stream channel to pre-disturbance conditions, improve the soil characteristics of the streambanks, and enable natural recolonization of riparian vegetation.
- Restore the stream channel, improve soil characteristics, and plant native riparian species.
- Replant with native species without restoring the physical characteristics of the stream corridor.
- Plant trees and shrubs adjacent to the stream channel to help regulate in-stream water temperatures, improve water quality, and enhance aquatic habitat.
- Establish buffer strips adjacent to streambanks
- Allow natural, self recovery of the stream system.
- Ensure that upland areas are not contributing stressors to the stream.

Streambank Vegetation. Plants play a crucial role in many stream ecosystems. They help regulate stream temperature (by providing shade during hot days and reducing heat loss during cold nights), filter upland runoff to remove sediment and nutrients, stabilize streambanks and prevent erosion, and provide habitat for terrestrial and some aquatic species. Existing native vegetation, especially mature trees, should be protected wherever possible during site cleanup and restoration activities. Many sites will require some revegetation. Species for vegetation should be selected for their ability to establish a long-lasting plant community rather than as quick fixes for erosion or sedimentation problems. For example, fast growing non-native species may quickly stabilize a denuded stream bank, but over the long term they may end up invading the entire stream corridor to the detriment of desirable native species.

As indicated above, there is a wide range of approaches that could be used to restore stream corridors. Some examples appear in the box on this page. Where possible, stream restoration or protection should focus on removing disturbances to enable natural processes to restore stream function over time. Approaches that attempt to establish ecosystems similar to pre-disturbance conditions tend to have more long-term success and result in less maintenance than more highly engineered solutions (*e.g.*, gabions or riprap) that reduce the amount of viable habitat. In addition, approaches that address the entire stream system tend to be more successful than those that attempt to ameliorate disturbance conditions for a specific species at a site.

Watershed Management. The sources of stress on a stream are not restricted to in-stream conditions and cleanup and restoration of a stream should consider all sources of stress. The health and condition of a water body is also affected by the watershed ecosystem. Therefore, cleanup and restoration may need to address watershed processes that tend to degrade ecosystems, such as sediment loading from road cuts or construction, increased runoff from impervious areas created by development, and other point and nonpoint sources of pollution. Sometimes, effective watershed management may obviate the need for in-stream restoration approaches.

5.3 Construction Techniques

Some aspects of stream construction, such as earthmoving operations, amending soil, and revegetation, need especially careful planning. Grading or earthmoving, especially with heavy equipment, should be monitored carefully to ensure that construction contractors adequately protect existing resources at the site. When unexpected subsurface conditions are revealed, the reuse design may need to be modified accordingly. If areas with clean, good quality topsoil will be disturbed, this topsoil can be stockpiled, and spread out on the surface after final grades are achieved. Soil amendments, such as mulch, fertilizer, lime, sand, or clay, may be added to provide optimum growing conditions for the desired plant community. A variety of strategies, such as transplanting, seeding, and natural recolonization, are available to achieve the desired post-restoration plant community and the timing of revegetation. Many sources of technical assistance on implementing a revegetation strategy are available (Section 5.5).

Bioengineering techniques have become an increasingly popular approach to streambank restoration and maintenance. Bioengineering refers to stabilizing the soil or streambank by establishing sustainable plant communities. A combination of live or dormant plant materials are typically installed sometimes in conjunction with other materials such as rocks, logs, brush, geotextiles, or natural fabrics. Bioengineering techniques can be more labor intensive than traditional engineering solutions and sometimes take longer to control streambank erosion. Nevertheless, over the long term, they often have lower maintenance costs and create important habitat.

Finally, some maintenance work, such as erosion controls, reseeding, and the application of soil amendments, may be required after evaluating the initial progress of stream corridor recovery.

5.4 Designing for Long-Term Habitat

Allowing natural processes to shape the ecosystem in the stream corridor will generally lead to self-sustaining, long-term recovery of in-stream, riparian, and upland terrestrial habitats in the stream corridor. Since this process takes time, providing short-term riparian and upland habitats may hasten the return of wildlife to the disturbed area. For example, many species of birds and mammals use trees for breeding, food, or cover. Nest boxes, cavities, or other artificial nest structures may provide important riparian and terrestrial habitats while natural habitat structures recover. Use of bioengineering materials in streambank restoration can create support for terrestrial habitats that enhance aquatic habitats (*e.g.*, provide cover and temperature control).

In-stream habitat quality is largely a function of flow, channel and in-stream structures, water quality, and riparian and streambank function. Long-term restoration of in-stream habitat is usually best achieved by relying on natural processes to shape the streambed. Common types of engineered habitat structures such as weirs, dikes, randomly placed rocks, riffles and pools, fish passage structures, and off-channel pools may be used to enhance in-stream habitat during the short term. They are most effective when installed as a complement to a long-term recovery strategy.

5.5 Sources of Technical Assistance on Stream Corridors

Selected sources for technical assistance for stream restoration are listed below. Other sources are provided in the References section, beginning on page 61.

Federal Interagency Stream Corridor Restoration Guide: *Stream Corridor Restoration: Principles, Processes, and Practices* (1999) – http://www.usda.gov/stream_restoration

Izaak Walton League of America, Save Our Streams Program, *A Citizen's Streambank Restoration Handbook* (1995) – 1-800-284-4952

Lortie, John P. S. Svirsky, D.S. Hopkins, Jr., and D.B. Gulick, Stream and Wetland Restoration–Restoring an High Value Trout Stream following the Removal of Contaminated Sediments, Proceedings of the Conference, American Society of Civil Engineers, Denver CO, March 1998.

National Park Service, Disturbed Lands Restoration – http://www2.nature.nps.gov/grd/distland

University of Nebraska-Lincoln, Cooperative Extension, *Bioengineering for Hillslope, Streambank and Lakeshore Erosion Control* (1996) – http://www.ianr.unl.edu/pubs/Soil/g1307.htm

U.S. EPA, Office of Water, *Ecological Restoration: A Tool to Manage Stream Quality*, EPA 841-F-95-007, November, 1995. http://www.epa.gov/OWOW/NPS/Ecology

U.S. EPA, Office of Solid Waste and Emergency Response. Contaminated Sediment Remediation Guidance for Hazardous Waste Sites: Peer Review Draft, January 2005. http://www.epa.gov/superfund/resources/sediment/pdfs/cover.pdf

U.S. EPA, Office of Water, Stream Corridor Restoration: Principles, Processes, and Practices. Web Page. http://www.epa.gov/owow/wetlands/restore

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Section 6. Terrestrial Ecosystems and Superfund Remediation

Plant and animal life at some Superfund sites have been seriously disturbed by the grading or earthmoving operations of the remediation or previous industrial activities. Some sites have been denuded of all vegetation and topsoil. Establishing a plant community that will thrive with a minimum of maintenance is a critical step in developing a healthy terrestrial ecosystem on these sites. Permanent plant communities can provide wildlife habitat and reduce flooding and runoff. Temporary plant communities, such as annual rye grass, may provide erosion control quickly, or until permanent plant communities can become established. The revegetation strategy for temporary erosion control during a remediation can be combined with the long-term strategy. Some restoration activities beyond those needed for the response may be considered "enhancements" (Section 1.4.3) and EPA may not fund such activities, nor require others to fund them. Regardless of whether activities related to habitat protection, restoration, or creation are considered enhancements and are funded by Trustees, communities or other parties, it is EPA's policy to coordinate its activities with Trustees (USPEA, 1999c).

This section discusses factors to consider when plant communities are to be established in disturbed areas. It addresses general revegetation principles and factors to consider in the course of protecting or creating natural meadows and establishing vegetation on semi-arid or arid lands.

6.1 General Revegetation Principles

Prompt vegetation of disturbed areas is an effective way to control erosion and sedimentation. Vegetation can prevent sediment and pollutants typically associated with sediment (*e.g.*, phosphorus and nitrogen) from entering nearby surface waters. Special attention should be given to steep slopes or areas of disturbed soil near drainages. Some general principles for the revegetation of disturbed areas are provided below (USEPA, 1993; U.S. Department of Agriculture, 1997a):

- Prepare the soil and the seed bed for the selected species. Soil testing may be required to evaluate whether the pH, nutrient availability, and organic material content can sustain the desired plant community. The seed bed should be prepared to ensure proper soil texture for successful plant establishment. At the Hillsides area of the Bunker Hill Superfund site in Kellogg, Idaho, soil was amended and modified to control for acidity and provide nutrients for planting native and non-native species that are now growing into more than a thousand acres of coniferous forest (See Bunker Hill case history in Appendix A).

- Select seed mixtures and plants adapted to the soil, climate, and topography of the site. Plant varieties and seeds propagated from local populations usually result in higher plant survival rates and maintain the integrity of the local gene pool. Executive Order 13112 promotes the use of native species for federally funded projects that involve revegetation and landscaping.

At ***Loring Air Force Base***, seedlings and saplings of desirable plant species from low value areas on the base (*e.g.*, areas beside barracks and the runway) were transplanted to areas that were being restored. This strategy is expected to reduce restoration costs and result in plants that are hardier because they are already adapted to the unique conditions of the site. Tree species were selected based on an inventory conducted at the beginning of the project. Appendix A provides additional detail on this project.

- Avoid the use of non-native, exotic species. Non-native species, once established, can out-compete and displace native species, disrupt ecological processes, and significantly degrade entire plant communities. Non-native species can easily become established in a disturbed area because of a lack of competition from native plants. Some invasive species are very difficult to eradicate during later attempts to establish native plants. Although non-native species have been used to vegetate disturbed areas in the past, most ecologists today recommend the use of native species.

- Seed during optimum periods for plant establishment. Timing will depend on the schedule of site operations, local growing conditions, and the species selected. Sometimes, a temporary variety of grass, such as annual rye, could be used as ground cover until the planting season for other varieties. Information on seeding techniques and conditions for individual species is usually available from U.S. Department of Agriculture (USDA) Natural Resources Conservation Service technical guides, university extension offices, and seed suppliers.

- Fertilize according to site-specific conditions and choose a fertilizer formulation that meets the growing needs of the selected species. Areas without adequate topsoil usually need fertilizer for the successful establishment of grass and other plants.

- Stabilize the surface to hold seed in place, aid in plant establishment, mitigate rainfall impacts on seed beds, preserve soil moisture, and control erosion. A variety of soil stabilization methods, such as mulching with straw, hay, or wood-fiber product, or installing synthetic matting, may be used. The type and amount of mulch applied varies with site conditions, the extent of erosion potential, and the materials available. Different kinds of mulches may also be selected for their ability to improve conditions for germination of the selected species. For example, some mulches may help adjust the pH of the seed bed (See Bunker Hill case history in Appendix A).

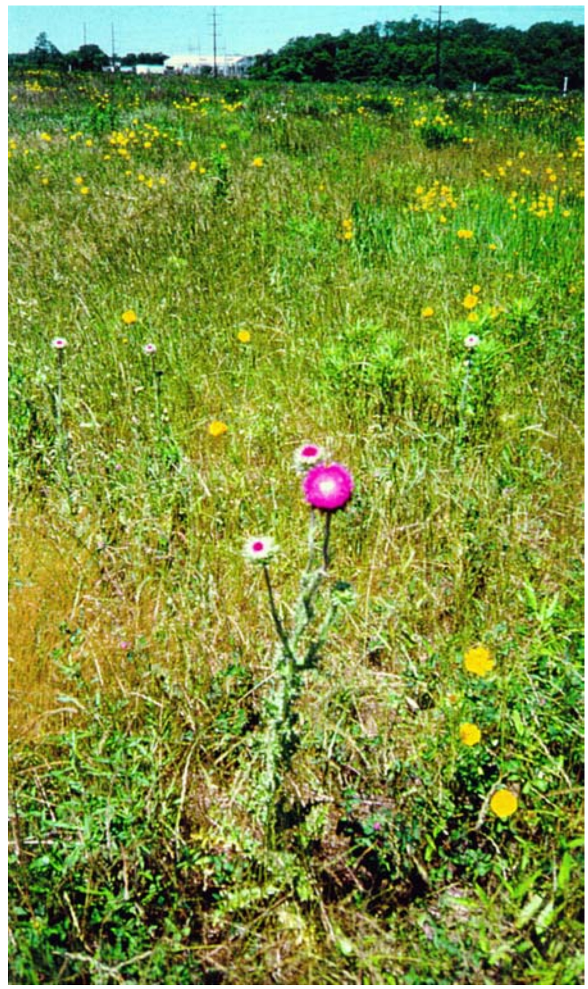
- Protect seeded areas from grazing animals, vehicles, and other disturbances until plants are well established. Protection can be provided by fencing, clearly marked access roads, animal repellants, trenches or berms to control run on and run off, and interim surface stabilization methods such as mulching or matting.

- Reseed within the planting season, if possible, to replace damaged vegetation or if the desired plant density is not achieved.

6.2 Meadows

For this report, a meadow is defined as an expanse of open land that is mainly covered with grasses, forbs, and legumes.[14] Natural grasslands generally have enough moisture to support these species, but not enough to support trees. Meadows often provide a vital habitat for many plants and animals. Even relatively small meadows can support hundreds of species of grasses, sedges, legumes, wildflowers, mammals, insects, and birds. Because of their extensive root systems, native plant species are generally more effective at reducing flooding and runoff and stabilizing soil than are cultivated landscaping grasses. A natural meadow can be a self-sustaining ecosystem, requiring little or no maintenance.

Common cool-season species found in meadows include smooth bromegrass, redtop bent, timothy, slender wheatgrass, quackgrass, Canada wildrye, reedgrasses, and numerous species of sedges, rushes, and spikerushes. Sedge and rush plant types tend to dominate wetter meadow sites. Common warm-season grasses include big bluestem, prairie cordgrass, indiangrass, and switchgrass. These species are generally planted in spring or early summer and produce most of their annual growth during the hot summer months. They can be used to create a meadow with very high wildlife habitat value, especially for ground-nesting birds and many mammals.



Establishing meadow at Army Creek Landfill

Proper establishment of warm season grasses generally requires more careful planning than do cool season grasses such as fescue (USDA, 1997a, 1997b, 1998). The ideal planting time for warm season grasses depends on the climate (*i.e.*, planting zones), soil moisture, and soil temperature. Generally, planting in April and May will increase the success of grass establishment. Because some fertilizer formulations (especially nitrogen) tend to encourage weed growth, fertilizers should only be applied during planting if soil test results indicate they are necessary. Information on planting procedures and seeding rates for individual species is available from the USDA Natural

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14 *Grasses* are characterized by jointed stems, sheathing leaves, flower spikelets and fruit consisting of seed-like grain. *Forbs* are herbaceous plants other than grasses and grass-like plants. They usually have solid stems and broad leaves that are net-veined. The flowers of forbs are often large, colored and showy, but they can also be smaller and less conspicuous. *Legumes* are plants that produce edible seeds in pods. Legumes are used for human food, livestock feed, or as a soil-improving crop.

> At the ***Rocky Mountain Arsenal*** in Denver, Colorado, five major seed mixes were used to create a plant community that would thrive in the area soils. Native grasses for covers were selected based on their ability to provide erosion control and discourage colonization by burrowing animals, evapotranspiration rates, and drought resistance. Appendix A (Case Histories) provides additional detail on this project.

Resources Conservation Service (USDA, 1997a. 1997b, and 1998). Generally, planting equipment (*e.g.*, a native grass drill) is required to ensure good seed to soil contact. Seed should be certified and purchased on a pure live seed basis.

Warm season grasses are generally slow to establish and it may take up to three years after the initial planting year to develop a good stand. The soil may need to be worked before planting to provide a firm, weed-free seed bed that will produce a healthy stand of grasses. During this period, it is important to control weeds and cool season grasses, because warm season grass seedlings cannot compete with these plants. The control of weeds and cool season grasses can begin before seeding using one or more of a number of techniques, such as the application of herbicides, use of a cover or nurse crop, seeding the native grass into the stubble of a previous crop, and the planting of a cultivated crop for two years, which will kill the roots of cool season grasses. The use of a nurse crop, such as oats or annual rye, may also control erosion.[15]

After planting, the area should be carefully monitored for weeds and protected from grazing to allow it to establish. Most weeds are difficult to control after warm season grasses are planted. For the first few years after seeding, perennial weeds and cool season grasses can be controlled through herbicides or mowing. Mowing just above the seedling height can prevent weeds from shading out the seedlings. Eventually, annual weeds will usually be crowded out by the developing stand of grasses, if the stand achieves good density after the first year.

Once established, grass stands usually do not require fertilizer or irrigation. They may require periodic efforts, such as controlled burning, mowing, and removal of plant litter, to suppress woody growth and encourage vigorous new growth. To maximize benefits to wildlife, these activities may be conducted outside of the primary nesting season, preferably in late winter or very early spring. To ensure that food and shelter are continually available to wildlife, these management techniques may be applied to only one-third of the grass stand at a time.

6.3 Semi-Arid and Arid Lands

Establishment of native plant communities in semi-arid or arid areas tends to be naturally slow because of the low amount, and high variability, of rainfall.[16] Disturbance in these dry lands from the activities that led to the contamination or from construction of the remedy can make plant establishment even more difficult. Techniques for the establishment of vegetation in semi-arid or

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15 Nurse crops are species that germinate quickly to form a protective cover over the soil, but are killed by the winter temperatures, leaving dead roots that continue to hold the soil until spring when the prairie seeds germinate.

16 Arid areas are those with desert climates where the mean annual precipitation is less than 10 inches. Deserts with large extremes in temperature and moisture have unique plants that are very difficult to establish.

arid areas are not as well tested as those for natural meadows. A number of factors should be considered in establishing vegetation in these areas, including the following.

Soil treatment is important because damage to soil structure and function is a common and serious problem in degraded semi-arid and arid areas. Soil properties should be examined and improved if necessary. Arid soil, compacted soil, and nutrient-poor soil may be improved by adding organic amendments, such as leaf and litter compost, composted manures and biosolids, and mulch that is certified weed-free. These amendments could help bind recalcitrant organic compounds and metals and increase the much-needed water holding capacity and fertility. Other measures to improve soil structure and function include soil surface treatments, such as pitting and imprinting, to increase soil moisture and gully control to improve plant establishment.

Water availability for plants may be improved by shaping the ground to collect and retain water. Transplanted seedlings may need limited irrigation to survive. However, too much irrigation may encourage the establishment of invasive weeds, leave salts at the soil surface that kill plants, or cause infiltration into subsurface contaminated materials.

Seed selection for arid areas is hampered by the limited availability of commercial stocks of dry land seeds. As discussed in Section 6.1, it is usually better to select seed propagated from local populations. Because the conditions needed for the growth of these genotypes generally match those in the area to be planted, they are more likely to successfully establish. If possible, a commercial seed collector can be hired to collect seed from the local area. Alternatively, seed can be collected from an area within a 100 mile radius and 500 feet of the altitude of the site to be planted; where the average rainfall is within two inches per year of the annual rainfall for the site; and with similar soil characteristics (U.S. Department of Interior, 1995). Seed testing may be used to ensure high quality, live seed. Proper seed storage will also help maintain the seed's viability until sowing.

Planting techniques primarily include direct seeding and transplanting. Direct seeding is generally less expensive. However, in dry areas this technique is more vulnerable to seed loss from wind, insects, and rodents, as well as declines in germination rates and plant growth as a result of insufficient rainfall in the months following planting. Container plants for drier areas are often grown from collected seed. Sufficient time must be allowed for plants to germinate and achieve the desired growth in a greenhouse or nursery before planting. Using container plants can be costly and labor intensive. Because plant losses usually occur, it is prudent to budget for monitoring and replacement.

6.4 Maintenance of Vegetated Areas

After the vegetation is in place, many sites will require periodic maintenance and monitoring to minimize the invasion of non-native species, eliminate deep-rooted plants that might damage protective covers, ensure that settlement or erosion does not interfere with the developing ecosystems or the effectiveness of the remedy, and to observe the meadow's ability to provide food, shelter, resting and nesting areas for wildlife. For the first few years after seeding, perennial weeds and cool season grasses may be controlled with herbicides or mowing.

At the Army Creek Landfill Superfund site in Delaware, the maintenance plan for the vegetated protective cap provides for mowing at certain times of the year and in particular patterns to provide food and shelter for birds and terrestrial animals. The site is mowed once a year before the nesting season for residential birds. Also, the site is mowed in alternating years in vertical or horizontal grids that leave straight stands of protective vegetative cover for terrestrial animals.

6.5 Sources of Technical Assistance

Selected sources for technical assistance for revegetation are listed below. Other sources are provided in the References, beginning on page 61.

Federal Interagency Committee for the Management of Noxious and Exotic Weeds, *Invasive Plants, Changing the Landscape of America: Fact Book* (1998) – http://bluegoose.arw.r9.fws.gov/FICMNEWFiles/FactBook.html

North Carolina Cooperative Extension Service, Leaflet No: 645, "Weed Management for Wildflowers" – http://www.ces.ncsu.edu/depts/hort/hil/hil-645.html

Plant Conservation Alliance – http://www.nps.gov/plants

U.S. Department of Agriculture, Natural Resources Conservation Service, PLANTS Database – http://plants.usda.gov

U.S. Department of Agriculture, Natural Resources Conservation Service, Plant Materials Program – http://plant-materials.nrcs.usda.gov

U.S. Department of Interior, National Park Service, Denver Service Center, Desert Restoration Task Force, *A Beginner's Guide to Desert Restoration* – http://www.serg.sdsu.edu/SERG/B.Guide/Pages/bguide.html

Weed Science Society of America – http://ext.agn.uiuc.edu/wssa

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Finding EPA Publications: Visit http://www.epa.gov/epahome/publications.htm for options on how to obtain EPA publications. Superfund publications available online are located at http://www.epa.gov/superfund/pubs.htm.

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Mahmood, A. 1998. Site Investigation, Remediation, and Closure: A Simplified Guide for Environmental and Real Estate Professionals. Rockville, MD: Government Institutes, Inc.

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U.S. EPA, 1985a. Covers for Uncontrolled Hazardous Waste Sites, EPA 540/2-85/002.

U.S. EPA, 1985b. Settlement and Cover Subsidence of Hazardous Waste Landfills, EPA 600/2-85/035.

U.S. EPA, 1986. Critical Review and Summary of Leachate and Gas Production from Landfills, EPA 600/2-86/073.

U.S. EPA, 1987a. Engineering Guidance for the Design, Construction, and Maintenance of Cover Systems for Hazardous Waste, EPA 600/2-87/039.

U.S. EPA, 1987b. Prediction/Mitigation of Subsidence Damage to Hazardous Waste Landfill Covers, EPA 600/2-87/025.

U.S. EPA, 1990a. Basics of Pump and Treat Remediation Technology, EPA 600/8-90/003.

U.S. EPA, 1990b. Air Emissions from Municipal Solid Waste Landfills - Background Information for Proposed Standards and Guidelines, EPA 450/3-90-011a.

U. S. EPA, 1990c. CERCLA Compliance With Other Laws Manual, Parts I and II, OSWER Directives 9234.1-01 and 9234.1-02.

U. S. EPA, 1990d. CERCLA Compliance With CWA and SDWA, pub. 9234.2-06/FS, February, 1990.

U. S. EPA, 1991a. Conducting Remedial Investigations/Feasibility Studies for CERCLA Municipal Landfill Sites, EPA 540/P-91/001.

U.S. EPA. 1991b. Handbook: Ground Water, Volume II: Methodology, EPA 625/6-90/016b.

U.S. EPA, 1991c. Design and Construction of RCRA/CERCLA Final Covers, EPA 625/4-91/025.

U.S. EPA, 1991d. Compilation of Information on Alternative Barriers for Liner and Cover Systems, EPA 600/2-91/002.

U.S. EPA, 1991e. Ecological Assessment of Superfund Sites: An Overview. *ECO Update*. Volume 1, Number 2, Publication 9345.0-051, Office of Solid Waste and Emergency Response.

U.S. EPA, 1992. Engineering Bulletin: Slurry Walls, EPA 540/S-92/008.

U.S. EPA, 1993a. Compilation of Ground-Water Models, EPA 600/R-93/118.

U.S. EPA, 1993b. Environmental Fact Sheet: Controlling the Impacts of Remediation Activities in or Around Wetlands. EPA 530-F-93-020, Office of Solid Waste and Emergency Response.

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Appendix A
Ecological Reuse Case Studies

This Appendix describes five projects where successful ecological reuse has occurred on remediated waste sites where contaminated material or waste treatment systems remain on site. Although these projects represent a wide range of sites, pollution problems, and ecological resources, they are not exhaustive of all circumstances that occur at Superfund sites. Nevertheless, they demonstrate how remediation and reuse efforts may complement each other. The discussion for each site includes a brief description of the site and contamination, key factors considered during remediation that were important to the planned ecological reuse, the reuse plan and results, and lessons learned. The cases are listed below.

- **Silver Bow Creek/Warm Spring Ponds, Butte, Montana:** Wetland and riparian areas were remediated and restored to provide a habitat for more than 230 types of resident or migratory waterfowl, birds of prey, brown and rainbow trout, and terrestrial wildlife. The site is also used for low-impact recreational activities, such as catch and release fishing and hiking.

- **Bowers Landfill, Pickaway County, Ohio:** A seven-acre wetland was developed in a pit created when clay was dug up for the landfill cap. The wetland functions as a buffer to protect the landfill from flooding and prevent damage to the cap.

- **Cherokee County Galena Subsite, Cherokee County, Kansas:** Native prairie grasses were used to stabilize the clean soil that was placed over mine tailings. The tall, wavy grass stands have encouraged the return of wildlife and now harbor birds and small mammals.

- **Army Creek Landfill, New Castle County, Delaware:** Grains, wildflowers, and other carefully selected vegetation were planted to attract migratory birds for resting, nesting, and feeding. In addition to the habitat for birds and wildlife, wetlands were also restored.

- **Bunker Hill Mining and Metallurgical Site, Kellogg, Idaho:** Three different types of ecosystems were restored at the second largest Superfund site in the country. A grassy riparian floodway is home to frogs, deer, birds, and other wildlife on approximately 200-acres along a 1-½ mile stretch of a river. A 1,000-acre hillside area was revegetated with native and non-native species to reduce the amount of sediment entering surface waters and provide a healthy wildlife habitat for elk and other native species, which are now returning to the area. A 27-acre wetland was planted with native grasses, and waterfowl and otters have returned to the site.

A.1 Silver Bow Creek/Warm Spring Ponds, Butte, Montana


Pond area prior to remediation

Site Background: This site includes three settling ponds covering approximately 2,500 acres, three wildlife ponds, and nearby streams and wetlands. The ponds are within the flood plain of Silver Bow Creek, just above the headwaters of the Clark Fork River. The site became contaminated between the late 1800s and 1980 as a result of mining wastes deposited haphazardly into and adjacent to streams, wetlands, and dry land in the vicinity. The streams carried an astounding 19 million tons of tailings and other mining wastes into the headwaters of the Clark Fork River, where they were the principle cause of fish kills.

To reduce the harmful effect of the tailings on the Clark Fork River, the Anaconda Copper Company dug three settling ponds, now called Warm Springs Ponds. Beginning in 1967, lime was added to the ponds to increase the system’s ability to precipitate out metals. Although these ponds helped reduce some of the adverse impacts of the mining wastes on the Clark Fork River, they eventually accumulated millions of cubic yards of metals-contaminated tailings, soil, and sediment. Concerns were also raised about the risk that a severe flood or earthquake could cause a catastrophic failure of pond berms, and result in the release of millions of cubic yards of tailings and sediment into the river. As a result of the contamination, EPA placed the site on its list of hazardous waste sites needing cleanup (National Priorities List) in 1983.

Despite the environmental problems, Warm Spring Ponds provided a major nesting and resting area for abundant waterfowl in the Upper Clark Fork River basin. Some of the tributaries also provided a fisheries habitat for species such as brown and rainbow trout. Two threatened and endangered bird species, the Bald Eagle and Peregrine Falcon, are occasionally seen at the ponds.

The most prominent Natural Resource Trustees (Trustees) at the site were the Department of Interior (DOI) (represented by the U.S. Fish and Wildlife Service (USFWS)), the Confederated Salish and Kootenai Tribes, and the State of Montana. These Trustees are developing plans for further restoration and improvement of the wetland and riparian habitats with the concurrence of USFWS, and subject to public review and comment.

Remedy: The remedy, which was built between 1991 and 1995, was designed to reduce waterborne and windblown migration of contaminants and included the following activities:

- About 450,000 cubic yards of tailings and contaminated sediment from the ponds and nearby areas were removed, the area was capped, and a comprehensive water treatment system was installed.

- About 200,000 cubic yards of tailings and contaminated soil from the Mill-Willow Bypass (which connects two streams) was excavated, and the bypass channel was restored.
- Tailings and contaminated soil were consolidated in the ponds.
- The performance of all the ponds was improved by raising and strengthening the berms, constructing new inlet and hydraulic structures, and upgrading treatment capabilities.
- Some portions of the ponds were dry closed and some were wet closed to isolate the metals-contaminated materials.[1]
- Pond 3 was enlarged to provide the capacity to receive and treat flows as large as those from a 100-year flood event.
- Spillways for routing excess flood water were routed into the bypass channel.

The ponds are used to precipitate heavy metals so that water discharged from Warm Springs meets ambient water quality guidelines, thereby protecting the trout fishery downstream in the Clark Fork River. The treatment of water entering the Ponds will be necessary until Silver Bow Creek upstream of the ponds is cleaned up.

Reuse Plan: Prior to the remediation, the Warm Spring Ponds area provided a major nesting and resting area for waterfowl, and a habitat for brown and rainbow trout. As a result of the remediation, the habitat for fish and wildlife has been vastly improved and the site is now being used for low-impact recreation. Some of the key activities that have allowed these reuses are:

- In the course of excavating contaminated materials in the Mill-Willow Bypass, the channel was reconstructed into a six-mile long meandering stream with diverse features such as riffles and pools. Plants were selected to stabilize the stream banks, provide cover for wildlife, and restore indigenous species of riparian vegetation. Part of the floodplain was relocated there and the area now serves as a flood bypass channel to divert flow in excess of a 100-year flood event and to protect the pond system and aquatic habitats.

- The wet closure of the dry parts of the ponds resulted in the creation of wetland habitat for resident and migratory waterfowl, as well as the improvement of fish habitat. To improve the existing habitat, nesting islands were installed around the ponds to protect waterfowl from predators. The neutratlization of the tailings in these ponds (by chemical fixation) has resulted in plant growth, forming additional wetland habitat.

- Grassland habitat was increased at the site. The capped dry closure areas were recontoured to control runoff and seeded with native grass species.

Major portions of the site are being used as a wildlife refuge, which is managed by the Montana Department of Fish, Wildlife, and Parks, as part of the Warm Springs Wildlife Management Area. Since the mid-1960s, the Department has leased the ponds from ARCO and its predecessor companies for this purpose, and the institutional controls in the remedy included renewal of this lease agreement.

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[1] The dry closures involved dewatering wet areas and covering them with a protective cap and vegetation. The wet closures involved flooding of dry portions of tailings areas to stabilize them under water;

Reuse Results: The site now provides habitat for more than 230 types of resident or migratory waterfowl, birds of prey, brown and rainbow trout, and terrestrial wildlife. The Mill-Willow Bypass is now a catch and release fishing area that attracts trout fisherman from miles around. The Montana Department of Fish, Wildlife, and Parks limits fishing to catch and release with artificial lures, and the record of decision (ROD) contains institutional controls that prohibit taking fish from the site for consumption.

Restored Pond at Silver Bow Creek

Other recreational activities available at the site include birdwatching, waterfowl hunting, dog training, hiking, biking, a self-guided walking tour, and picnicking. Dog training is permitted during the fall and winter when breeding birds will not be disturbed. The hiking and biking trails were built on the dikes that separate the ponds. Signs have been posted to prohibit swimming in the ponds. Further improvements, such as a footbridge, playground, athletic fields, and additional walking trails and fishing areas, are expected in the future.

Lessons:

- If the contaminated material at a site is stable and can be covered with protective materials, it can remain in the subsurface of a functioning wetland or grassland.

- Creative remedy design based on knowledge of the local ecosystem and hydrology can lead to valuable ecological reuses.

- The need to regrade areas disturbed by a remediation can be turned into an opportunity to consider the establishment or restoration of habitats, such as the riparian habitat along the bypass.

- Some remediation features can serve dual purposes as aids to both habitat restoration and low-impact recreation. For example, hiking and biking trails can be built on top of berms.

- Institutional controls are important to prevent undesirable uses, such as swimming or consuming fish from potentially contaminated waters. Trustees should be involved in their implementation.

A.2 Bowers Landfill, Pickaway County, Ohio

Wetlands created at the Bowers Landfill site support provide habitat for plants and wildlife

Site Background: The 12-acre Bowers Landfill started in 1958 as a rock quarry but soon became a dump for municipal waste. From 1963 to 1968, the landfill also accepted chemical and industrial wastes. As was common at the time, the waste was dumped directly on the ground and simply covered with soil. When the site was abandoned in 1968, the debris and contaminated materials were left behind. Over the years, flooding of the nearby Scioto River caused considerable erosion damage to the banks leading up the landfill. Rain and floodwaters carried chemicals from the landfill into the groundwater under the site and into the river. Contamination was found in surface water, groundwater, sediment, on-site soil, and off-site soil.

The site is within the Scioto River floodplain. The area between the landfill and river generally floods twice a year for nearly 30 days annually. Although this flooding pattern contributed to the release of contaminants from the landfill, it made the site ideal for creating a wetland. The site's location in a floodplain and a rural area also facilitated its reuse as a wetland area and wildlife habitat. Because the wetland was created adjacent to the Scioto River, which is a migration corridor for waterfowl and shorebirds, there was existing habitat nearby to support ecological reuse.

Remedy: The remedy involved hauling away some of the materials in the landfill, building a protective cap over the landfill, and protecting it from the floodwaters. The protective cap was built of clay taken from elsewhere on the property. To address drainage and erosion concerns a seven-acre wetland was developed in a pit created when clay was dug up for the landfill cap. The wetland functions as a buffer to protect the landfill from flooding and prevent damage to the cap. Measures were also taken to manage the buildup of explosive gas under the cap.

The original ROD called for the installation of riprap in areas of the landfill prone to the scouring effects of flood waters and the regrading of these areas to allow water to drain away from the landfill. Wetland creation was not included in the ROD. However, as the remedial design progressed, recommendations from the Ohio Division of Wildlife and U.S. Fish and Wildlife Service led to the design and creation of a seven-acre wetland. Although its primary purpose was to protect the newly-capped landfill from the floodwaters that frequently inundate the area, the wetland also provides a valuable ecological resource.

Reuse Plan: The wetland was developed in the seven-acre pit that was created when clay was dug up for the landfill cap. That area was graded to provide waterways and retention ponds and seeded to promote growth of wetland plants. Occupying the area between the landfill and river, the wetland functions as a buffer to protect the landfill from flooding and prevent damage to the cap. When the Scioto River floods, the wetland holds the flood waters and releases them slowly, reducing possible damage to the protective cap.

Monitoring wells were installed in the new wetland area to ensure that leachate from the landfill does not migrate to the underlying groundwater. These wells were fitted with risers and the surrounding earth was mounded to minimize water intrusion through the wells and to make access easier during flood periods. Consequently, ecological reuse of the site does not affect the use of monitoring wells.

Reuse Results: The final remedy took advantage of the location of the landfill to develop a design that incorporated the creation of a wetland to help protect the landfill's containment system. The man-made wetland was designed to require minimum maintenance. After seeding, wetland plants have flourished providing habitat for wildlife and migratory birds.

Lessons:

- Newly created wetlands can thrive and provide great benefits to communities and the environment, if established in an appropriate location.

- The need to regrade areas disturbed by remediation can be turned into an opportunity to establish a wetland, given appropriate hydrological conditions.

- Some remediation features can serve as aids to habitat creation and low-impact recreation.

- Monitoring programs can be designed to be compatible with wetland reuse. For example, to ensure that groundwater monitoring wells remain accessible during flood periods, they can be fitted with risers and surrounded with earth mounds.

A.3 Cherokee County Galena Subsite, Cherokee County, Kansas

Site Background: The Galena subsite is a 25-square mile area that is part of the 115-square mile Cherokee County Superfund site in southeastern Kansas. The Galena subsite, also known as Operable Unit 5 (OU5) of the Cherokee County site, had large tracts of mine wastes, water-filled subsidence craters, open mine shafts, and pits. The Cherokee County site is a former lead and zinc mining area, which has been divided into six subsites and seven OUs. Over 100 years of mining produced several million tons of mining wastes, destroyed vegetation and wildlife and presented potential human health risks. OU 5 addresses the contamination of groundwater and surface water at the Galena subsite.

The barren countryside was covered with mounds of gray rocks, gravel, and mine waste, and pockmarked by open mine shafts, pits, and craters filled with murky, contaminated water. Acidic waters in abandoned mine shafts, runoff from tailings piles, surface waters in mine pits, and streams draining the site contained significant concentrations of lead, cadmium, and zinc. These heavy metals have leached into the shallow groundwater. The site is surrounded by homes, businesses, light industry, farms, and grazing lands. The mining wastes have affected the quality of the soil, surface water, and groundwater.

Remedy: The remedy included consolidating surface mine wastes in abandoned mine pits, mine shafts, and subsidence areas on the site, diverting streams away from waste piles, recontouring of the land surface, and revegetating the area. The wastes were covered with clean soil and planted with specially selected mixtures of native prairie grasses to control runoff and erosion. Surface streams were diverted away from the stored contaminants. The land surface was re-contoured with clean soil and vegetated to control runoff and erosion. Over two million cubic yards of contaminated mine wastes were relocated and 900 acres of surface mine wastes were cleaned up.

Reuse Plan: The cleanup work was begun in 1993, and by 1994 the native prairie grasses were well on their way to becoming established. These grasses stabilize the soil and have encouraged the return of wildlife. The tall, wavy grass harbors birds and small mammals. Future uses of the site may include light industry and grazing. Portions of the site are likely to remain open space because future development is limited by the potential for cave-ins of old mines.

Native grasses above containment area at the Cherokee County site

Lessons:

- Prairie grasses grown from selected native seed will thrive with little or no maintenance and serve to protect caps over contaminated materials from erosion and infiltration.
- Native grasses can significantly improve the aesthetics of a barren area, thereby improving the attractiveness of the nearby communities.

A.4 Army Creek Landfill, New Castle County, Delaware

Thriving meadow planted at the Army Creek Landfill site

Site Background: Army Creek Landfill is a 47-acre abandoned sand and gravel quarry that was used as a landfill from 1960 to 1968 by New Castle County, Delaware. About two million cubic yards of municipal and industrial waste were disposed of in the landfill. During the rainy season, the groundwater level would rise and saturate nearly 30 percent of the waste. In 1971, after contamination from landfill leachate was discovered in a nearby residential well, New Castle County installed a groundwater recovery well system to control the movement of contaminants toward an aquifer and nearby public water supply wells. To address contamination in Army Creek, which is adjacent to the landfill, and groundwater contamination that threatened the local water supply, the site was added to the NPL in 1983.

The site abuts high-quality wetlands to the south and east along Army Creek, which feeds into the Delaware River. These wetlands, their aquatic life, and other wildlife frequenting the wetlands were at risk of contamination from hazardous substances such as mercury and chromium. The creek and Army Creek Pond, a small body of water southeast of the landfill, were partially degraded by the discharge of contaminated groundwater from the County's recovery wells.

Remedy: The selected remedy included constructing a multi-layered RCRA type C cover over the landfill to prevent infiltration of rainwater, continuing the operation of the groundwater recovery well system to capture contaminated groundwater, and installing an on-site water treatment facility to treat groundwater before it is discharged into Army Creek and the pond. As construction of the protective cover began, opportunities for future use of the site as a habitat for birds and wildlife were investigated and measures to improve wildlife habitat were incorporated into the design of the cap. Reuse design ideas and other assistance were obtained through consultations with the USFWS and the Delaware Division of Fish and Wildlife.

Additional construction was undertaken to address concerns about flooding in low-lying areas where treated water feeds into the adjacent Army Creek. The slope and location of discharge pipes from several existing, on-site sediment basins were modified to create a wetland area. One of the sediment basins, which was already colonized with native wetland plant species, was left in its natural state. The second basin was replanted with species typical of riparian wetlands in the area. The wetlands prevent erosion and flooding, and provide habitat for numerous species of plants, terrestrial animals, and birds.

Reuse Plan: The site's location supports its reuse for wildlife habitat and wetlands. There are existing ecological resources near the Army Creek, such as high-quality wetlands, and the site is not located in a densely urbanized or industrialized area. Grains, wildflowers, and other carefully selected vegetation were planted to attract migratory birds for nesting and feeding. The selected plants provide the erosion control needed to maintain the integrity of the protective cap as well as food and habitat for a variety of plants and animals. One of the seeds included in the mixture, red clover, attracted unwanted burrowing animals and is no longer recommended for use above containment areas. Bird boxes were installed along the riparian wetlands of Army Creek to encourage nesting. Gooseberry was planted around the cap's gas vent pipes to provide visual cover as well as food for animals.

The operation and maintenance (O&M) plan provides for a specific mowing regimen, and activities to remove undesirable vegetation and burrowing animals. Mowing is done only at specific times of the year, and in particular patterns, to provide food and shelter for birds and terrestrial animals. For example, the site is mowed once a year before the nesting season for residential birds. Also, the site is mowed on alternating years in vertical or horizontal grids that leave straight stands of protective, vegetative cover for terrestrial animals. Cap integrity is also maintained through periodic removal of deep rooting, woody plants from the capped area and humane trapping and relocation of woodchucks, which can burrow into the cap. O&M also includes activities to minimize the invasion of non-native reed species into the wetland areas.

Wetland restoration was conducted by federal and state natural resource Trustees, which included the National Oceanic and Atmospheric Administration, USFWS, and State of Delaware. The funds for this restoration came from payments by the settling parties to offset injury to wetlands and aquatic life resulting from the previously described releases of hazardous substances into the creek and pond.

Lessons:

- Avoid the use of plants that tend to attract unwanted burrowing animals.
- Work closely with Natural Resource Trustees, such as the U.S. Fish and Wildlife Service and state and local agencies, to develop restoration plans.
- Funds for restoration may be derived from settlements for natural resource damages.
- Plant appropriate vegetation around permanent features of a remedy, such as gas vent pipes or monitoring wells, to make them more aesthetic and compatible with the ecosystem.
- In developing O&M plans, consider specific needs to remove deep rooting, woody plants from capped areas; humane trapping and relocation of burrowing animals; and activities to minimize the invasion of non-native species.
- Work with local authorities and Trustees to ensure that cap integrity is maintained over time.

A.5 Bunker Hill Mining and Metallurgical Site, Kellogg, Idaho

***Site Background*:** Bunker Hill, the second largest Superfund site in the country is located in Northern Idaho and northeastern Washington. Mining operations began in 1886 with lead smelting starting in 1917. These operations produced refined lead, zinc, cadmium, silver, gold, and alloys of these heavy metals. Other activities in the area produced sulfuric acid, zinc oxide, and phosphate fertilizers. Prior to 1938 all liquid and solid residues of mineral processing were routinely discharged into the Coeur d'Alene River and its tributaries or used for fill. Later, waste streams were directed to a plain just north of the Bunker Hill industrial complex. Lead smelter slag was deposited in a pile on the western end of the plain. An impoundment area developed on the eastern end of the plain was surrounded by a dike of mine tailings and waste rock that over the years grew to 70 ft in height. All liquid wastes were directed to the pond for settling and then discharged to the river. In the early 1970s a central treatment plant was constructed at the edge of the pond to treat water prior to discharge into the river. In 1973, a fire at the smelter damaged the air emissions controls, dramatically increasing lead emissions at the site. The smelter closed in 1981 and Bunker Hill was placed on the NPL in 1983 (USEPA, Region 10 web site).

This case study addresses three areas within the Bunker Hill Site that represent distinct ecosystems: Smelterville Flats - a riparian floodway; Hillsides - an upland terrestrial ecosystem; and, West Page Swamp - a wetlands. These areas had high concentrations of metals, low pH, low soil nutrients and organic matter, and/or poor soil physical properties.

Bunker Hill in the Coeur d'Alene River Basin in Idaho is the second largest Superfund site in the U.S.

***Remedy*:** For cleanup purposes the site was divided into three operable units - OUs 1 and 2 focus on the 21-square mile area called the Bunker Hill Box. OU 1 includes residential (about 6,000 people) and other community areas in Shoshone County and OU 2 includes historic mining and smelting areas. OU 3, called the Basin, runs along the Coeur d'Alene River, through Lake Coeur d'Alene, and into the Spokane River. About 242,000 people live in the vicinity of the Basin, affecting numerous communities in two states and the lands of the Coeur d'Alene and Spokane Tribes.

The three areas of ecological reuse in this report are all within OU 2. Due to the bankruptcy of the major PRP, most of the work in these areas are paid for by the Superfund Trust Fund. EPA and the State of Idaho are responsible for implementing the remedial action. Each of the three areas, which are described below, represent the three different ecosystem types addressed in Chapters 4, 5, and 6 of this report (wetlands, stream corridors, and terrestrial).

Smelterville Flats Remedy and Reuse: The Smelterville Flats cover approximately 200 acres along a one and one-half mile stretch of the South Fork of the Coeur d'Alene River. During the almost 100 years of operations at Bunker Hill, much mining waste materials and tailings discharged upstream into the river were deposited at the Flats. When the river was dammed, from 1910 to 1932, the Flats served as a tailings pond. The dam failed in 1933 resulting in some portion of the tailings spreading downstream.

Remedial action called for minimizing direct contact with contaminants, surface erosion, and migration of contaminants to surface water and groundwater. Tailings were removed from the floodplain and deposited in the Central Impoundment Area (CIA); portions of the river were restructured to provide soil barriers; and the flats were revegetated as necessary. The CIA is a 260-acre area constructed over river gravel and jig tailings. Most of the disposal to the area was discontinued when the mine shut down in 1982. Approximately 1.3 million cubic yards of tailings were removed. The South Fork of the river was re-routed with the use of small dams and earth moving equipment to enable the excavation of the tailings.

Clean fill was brought in to reshape the river channel, creating more pools, meanders, and shaded areas. Topsoil was trucked in to revegetate the Flats. One ton per acre of lime and Biosol, an organic fertilizer, were applied to the soil to help limit toxicity and generally improve soil conditions. The reconstructed floodplain was revegetated with native grasses. Today the flats are an established grassy riparian floodway with increased shaded areas and is more hospitable to plants and wildlife. The U.S. Fish and Wildlife Service conducts bio-monitoring and the State of Idaho is responsible for long-term monitoring of the Flats (USEPA, Region 10 web site; USEPA, 2003; and Macintyre, 1998).

Hillside Remedy and Reuse: The Hillsides within Bunker Hill have been impacted by years of metal mining and refining and associated activities, such as logging, clearing, and mine waste rock dumping. These activities, combined with natural events such as forest fires, resulted in an almost total loss of vegetative cover across much of the hillside area. Construction of terrace benches disturbed native soils and introduced over-steepened cut and fill slopes. The erosion of the contaminated soils from the hillsides carried the contaminants to the streams, gulches and other areas (USEPA, 2000).

The revitalized hillsides area of the Bunker Hill Superfund site are now home to plants and animals, such as this elk.

The 1992 ROD called for remedial action focusing on approximately 3,200 acres of hillside. From the mid-1990s on, the primary focus has been on a 1,050-acre almost contiguous block of land on the southern hillsides of Bunker Hill. The entire hillside was highly eroded, acidic, lacking in moisture and nutrients, and steeply sloped. The ultimate goal was to return the hillsides to a coniferous forest ecosystem similar to that found elsewhere in northern Idaho. In addition to the challenges posed by the physical conditions of the site, restoration was hampered by the limited road access, the cost of shipping the volume of materials needed, and efforts needed to sustain the seedlings that were planted on the hillside over the years until they become established (White, et. al., 2003)

Prior to treatment denuded slopes dominated hillsides in Government Gulch. Tree seedlings, although present, are invisible in this photograph. Coarse woody debris lie on the slope to the right and toward the foreground (1997).

Post-treatment hillsides environment in Government Gulch (May 2003). a mixture of biosolids and ash was successful in helping revegetate the area to reduce sedimentation and provide a healthy wildlife habitat for elk and other native species.

Demonstration plots were installed in 1997 on some of the steepest portions of the site. Large-scale revegetation was conducted in 1998, 1999, 2000 and 2001, using helicopters to apply lime and hydroseed. Soils were amended and modified to control for acidity and provide nutrients. The plantings included both native and non-native species. The selection of species was based on their ability to sustain themselves on harsh sites, help stabilize the sediment, and conserve soil resources. For instance, black locust was planted alongside mountain alder because of its ability to fix nitrogen. Some species were selected to allow for sunlight to reach seedlings. Hardwood species of trees were added to areas where conifers had been planted to enhance diversity and further improve soils. The planting of trees and shrubs was completed in the fall of 2002.

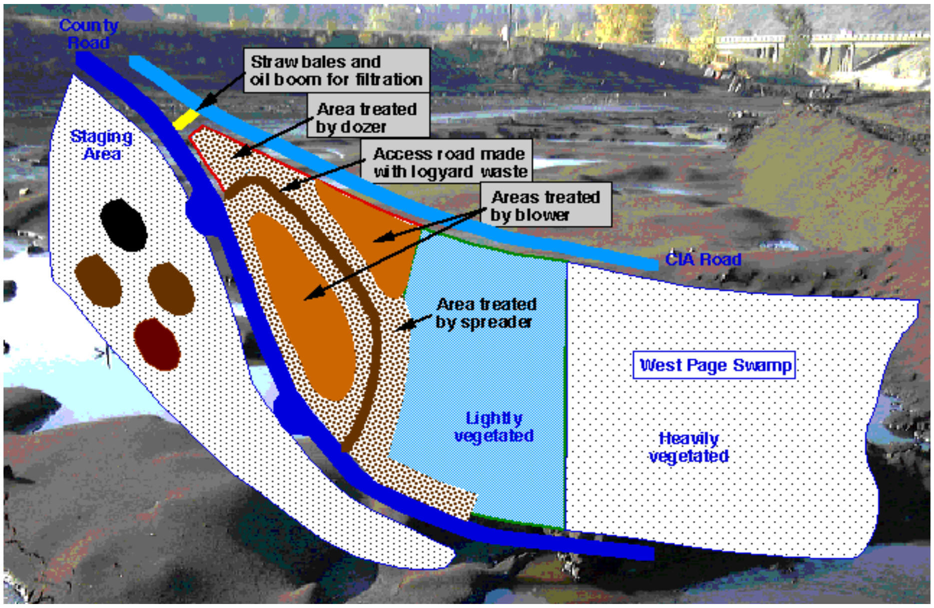
Plant cover is monitored annually after a seeded area is two years old. Surface water is monitored annually on a continuous basis (White, et. al., 2003). Seventy-three percent of the acres that had been seeded were found to contain greater than 50 percent cover. This good-to-excellent cover exists in all watersheds. Studies suggest that the present cover is sustainable. Surface water hydrology indicates that the revegetation is reducing the amount of sediment entering the basin from the hillside. Continual monitoring shows that turbidity levels of surface water discharging from the watershed has dropped significantly following treatment. Native species, such as elk, deer and coyote, along with native plants such as fireweed, Douglas-fir, willow, aspen, snowberry, and other species are flourishing the hillsides (USEPA, 2003).

West Page Swamp Remedy and Reuse: West Page Swamp is a 27.2-acre wetland section of the approximately 170-acre Page Pond area of the Bunker Hill Superfund Site. Page Pond was used as a disposal area for tailings resulting from mineral mining and processing activities at the former Page Mill in nearby Humboldt Gulch. The West Page Swamp area was used by the Hayes Company Mill from 1918 to 1929 for tailings deposits. The water levels and surface areas of the swamp fluctuate seasonally with high water levels during periods of heavy rainfall and snowmelt and low levels during dry seasons (USEPA, 2000). The major metal contamination in the swamp is from lead, zinc, cadmium, and arsenic and, prior to the remediation, the swamp had no ecosystem functions. Elevated levels of lead in wetlands are the primary ecosystem risk to migratory fowl that use the wetlands for seasonal feeding and nesting.

The remedy for Page Pond called for (a) the removal of approximately 40-60 thousand cubic yards of jig tailings from the West Page Swamp area and the placement of this material on the Page Pond benches as a sub-base for a vegetation cap; (b) evaluation of wetlands associated with the pond for water quality and habitat considerations, including bio-monitoring; and (c) the use of hydraulic controls to enhance existing wetlands in West Page Swamp. The objectives of these remedial actions were to minimize exposure from fugitive dust, minimize releases to surface and groundwater, minimize habitat destruction, and improve wetland vegetation and habitat.

As part of a closure agreement with U.S. EPA Region 10, the mining companies involved with the site excavated a 4.9-acre portion of the swamp. In 1997, tailings in this area were removed to a depth of 0.7 meter to reduce the potential for exposure of wildlife to metal contamination. This effort was followed in 1998 by a project to test the feasibility of using biosolids compost in combination with other residuals, like wood ash, to help revegetate the area, reduce the bioavailability and accessibility of the remaining contaminated materials, and restore ecosystem function. The biosolid mixtures were delivered with the use of front end loaders and bulldozers.

However, when rising groundwater in the fall caused standing water, access with heavy equipment became difficult. To gain access, logyard debris was used to build a road over road fabric. Compost and wood ash were mixed and spread with a thrower from both the newly constructed road and the county highway. A significant portion of the test area not reached during initial application was treated in 2000. The wetland was closed on the outlet end in order to maintain a 2-foot water depth.



At West Page Swamp, EPA used biosolids compost and other materials to accelerate revegetation and limit the ecosystem impact of metals contamination in wetlands.

Reuse Results:
Today, Smelterville Flats is a vigorous, complex ecosystem composed of extensive wetland and upland grass/shrub riparian communities. The area is home to frogs, birds, other wildlife, and plants. The U.S. Fish and Wildlife Service conducts bio-monitoring and the State of Idaho is responsible for long-term monitoring of the Flats.

A coniferous forest that harbors elk, deer, and other wildlife is now growing on approximately 1,000 acres of *hillsides* that were severely eroded and acidic. The combination of native bunchgrasses and forbs and application of appropriately targeted soil amendments have resulted in slower water movement, invigorated stagnant tree seedlings, and stabilized hillsides with vegetative coverage.

Native grasses, such as cattails and bulrushes, thrive at *West Page Swamp*. Waterfowl have returned and lake otters have moved into the swamp. The area is now a functioning wetland that is beautiful to view. Water and plant samples are regularly collected to monitor for toxicity. Monitoring is conducted by the University of Washington, USEPA, and the Idaho Department of Environmental Quality.

Lessons:

- Biosolid composts and other materials, can be applied to the soil to help limit toxicity, improve soil conditions, and allow the establishment of valuable riparian ecosystems.
- Seriously damaged steep hillsides can be successfully revegetated with native and non-native species, if the soils can be amended and modified to control acidity and provide nutrients.
- If species that have the ability to sustain themselves on harsh, steep sites are selected, they can help stabilize the sediment, conserve soil resources, and contribute to restoration or maintenance of important ecosystems.
- The impacts of construction of a remedy can be mitigated by using indigenous materials to build temporary roads that are designed to either be removed or biodegrade.
- In-depth knowledge of a site, collaborative planning, and comprehensive site characterization can lead to more cost-effective development of viable ecosystems.
- If properly managed, contaminated material can be left on site and the site can be restored to support a variety of ecological or other reuses.

References for Bunker Hill Site

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Web Sites

U.S. EPA. Operable Unit Fact Sheets. http://www.epa.gov/superfund/accomp/success/bunker_ou12.htm

U.S. EPA, Region 10. Fact sheet and other documents, http://yosemite.epa.gov/r10/cleanup.nsf

Bunker Hill, Idaho, Ecological Restoration Demonstration, http://faculty.washington.edu/clh/bunker.html

West Page Swamp Wetland Restoration Project, Bunker Hill, http://faculty.washington.edu/clh/wet.html

Appendix B. Acronyms

ARARs	Applicable or Relevant and Appropriate Requirements
BRAC	Base Realignment and Closures
BTAG	Biological Technical Assistance Group
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CIA	Central Impoundment Area
CWA	Clean Water Act
EE/CA	Engineering Evaluation/Cost Analysis
EPA	Environmental Protection Agency
GPS	Global Positioning System
MEDEP	Maine Department of Environmental Protection
NCP	National Oil and Hazardous Substances Contingency Plan
NRDA	Natural Resource Damage Assessments
O&M	Operations and Maintenance
OPA	Oil Pollution Act
OSWER	Office of Solid Waste and Emergency Response
OU	Operable Unit
PAHs	Polynuclear Aromatic Hydrocarbons
PCBs	Polychlorinated Biphenyls
PRB	Permeable Reactive Barriers
PRP	Potentially Responsible Party
RCRA	Resource Conservation and Recovery Act of 1976
RI/FS	Remedial Investigation and Feasibility Study
ROD	Record of Decision
RPM	Remedial Project Manager
SARA	Superfund Amendment and Reauthorization Act of 1986
S/S	Solidification/Stabilization
TCE	Trichloroethylene (or Trichloroethene)
USAF	United States Air Force
USDA	United Department of Agriculture
USFWS	United States Fish and Wildlife Service
VOCs	Volatile Organic Compounds