National Park Service
Pacific Northwest Region

Revegetation Handbook

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Chapter 1. Introduction

Natural resources are composed of an inherently complex mix of organisms, processes, and systems. These resources and values include ecosystems and their component plants, animals, water, air, soils, topographic, and geologic features.

Understanding of these processes and systems is far from complete, yet the National Park Service (NPS) is charged with the management and protection of the natural resources of NPS areas into the future. The fundamental objectives of NPS natural resource management, as prescribed in policy, are to manage the natural resources of the National Park System to maintain, restore, and perpetuate their inherent integrity and, when consistent with the foregoing, to provide opportunities for visitors to benefit from and enjoy natural environments which are evolving through natural processes minimally influenced by human action. (NPS-77 1:1)

Within this context, and in light of the increasing numbers of visitors to our national parks, the role of restoration programs to maintain, restore, and perpetuate natural resources becomes even more important.

The Goal of Restoration Programs

The National Park Service is directed to manage the natural resources of the national park system in order to maintain, rehabilitate, and perpetuate their inherent integrity (NPS Management Policies 4:1). The National Park Service will also seek to perpetuate native plant life as part of natural ecosystems (NPS Management Policies 4:8).

The National Park Service recognizes the importance of preserving the diversity and integrity of ecosystems and natural gene pools. Following these management policies, the goal of restoration

programs is to restore as closely as possible the natural ecosystem that was damaged or destroyed, and to minimize or stop further damage. How this goal is implemented will vary by NPS management zone. Management of natural resources is based on management zones, as established by the approved general management plan of each national park. Management zones include: **natural, cultural, park development,** and **special use.** Restoration work will use native plants and soils to protect park resources and values whenever it is compatible with the primary management objectives of each zone.

Natural zones are managed to protect, maintain, and perpetuate the natural resources and values as closely as possible to their natural condition, while allowing compatible visitor use and enjoyment. Wilderness lands are a subzone in this classification.

Cultural zones are managed to preserve and appreciate cultural resources. When compatible with cultural resource objectives, the zone will be managed similar to natural zones.

Park development zones are managed for intensive visitor use. When compatible with development zone objectives, the natural resources will be maintained in as natural a condition as possible.

Special use zones are managed for activities which are not appropriate in the other zones, including commercial uses, mineral development activities, and others.

Types of Habitats

Although the national parks in the Pacific Northwest Region cover a wide range of ecosystems, they can be divided into three basic groups: low to mid-elevation forests on east and west slopes of

the mountains, subalpine areas, and alpine areas. Forests on both east and west sides of the mountains generally have long growing seasons (six months or more), and moderate to deep soil. Both east and west-slope forests support trees, shrubs, and herbaceous vegetation. Forests on the western slopes receive heavy precipitation which, combined with moderate year-round temperatures, encourages lush vegetative growth. Forests on the eastern slopes are in the rainshadow (lee-slope) of the mountains, resulting in drier conditions and sparser vegetation.

Subalpine and alpine areas commonly have shallow, rocky soil, and a short growing season (often less than 4 months). Subalpine areas are moderated in the winter by a blanket of snow which provides moisture in the growing season and allows for more lush vegetation than in the higher alpine. The more exposed alpine areas frequently have much of their winter snow cover blown away, resulting in drier soil conditions and sparser vegetation. Restoration of forested sites may only take a few years because the moderate environment encourages plant growth. In contrast, the short growing season of alpine and subalpine sites slows the restoration process to decades or centuries.

Types of Impacts

Impacts to vegetation and soil are due to human and natural processes. Human-caused impacts are commonly visible as denuded vegetation; social trails to viewpoints, water, or between campsites; campsites in undesignated areas; post-construction scars adjacent to roads and buildings; and exotic plants and animals. Examples of natural impacts include landslides, avalanches, elk wallows, and areas of tree fall. Although there are numerous causes and types of impacts, and differing physical characteristics of disturbed sites, many of the restoration techniques are the same. The basic information and techniques for planning a restoration project; growing plant stock; preparing, planting, and maintaining a site; and educating visitors about restoration and resource management; can be applied to many different sites and situations.

National Park Service Restoration Programs

All the major parks in the Pacific Northwest (Mount Rainier, North Cascades, and Olympic National Parks) have active plant restoration programs. Although some restoration work was done in earlier years, the programs were developed more fully in the 1970's and 1980's as the numbers of people using the parks grew dramatically, and the impacts of decades of human use became more evident. The revegetation program at North Cascades National Park was started in 1970, with the first project being the restoration of impacted sites at Cascade Pass. Olympic National Park began restoration of the Grand Lake area in 1975, using Student Conservation Association workers. Mount Rainier National Park began their most comprehensive and documented restoration program in 1986 with work in Paradise Meadows. The restoration programs have grown and expanded with the growth in our knowledge and experience in the ensuing years.

Restoration projects have occurred in park development zones, natural zones, and wilderness subzones. Campsites and social trails in subalpine areas have been the major focus of restoration projects. Other projects include campsites and social trails in lower elevation forests, and revegetation of road corridors after construction. A recently-developed technique involves salvaging plants from road and trail construction sites before work begins, and using the salvaged material to revegetate the same sites when construction is completed. Determining the plants that work well for revegetation, and the most effective propagation methods for each species, is an on-going learning process.

Purposes, Objectives, and Scope of this Handbook

The handbook will provide information about restoration processes for NPS seasonal and permanent staff working on restoration projects. Additionally, the information in the handbook can be used by interpreters and rangers to educate park visitors about the natural resources that shape the spirit and character of our national parks, and the need for resource protection.

This handbook is a compilation of revegetation information, and restoration processes and techniques from Mount Rainier, North Cascades, and Olympic National Parks. The restoration information is directly applicable to restoration projects west of the Cascade Mountains. Although restoration of arid lands is not covered in this handbook, much of the information and techniques can be extrapolated for restoration projects on the east side of the mountains. There are plans for additional chapters addressing dry-lands restoration in the future. Assessing impacts and planning restoration projects are the first steps in any restoration work and are fully described in this handbook. Techniques for collecting seeds and plants, and propagating plant material in the greenhouse and on-site are given, as well as information on contracting out for plants. Methods are given for stabilizing a site, preparing it for revegetating, and maintaining it after planting. The chapter on site maintenance and protection includes information on mechanical and educational strategies to inform park visitors about restoration work and resource protection. After restoration work has been completed, sites need to be monitored to measure changes, and to determine how effective the restoration and educational efforts have been. Several kinds of monitoring techniques are detailed so that the appropriate level of monitoring for each site can be determined. A chapter about contracting and funding restoration work, key issues for many restoration projects, is followed by a discussion of restoration experiments and research needs within the region—what our current state of knowledge is, and where we go from here.

The terms **revegetation** and **restoration** are often used interchangeably in vegetation management. In this handbook **revegetation** is used to mean the process of seeding or planting a site where the natural vegetation has been disturbed. **Restoration** of a site may involve stabilizing, filling and recontouring with soil , and reestablishing the drainage, in addition to replanting.

Chapter 2. Laws, Policies, and Guidelines

Laws, policies, and guidelines have been established directing the National Park Service to protect the resources and values encompassed by park lands. The goal of this chapter is to familiarize people working in NPS restoration and revegetation programs with the mandates to protect and restore these resources which give the parks their natural character. Several major laws, summarized below, show the growth in natural resource protection over the last 120 years. Specific policies for managing natural resources conclude the chapter.

In 1872, Congress recognized the beauty and public value of certain federal lands, and the need to protect and preserve their natural character. That year, Yellowstone National Park was created—the first of many to come. The Act establishing Yellowstone states that the land shall be:

> ...reserved and withdrawn from settlement, occupancy or sale under the laws of the United States and dedicated and set apart as a public park or pleasuring ground for the benefit and enjoyment of the people... That...the Secretary of the Interior...shall provide for the preservation, from injury or spoilation, of all timber, mineral deposits, natural curiosities or wonders within said park, and their retention in their natural condition. (Yellowstone Park Act, 16 USC 21-22)

By 1916, Congress had authorized 31 national parks and 19 national monuments. The lands were administered by several government agencies. To bring the lands under one administration Congress created the National Park Service with the Organic Act of 1916. The purpose of the National Park Service was mandated under this Act:

> ...to conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations. (NPS Organic Act, 16 USC 1)

The General Authorities Act of 1970 was enacted by Congress to reaffirm that all lands administered by the National Park Service are part of the National Park System and subject to the provisions of the Organic Act.

> ...these areas, though distinct in character, are united through their inter-related purposes and resources into one national park system as cumulative expressions of a single national heritage; that, individually and collectively, derive increased national dignity and recognition of their superb environmental quality through their inclusion jointly with each other in one national park system preserved and managed for the benefit and inspiration of all the people of the United States. (General Authorities Act, 16 USC 1a-1)

The mandate to protect the resources and values within national park lands was further strengthened by the act expanding Redwood National Park in 1978 which states:

> Congress further reaffirms, declares, and directs that the promotion and regulation of the National Park System...shall be consistent with and founded in the purpose established by [the Organic Act], to the common benefit of all the people of the United States. The authorization of activities shall be construed in light of the high public value and integrity of the National Park System and shall not be exercised in degradation of the values and purposes for which these various areas have been established, except as may have been or shall be directly and specifically provided by Congress. (16 USC 1a-1)

Congress, recognizing the importance of preserving the wilderness character of some federal lands, initiated a National Wilderness Preservation System with the establishment of the Wilderness Act of 1964. The Act states that:

> ...it is hereby declared to be the policy of Congress to secure for the American people of present and future generations the benefits of an enduring resource of wilderness. For this purpose there is hereby established a National Wilderness Preservation System to be composed of federally owned areas designated by Congress as "wilderness areas", and these shall be administered for the use and enjoyment of the American people in such manner as will leave them unimpaired for future use and enjoyment as wilderness, and so as to provide for the protection of these areas [and] the preservation of their wilderness character...

Wilderness character is defined by the Wilderness Act as:

> ...an area where the earth and its community of life are untrammeled by man, where man himself is a visitor who does not remain. An area of wilderness is further defined to mean...land retaining its primeval character ...and which ...generally appears to have been affected by the forces of nature, ...has outstanding opportunities for solitude...is of sufficient size as to make practicable its preservation and use in an unimpaired condition; and...may also contain ecologic, geologic, or other features of scientific, educational, scenic, or historical value.

With the Washington Park Wilderness Act of 1988 Congress designated wilderness areas to be preserved within Mount Rainier, North Cascades, and Olympic National Parks.

Clearly, Congress has given the National Park Service a strong mandate to protect, preserve, and restore the natural character of the lands within the NPS system. Additionally, the enabling legislation or executive orders establishing each national park mandate protection of the natural and cultural resources. The three primary examples from the Pacific Northwest include:

Mount Rainier National Park (established 1899)

> That all those certain tracts, pieces, or parcels of land...are hereby dedicated and set apart as a public park, to be known and designated as the "Mount Rainier National Park", for the benefit and enjoyment of the people...for the preservation from injury or spoilation of all timber, mineral deposits, natural curiosities, or wonders...and their retention in their natural condition... (30 Stat 993)

Olympic National Park (established 1938)

> That ...tracts of land...are hereby reserved and withdrawn from settlement, occupancy, or disposal under the laws of the United States and dedicated and set apart as a public park for the benefit and enjoyment of the people and shall be known as the Olympic National Park... (52 Stat 1241)

> The purpose of the proposed national park is to preserve for the benefit, use and enjoyment of the people, the finest sample of primeval forests of Sitka spruce, western hemlock, Douglas fir, and western red cedar in the entire United States; to provide suitable winter range and permanent protection for the herds of native Roosevelt elk and other wildlife indigenous to the area; to conserve and render available to the people, for recreational use, this outstanding mountainous country, containing numerous glaciers and perpetual snow fields, and a portion of the surrounding verdant forests together with a narrow strip along the beautiful Washington coast. (H.R. 2247)

North Cascades National Park Service Complex (established 1968)

In order to preserve for the benefit, use, and inspiration of present and future generations certain majestic mountain scenery, snowfields, glaciers, alpine meadows, and other unique natural features in the North Cascade Mountains...there is hereby established...the North Cascades National Park...(PL 90-544)

...In order to provide for the public outdoor recreation use and enjoyment of portions of the Skagit River and Ross, Diablo, and Gorge Lakes, together with the surrounding lands, and for the conservation of the scenic, scientific, historic, and other values contributing to public enjoyment of such lands...there is hereby established...the Ross Lake National Recreational Area...(PL 90-544)

...In order to provide for the public outdoor recreation use and enjoyment of portions of the Stehekin River and Lake Chelan, together with the surrounding lands, and for the conservation of the scenic, scientific, historic, and other values contributing to public enjoyment of such lands...there is hereby established...the Lake Chelan National Recreational Area...(PL 90-544)

Natural Resources Management and Restoration

Much of the spirit and natural character of our national parks is embodied in their natural landscapes and resources. The role of protecting and perpetuating these natural resources is the ultimate

responsibility of park resource managers, rangers, and biologists, in cooperation with other park staff and the public.

NPS Management Policies (1988) sets the framework for natural resource management within the National Park Service. The policies apply to national parks across the country. Topics and policies that specifically apply to vegetation management and restoration are excerpted below. For more detail consult the original document. The Natural Resources Management Guidelines (NPS-77) provides additional information.

Natural Resource Management

> The National Park Service will manage the natural resources of the national park system to maintain, rehabilitate, and perpetuate their inherent integrity. (4:1)
>
> The natural resource policies of the National Park Service are aimed at providing the American people with the opportunity to enjoy and benefit from natural environments evolving through natural processes minimally influenced by human actions. (4:1)
>
> Management of natural systems will be based on a park's management zones as established in an approved statement for management or general management plan. (4:1)
>
> **Natural Zones:** The primary objective in natural zones will be the protection of natural resources and values for appropriate types of enjoyment while ensuring their availability to future generations. Natural resources will be managed with a concern for fundamental ecological processes as well as for individual species and features. (4:1)

Ecological processes altered in the past by human activities may need to be abetted to maintain the closest approximation of the natural ecosystem where a truly natural system is no longer attainable. (4:2)

Naturally evolving plant and animal populations, and the human influences on them, will be monitored to detect any significant unnatural changes. Action will be taken in the case of such changes based on the type and extent of change and the appropriate management policy. (4:2)

Cultural Zones: The primary resource management objectives in cultural zones are to preserve and foster appreciation of the cultural resources. The management of their natural resources will support these cultural resource objectives. Where compatible with cultural resource objectives, the policies for natural zones will be followed. (4:2)

Park Development Zones: Park development zones are managed and maintained for intensive visitor use. Accordingly, roads, walks, buildings, and other visitor and management facilities may occupy much of the zones, and the natural aspect of the land in the zones may be altered. In development zones adjacent to natural zones, management will aim at maintaining as natural an environment as possible, given the use of the zone. Such management may involve the manipulation of natural resources, but any manipulation will be the minimum necessary to achieve the planned use. (4:2)

Inventory and Monitoring

The National Park Service will assemble baseline inventory data describing the natural resources under its stewardship and will monitor those resources at regular intervals to detect or predict changes. The resulting information will be analyzed to detect changes that

may require intervention and to provide reference points for comparison with other, more altered environments. (4:4)

Landscapes and Plants

The National Park Service will seek to perpetuate native plant life as part of natural ecosystems. Landscapes and plants may be manipulated only when necessary to achieve approved management objectives. These objectives will vary according to management zones, as described below. To the maximum extent possible, plantings in all zones will consist of species that are native to the park or that are historically appropriate for the period or event commemorated. Only native species will be allowed in natural zones. Use of exotic species in other zones will conform to the exotic species policy. In any zone, landscapes and plants may be manipulated to maintain habitat for threatened or endangered species, but in natural zones only native plants may be used if additional plantings are done, and manipulation of existing plants will be carried out in a manner designed to restore or enhance the functioning of the plant and animal community of which the endangered species is a natural part. (4:8)

Natural Zones: In natural zones, landscape conditions caused by natural phenomena, such as landslides, earthquakes, floods, ...and natural fires, will not be modified unless required for public safety or for necessary reconstruction of dispersed-use facilities, such as trails. (4:9)

Terrain and plants may be manipulated where necessary to restore natural conditions on lands altered by human activity. Management activities may include, but will not be restricted to:

removing constructed features, restoring natural gradients, and revegetating with native park species on acquired inholdings and on sites from which park development is being removed,

restoring a natural appearance to areas disturbed by activities such as fire control and hazard tree removal,

rehabilitating areas disturbed by visitor use,

maintaining open areas and meadows where they were formerly maintained by natural processes. (4:9)

Natural Zones: Wherever possible, revegetation efforts in natural zones will use seeds, cuttings, or transplants representing species and gene pools native to the ecological portion of the park in which the restoration project is occurring. Where a natural area has become so degraded that restoration with native species has proven unsuccessful, improved varieties or similar native species may be used. (4:9)

Cultural Zones: Trees, other plants, and landscapes in a cultural zone generally will be managed to reflect the historic designed landscape or the scene that prevailed during the historic period, except that soil erosion will be prevented wherever possible. (4:9)

Park Development Zones: Landscapes and plants in park development zones may be manipulated as necessary to achieve the purpose of the zone. Landscapes and plantings adjacent to natural or cultural zones will use native or historic species and materials to the maximum extent possible. Certain native species may be fostered for aesthetic, interpretive,

or educational purposes. Use of exotic species or materials will conform with the exotic species policy. (4:9)

Genetic Resources

The National Park Service will strive to protect the full range of genetic types (genotypes) native to plant and animal populations in the parks by perpetuating natural evolutionary processes and minimizing human interference with evolving genetic diversity. (4:10)

The introduction of native plants and animals will be accomplished using organisms taken from populations as closely related genetically and ecologically as possible to the park populations, preferably from similar habitats in adjacent or local areas. (4:10)

All resource management actions involving planting or relocating species, subspecies, or varieties will be guided by knowledge of local adaptations, ranges, and habitat requirements and detailed knowledge of site ecological histories. (4:10)

Restoration of Native Plants

The National Park Service will strive to restore native species to parks wherever all the following criteria can be met:

> Adequate habitat to support the species either exists or can reasonably be restored in the park and if necessary on adjacent public lands and waters, and once a natural population level is achieved, it can be self-perpetuating.

The species does not, based on an effective management plan, pose a serious threat to the safety of park visitors, park resources, or persons or property outside park boundaries.

The subspecies used in restoration most nearly approximates the extirpated subspecies or race.

The species disappeared, or was substantially diminished, as a direct or indirect result of human-induced change to the species population or to the ecosystem. (4:10)

Exotic Plants

Exotic species are those that occur in a given place as a result of direct or indirect, deliberate or accidental actions by humans (not including deliberate reintroductions). (4:11)

Decisions on whether to introduce an exotic species will be based on the purposes and designated zones of the park and will be undertaken only after rigorous review of the proposal. (4:11)

Non-native plants and animals will not be introduced into natural zones except in rare cases where they are the nearest living relatives of extirpated native species, where they are improved varieties of native species that cannot survive current environmental conditions, where they may be used to control established exotic species, or when directed by law or expressed legislative intent. (4:12)

In cultural zones, nonnative plants and animal species may be introduced in rare cases as described for natural zones. In addition, nonnative species that are a desirable part of the historic scene being represented in a cultural zone may be introduced, but only if they are controlled by such means as cultivating for plants... (4:12)

In park development zones and special use zones (particularly landscape subzones), exotic species of plants ... may be introduced to carry out NPS programs consistent with park objectives only when all the following conditions exist:

> Available native species will not meet the needs of the management program.
>
> Based on scientific advice from appropriate federal, state, local, and nongovernmental sources, the exotic species will not become a pest.
>
> Such introductions will not spread and disrupt desirable adjacent natural plant ...communities and associations, particularly those of natural zones. (4:12)

Clearly, there is history, justification, and management policy towards ecological restoration and revegetation activities in National Parks. The challenge lies in discovering the methods to best carry out the mission, including educating the public in caring for the land.

Chapter 4. Site Assessment And Project Planning

Landscapes are not static; they evolve throughout the seasons with changes in snow cover, vegetation, soil moisture, and amount of use. Consequently, disturbed sites must be observed and documented throughout the year. In doing so, patterns of natural processes, human use, and impacts may become more apparent, leading to a greater understanding of restoration processes. This chapter describes the process of assessing sites and planning restoration projects. The specifics of how to measure, map, and monitor impacts, briefly outlined in this chapter, are detailed in Chapter 9.

Restoration programs require considerable planning. Frequently, numerous sites are impacted, each with a range of problems and restoration work needed. Understanding the dynamics of why an impact has occurred is essential before the most effective approach to restoration can be determined. The location (forest, subalpine, alpine), physical characteristics (slope, aspect, elevation), size of the impact, extent of erosion at the site, amount of visitor use, and NPS management objectives all affect the restoration process.

Restoration projects may be as simple as closing one social trail, putting up a revegetation sign, and letting the site recover on its own—or the project may take many years and cost many thousands of dollars. Mount Rainier National Park has defined a small site as one in which the restoration work can be completed in one field season with local people and needs less than 15 yards of soil to be brought in. A large site involves more than one season, more people and supplies, and more than 15 yards of soil. The components of a restoration plan are similar for large and small sites, although there will generally be more detail in the plan for a large site.

Each site requires an individual plan that takes into account:

1. Where the damage is;
2. What is causing it;
3. Why it is happening;
4. How extensive the damage is;
5. How much more damage may occur without rehabilitation work.

Problems and conditions at impacted sites must be documented; these baseline qualitative and quantitative descriptions, measurements, and maps will be an invaluable reference to the restoration program in future years. Individual site plans must clearly describe the site assessment, the work to be done, the materials and equipment needed, and the people responsible for doing the work.

A restoration plan for the entire park is also necessary. This plan allows park managers to look at each site within the framework of the larger restoration and management goals of the park, to prioritize projects, and to develop a work schedule for individual projects. Setting priorities is an integral part of the restoration process.

Sites and activities which may require restoration include:

campsites	fire suppression activities
social trails	quarry sites
trail corridors	stock activities
road corridors	removal of structures
overlooks	water/sewer lines
rest areas	exotic vegetation/animals
historic landscapes	

Identifying the Source of the Problem

Identifying the source of the problem begins with a careful examination of the site. What has caused the disturbance to the vegetation and soil? Is it natural (an elk wallow or a natural landslide), or was it caused by people (social trail, campsite) or by park management activities (fire trail, helicopter landing site)? Begin by describing the appearance and impacts at the site, along with the appearance of adjacent undisturbed areas.

Natural disturbances, such as those from native wildlife, floods, snow avalanches, landslides, and tree fall, are natural processes of the ecosystem and likely to recur. In most instances, management policies recommend against revegetating or restoring these sites.

If the disturbance is caused by people, examine why it is occurring. If it is a social trail, what is the attraction—a view, a resting spot, a shortcut, water, or toilet trail? Is it a lunch spot or undesignated campsite along the main trail? How far is it to the nearest designated camp? Estimate how much use the disturbed area has received (many people or a few?) and how recent the disturbance is (does it look like an old well-established trail or a recent occurrence?).

Snowmelt, and the changes in human-use patterns caused by snowmelt, are additional sources of impacts. When campsites and trails are constructed in areas of late snowmelt, parallel trails and camps are frequently created in adjacent, early snowmelt areas by people avoiding the late snow or mud. Vegetation in areas where people congregate and spend time can receive heavy impacts; people tend to sprawl in cooking and eating areas, and where equipment is stored.

Exotic animals, such as mountain goats in Olympic National Park, and exotic vegetation brought in by vehicles and livestock, are human-caused impacts that must be addressed. Exotic animals and vegetation can invade and dominate natural habitats, destroying native plant communities. Impacts from exotic species are a serious concern.

Park management activities may require restoration work. Trail or road construction, removal or relocation of structures and campsites, and fire suppression activities, all cause impacts that may require restoration. Some management impacts are inadvertently caused by poor planning, such as no trail access to an obvious viewpoint or adequate water spot, or construction of trails and campsites in areas that melt out from snow much later than adjacent areas.

Assessing the Site

Site assessment is the next step in the restoration process. This initial assessment will provide baseline data against which to measure future changes. We need to know where an impacted site "started" so we can measure changes in vegetation and soil to determine if the site condition is improving or worsening. These measurements also give us valuable information about the recovery time needed for various sites and plant species. Examples of site assessment forms are given in Figures 9-5 and 9-6, pages .

Evaluate and measure the site carefully. Factors to assess include:

1. Origin of the impact and why it is occurring.
2. Estimate of the amount of use, and whether the impact is recent or well established.
3. Habitat and plant community at the site and immediately adjacent.
4. Elevation, slope, and aspect of the site.
5. Size. Measure the linear (trail) or square meters (campsite), and depth.

6. Vegetative impacts. Measure the percent and type of plant cover on the disturbed site and the adjacent or nearby undisturbed area using transects or plots (see Chapter 9).
7. Soil loss. Measure the cubic volume of lost soil and determine which soil horizons (organic layer, A, B, C, and bedrock) are gone.
8. Soil conditions. Estimate how compacted the soil is by looking at the soil texture, slope, amount and type of vegetative cover, exposure (forested or open), and amount of organic matter. Describe the erosion at the site.
9. Siltation. Is eroding soil entering a pond, lake, stream, or river, and if so, estimate the amount?
10. Site map. Draw map of site, including all impacts, measurements, and landmarks (see Chapter 9, p. 9:5).

Qualitative descriptions and comments are useful to get a "picture" of the site, although their subjective character does not provide measurable baseline data for future evaluations. Quantitative data (transects, plots, length and depth measurements) provide an accurate database for future site evaluations. Field notes need to be carefully written.

Photographs are a qualitative method to show conditions at a site, and if documented, work well to show changes over time. The location of the photographer, distance from the site, aspects of the photos (north, south, etc,), and other elements of photo-monitoring (see Chapter 9, p. 9:7) must be well-documented for the information to be useful and repeatable in the future. Color photos may fade over time, but the vegetation and bare soil show up well. Black and white photos last longer, but it can be difficult to differentiate vegetation, bare soil, and shadows.

Well-drawn maps of the site, showing locations of vegetation, topographic features, camps, trails, bare ground, creeks, and reference points, are crucial for finding and making sense of the site later. It is frustrating and not uncommon to get field notes out of the files and be unable to read the faint pencil marks, or locate the transect. Undecipherable field notes result in lost information. Site

maps should be based on true north and drawn to scale. The north arrow (usually oriented to the top of the page), legend, scalebar, features, reference points, and measurements need to be clearly marked (see Chapter 9, p. 9:5). Olympic National Park has found that a circular grid works well to draw site maps (Chapter 9, Figure 9-4).

Planning Tools

Topographic maps and aerial photos are essential tools when planning restoration work. Frequently, conditions can be shown on a map or in a photo that are difficult to describe with words or measurements. Xeroxed copies of topographic maps and aerial photos can be taken in the field and used as the base on which to draw preliminary field maps. A scale of 1:24,000 can be used (many USGS maps are this scale), although it is often easier to enlarge the maps or photos 5 to 10 times to be able to draw more detailed maps. Topographic maps can be enlarged with a xerox machine. National Park offices have stereo-pair aerial photos. Enlargements may be purchased from the USDA Aerial Photo Field Office in Salt Lake City, Utah (Appendix 1).

In addition to maps and photos there are other useful tools. Sociological surveys, showing where and how visitors want to experience nature and wilderness, can be helpful. Research on visitor-use patterns may highlight where trouble spots are, or point out patterns that help identify why certain areas are being impacted. Local knowledge, by people familiar with the area, can be an important, and often overlooked, planning tool. Talk with people who have been to the area: rangers, trail crew, volunteers, or frequent visitors; they may have significant observations that will help when planning the restoration work.

Determining What and When to Revegetate

All restoration work must conform to NPS management objectives for the particular zone where the site is located. Within that framework, additional factors to consider when determining what to revegetate include: snowmelt patterns; visitor use patterns; the ease or difficulty in revegetating the site; the amount of use a site has received; the presence of parallel trails and multiple social trails, and other management decisions.

Snowmelt patterns are an important consideration in the planning process; early snowmelt areas will be hiked and camped upon as the snow is melting from designated trails and campsites. Some of the trails and campsites in our national parks developed from historical use rather than being planned around snowmelt patterns, and thus have perpetual problems in early season. Closing the camps and trails in late snowmelt areas and establishing designated camps and trails in early snowfree sites may reduce impacts and be the only way to solve a persistent problem.

Restoration projects will be more successful if they are planned to work with visitor use patterns instead of against them, as long as they are compatible with the NPS management objectives for the zone. If numerous social trails to a viewpoint or around a lake indicate that many people are using an area, it may be difficult to stop all use unless absolutely necessary to protect the natural resource. A more effective restoration plan would designate one trail to be maintained and restore the others.

When determining which of the parallel trails or multiple social trails to restore, look at the site both ecologically and from a management standpoint. Are the multiple trails a result of snowmelt patterns, or has poor drainage caused muddy trails that people are avoiding? If poor drainage is the problem, one solution is to improve the older designated trail with reconstruction and additional water bars, and restore the newer trails.

The criteria for maintaining a site include: management policies, early snowmelt, heavy use, difficulty to revegetate, and maintenance factors. Conversely, the criteria for restoring a site include: management policies, late snowmelt, less use, easier to revegetate, and maintenance factors. Not all restoration sites will match all the criteria for restoration. Advantages and disadvantages of restoring the various sites must be weighed when making decisions. Consult the Limits of Acceptable Change (LAC) factors and standards for each park when deciding what and when to restore.

Changing management techniques, rather than active restoration, is another solution for disturbed sites. Limiting group size or closing a site to overnight camping are some alternatives that may allow a site to recover to its natural condition. The amount and type of disturbance at a site must be evaluated carefully to determine whether changing management techniques will allow the site to recover sufficiently, or if more active restoration work (recontouring, revegetating, etc.) is needed.

Other factors to consider when planning restoration work are the "minimum tool" regulations and policies. The minimum tool concept involves using tools which are the least disruptive to natural resources and social considerations, yet are still adequate to perform necessary work. In general, minimum tool guidelines limit the use of power tools, motorized equipment, and aircraft. Check with appropriate NPS personnel for guidance when planning restoration work.

Developing a Plan

Components of a restoration plan include:

1. Problem Statement : This is a description of the site assessment. Describe where the problem is (forest, subalpine meadow), what the problem is (social trail, campsite, etc.), what is causing it

and why, the extent of the problem, and any special considerations (rare or exotic plants, wildlife, safety, etc.). Indicate how long the problem has existed, and if the situation is stable, worsening, or improving.

2. Urgency: How serious is the problem, and how soon does it need to be addressed?

3. Priority Rating: How high of a priority is this site when looked at within in the context of the larger restoration program of the park? Give the site a priority rating and your reasoning for the rating. (See section on prioritizing below.)

4. Project Description: Describe and discuss several alternatives for restoration of the site, then give your recommendation and reasoning in support of one alternative.

5. Work Elements: Break the project down into work elements and describe them with as much detail as possible. An example of a small restoration project work plan used at Mount Rainier National Park is shown in Figure 4-1. Basic elements should include:

   a. equipment, supplies and materials, and costs.
   b. number of people and workdays needed, and costs (Table 4-1).
   c. transportation of supplies and materials (written after applying Wilderness Standards where applicable).
   d. site preparation.
   e. planting.
   f. plant maintenance.
   g. site protection.
   h. monitoring.

6. Contacts: List the people who were consulted in the planning process.

Table 4-1. Personnel Requirements from Mt. Rainier National Park
Estimates of time requirements to accomplish filling, scarification, planting, and mulching. All estimates are based on figures reported from the Paradise project.
Fill - 0.25 cubic yards/hour Scarification - 100 square feet/hour Installation of silt bars - 1 bar/40 minutes Planting - 13 plants/hour Mulching - 4 hours/roll
Plants - minimum of 3 plants/square foot, preferred estimate is 6 plants/square foot.
Soil - cost estimate is $25/cubic yard.
Helicopter cost - estimate $100/cubic yard at Panorama Point.

Other Considerations

Personnel Needs: Based on the extent of impacts at the site and the necessary restoration work, determine the number of people and work-days needed to complete the project (Table 4-1). Rangers, trail crew, botanists, biological technicians, Student Conservation Association, Youth Conservation Corps, and volunteers such as Native Plant Societies are potential workers.

Logistics and Transportation: Transporting supplies and materials to the impacted site can be difficult and requires careful planning, particularly if the site is in the backcountry or needs large amounts of materials. Calculate the amount of supplies and materials required for the project. Backpacks, litters, wheel barrows, livestock, and helicopters, have all been used to transport supplies. The cost of each type of conveyance is an important consideration; transporting supplies by backpack is relatively inexpensive, while helicopters cost $500 an hour. Check local

SMALL PROJECTS DATA SHEET PROJECT NUMBER _____

RESOURCE MANAGEMENT SMALL PROJECTS WORK PLAN: YEAR: _____

Note: A "Small" resource management project is one which hasn't been formally planned for large crew work by the Natural Resources Planning Division and which, although it may take a number of years to finish, can logically be worked on by one or two persons as a collateral duty. Draw sketch map on back of this sheet of the project area.

I. PROJECT DESCRIPTION

Summary of work to be done this year:

Estimated years remaining till project completion:

II. RESOURCE NEEDS

Employees:

_____ person(s) for _____ 8 hrs. work days (includes carrying supplies to site of hiking to and from the site.

Supplies and Materials:

Source: Native to the site ____; Imported ____; Some of Both ____

Items:

_____ Water bars (number needed & length)

_____ Erosion bars (number needed & length)

_____ Cu Yds. of fill material

_____ Cu yds. of topsoil

_____ Transplants

_____ lbs. of seed

_____ Excelsior or other similar material

_____ Bales of peat

_____ Sign needs (attach Sign Requests)

_____ Specialized tools required - e.g., chainsaw

_____ Other (specify)

Method of getting materials to site:

Human _____ 50 lb. trips

Mule _____ 200 lb. trips

Helicopter ___ 500 lb. loads (or lighter but bulkier loads)

Other _____ (specify) e.g., Cushman scooter, pickup truck, etc.

*List any assistance required by Maintenance Division - e.g., Trail Crew help, dump truck to haul topsoil, etc.

III. RESPONSIBLE PERSON(S) AND COMPLETION DATE

Permanent Ranger _____ Seasonal Ranger _____

This season's intended completion date _____

_____ _____

Recommended Date Approved (Division Chief) Date

Figure 4-1. Small Restoration Project Work Plan used at Mount Rainier National Park.

regulations: livestock are prohibited from some subalpine and alpine areas; and helicopter use is restricted or banned in certain wilderness areas.

Equipment: The equipment necessary to complete the project will depend on the kinds of rehabilitation work needed, the soil characteristics, and the revegetation work to be done. Sites that only require revegetating will need small hand tools. Sites that require extensive recontouring and erosion-control will need larger tools to move soil and rock, and install water bars and silt dams.

Protection: Once the restoration is completed the site must be protected from further damage. Site protection can be accomplished first by changing visitor use patterns through educational efforts (interpreters, signs, and other means of educating visitors), then patrol rangers and regulations if necessary. Site maintenance and protection are detailed in Chapter 8. Site monitoring, discussed in Chapter 9, will indicate whether the site protection measures are effective.

Setting Priorities

Restoration work will be more effective if the sites are prioritized, particularly when there are many impacted sites. How the sites are prioritized will depend on the restoration goals of the park. Factors to evaluate include: the location, amount and types of impacts; extent of erosion; number of visitors; time of year; presence of rare, threatened, or endangered plants and animals, personnel; and costs.

Most commonly, sites with extensive erosion or damage to the vegetation are given a high priority. Sometimes a small site that can be restored in one season will be made a higher priority than a more impacted site which involves more planning and time. The educational value of site restoration can influence priority ratings; a site which typically would be given a low-priority rating may be given

a higher rating if it receives many visitors and can be used to teach the public about minimum-impact wilderness usage. Time of year can play an important role in setting priorities and timing of restoration work; in the Pacific Northwest restoration work takes place in the low elevation forests in the spring and early summer because the higher priority subalpine sites are snow-covered and inaccessible until later in the summer.

When there are relatively few impacted sites they can be prioritized in a simple, qualitative manner based on the kind of habitat and impacts at a site, and the number of visitors. At North Cascades National Park, sites in alpine and subalpine habitats are given the highest priority because they have many visitors and are also the places where the recovery time is slowest. Mount Rainier National Park has developed a more comprehensive and quantitative method of setting priorities with a Restoration Rating Criteria which evaluates five components: soil erosion potential, visual characteristics, administrative considerations, and water and wildlife resources (Appendix 2). Olympic National Park gives a high priority rating to sites where the trail crew and revegetation crew can work together—as the trail crew produces vegetation plugs the revegetation crew plants them.

Chapter 5. Plant Propagation

This chapter will cover the propagation and procurement of plants for revegetation projects. Plant material may be obtained several ways. Plants may be propagated vegetatively, or by seed, in a park greenhouse; propagated or obtained at the impacted site; or propagated on contract by an outside agency or private company. Plants may also be transplanted from areas adjacent to the impacted site, or salvaged from construction sites.

Seed propagation is a common method of growing plants. Sexual reproduction of plants, which produces seeds, allows genes to join in many combinations, resulting in individuals of a species looking similar but having a wide range of genetic composition.

Vegetative propagation involves the separation of a portion of a plant from the parent plant, with this separated part then growing into a new plant. This asexual reproduction produces clones whose genetic make-up is identical to the parent plant. Almost every part of the plant is capable of asexual reproduction. Cuttings, divisions, and layering are common methods of vegetative propagation.

Native species used for revegetation, and the various methods for propagating them, are listed in Appendix 3.

General Propagation Techniques

Collecting Plant Stock

When collecting plant stock for restoration work three objectives are important:

- use native species
- maintain genetic integrity
- replace the species that were lost from an area

Ideally, plant species are collected and propagated in the same proportion in which they occur at the revegetation site, with the goal being to restore the composition of the native community. However, we are still learning how to grow certain species, and in adequate quantities for revegetation work.

There are situations, however, where site factors may override the goal of restoring the natural species composition. Some of the original native species in the community may be vulnerable to trampling damage, and will be eliminated from a site even when replanted repeatedly. At some sites, large areas of bare ground are causing erosion problems.

Plants susceptible to trampling damage may do well at a revegetation site closed to all use. In a situation where site use is restricted, but not eliminated, revegetation will be more successful if species native to the site, and resilient to trampling, are used. When dealing with erosion the first goal may be to stabilize the site by replanting with rapidly spreading native plants. Once the site has been stabilized, other components of the natural community can be restored.

Evaluate the site conditions and use-patterns carefully to determine the most appropriate course of action: collecting species to restore the natural composition of the community, or collecting hardier or more rapidly spreading native plants.

General guidelines for collecting plant material (Rochefort 1990):

- collect plant material from the same habitat and community type as the impacted site (or adjacent to the impacted site);
- stay within topographic and vegetative boundaries around the impacted site; stay within a cirque or lake basin, do not cross a ridge or walk from a subalpine meadow through a forest to another meadow;
- stay within broad elevational ranges: 1500'-3000', 3000'-5000', 5000'- 7000', 7000'-9000'.

Native plants that have been used in revegetation are shown in Appendix 3. The table shows the propagation methods that have been successful with each species.

Gathering seeds: All annual plants and some perennial plants produce seeds for reproduction. These seeds can be collected and grown in a greenhouse, or in the field, for revegetation projects. To ensure germination the seeds must have matured (ripened) before they are collected. The timing for seed collecting will vary by species, elevation, and seasonal conditions. Ideally, seeds are fully mature when collected. Many species shed their seeds quickly at this point, which can make collecting difficult.

Visit the area to be revegetated, and make a list of the dominant, subdominant, and occasional species. Generally, more seeds will be collected from dominant and subdominant species. Note the phenology of the plants throughout the summer, particularly the development and maturation of

fruiting structures. Seeds of subalpine and alpine plants generally have low viability, and seed production varies from year to year

The fruiting structures have matured when the pods are desiccated, have begun to dehisce (split open), or seeds are rattling around inside the capsule. With most seeds, if the embryo is hard or firm, and the seed coat is beginning to change to its mature color, the seeds have ripened sufficiently to begin collecting (Gray and Leiser 1989). Lupines are one of the more difficult species to collect because the pods burst open, shedding their seeds, when they are ripe. The pods have matured sufficiently if they are brown and dry, not fleshy, and the seeds within are plump. Collect fruiting structures from many individuals of the same species to ensure that seeds will be available with a range of maturity. Do not collect all the seeds in any one area; leave some for natural processes.

Collect the entire inflorescence (flower head) of the plant, not just the seeds. Seeds of many species will continue to mature after being collected if they are harvested with part of the plant and allowed to dry naturally. Seeds should be collected as they ripen throughout the summer. Collect seeds in dry weather whenever possible to reduce the drying time and problems with mold. In the field, place the seeds in small paper bags (lunch bag size) that have been doubled so the seeds do not fall through the seams. Label each bag with the date, species name, collection location, habitat, community type, elevation, aspect, and name of the collector.

Store the open bags of seeds in a dry room for four to six weeks. If any seeds were wet when they were collected, spread them out in a thin layer on newspaper to begin the drying process, then put them into paper bags again to finish drying in the room with the other seeds. The drying process is important. The seeds must be dry enough that they will not mold, and can be cleaned easily, yet not over dried or they will not germinate. Make sure there are no mice in a room where seeds are being dried.

Once the seeds are dry they can be cleaned. Some authorities find cleaning unnecessary for planting directly in the field, although cleaning is necessary for greenhouse work. Seeds can be cleaned on screens that can be made, or purchased from most seed suppliers (Appendix 1). The seeds of most species will separate from the chaff if shaken and sifted on a #12 screen. Heather seeds must be rubbed on a #30 screen. *Sorbus* fruits need to be pushed through a screen to separate the fruity pulp from the seed--#12 screens may work, but experiment with other sizes.

Vaccinium and *Gaultheria* seeds are cleaned using a special process. Blend the berries (separated by species) with water in a blender to make a 'sludge'. On a rainy day put 3'x3' squares of Remay cloth (a type of landscape fabric) on big drying screens on the ground. Put the *Vaccinium* or *Gaultheria* mix on the Remay and spread it over the whole cloth. The rain will wash the pulp through the Remay, leaving the seeds and berry skins on the surface. Paper towels will also work, if Remay is not available. A gentle misting with a hose may also work, rather than waiting for a rainy day. Let it dry, then scrape the seeds and skin off into paper bags for three or four days of more drying.

After seeds have been dried and cleaned, put them into zip-lock bags sealed with the date, species name, collection location, habitat, community type, elevation, aspect, and collector, and store in the refrigerator for the winter. Some authorities recommend storing seeds in paper bags in an unheated room rather than in a refrigerator; if the zip-lock seal failed the seeds could become over-dried and lose their viability in a frost-free refrigerator. The storage life of seeds varies by species from a few days for willows and poplars to months and even years for other species (Gray and Leiser 1989). The seeds of most subalpine species may be stored indefinitely if they are kept below 32 degrees F (0 degrees C) (Schopmeyer 1974). The viability will decrease when seeds are stored above 32 degrees F.

Gathering plants: When digging up plants to transplant nearby, or to bring back to a frontcountry facility for propagation, it is important to minimize impacts to both site and plants. Choose healthy plants located out of sight of trails and campsites, and collect from a wide area rather than concentrating in one location. It is best to dig the plants on cool, cloudy days; on sunny days dig in the morning or evening. Plants will experience the least transplanting shock if the leaves are turgid, not wilted. Water the plants before digging. Dig carefully straight down in a circle around the plant, just outside the drip line (the outermost perimeter of branches and leaves). Most plants to be transplanted will be less than 12 inches tall; estimate the root ball to be approximately the same size as above-ground vegetation. Put the plugs carefully into plastic bags to reduce moisture loss. Backfill the holes with soil to match the surrounding grade and plant seeds to promote revegetation. Label the bags with the date, species name, collection location, habitat, community type, elevation, aspect, and the name of the collector.

Soil Mixes

There are many kinds of rooting mixtures and most have been successful to varying degrees. A few guidelines will be helpful to the propagator.

1. Soil should never be used when rooting softwood or semi-hardwood cuttings; it is difficult to sterilize and there is a strong chance of fungal infection.

2. Coarse, clean sand alone works well with many plants, but because sand drains so rapidly it is difficult to keep moist. Also, cuttings rooted in straight sand sometimes develop unbranched, brittle roots instead of a fibrous root system.

3. Peat moss is usually added to sand to increase its water holding capacity. Proportions vary from 1:1 peat:sand to 1:3 peat:sand. Mixes high on the peat end tend to have

poorer drainage and may cause roots to rot, particularly in a mist bed. This is of particular concern when propagating species which take a long time to germinate or to develop roots.

4. Horticultural grade perlite is frequently used in cutting mixes to take the place of sand and reduce the weight of the flats.

5. Vermiculite should not be used alone but may be combined with sand or perlite in seeding and potting mixes; never use vermiculite in cutting mixes because it holds water.

6. A 'wetting agent' is perlite which has been impregnated with chemicals to break the surface tension of water, thus allowing the water to penetrate the soil particles more easily. A common commercial wetting agent is called "Water In", and may be used in place of some, or all, of the perlite in the potting mix.

7. Any rooting medium should be well moistened before being placed in the flats. Plastic garbage cans are excellent for storing pre-moistened rooting mixes. Pack down the mix in the flats with a piece of board.

Olympic National Park has developed soil mixes for seeds, cuttings, and potting. The potting soil contains ground Douglas Fir bark, recommended by *Rhododendron* growers to prevent the *Phytophthora* root rot common to *Ericaceous* species. Fir bark also seems to work well with other native species. A 5-gallon bucket is used as one unit in the recipes, although the unit size can be made larger or smaller.

Seeding mix:

2 peat

2 vermiculite

1 sand

or

1 perlite

Cutting mix:

1 peat

1 sand

1 perlite

Mount Rainier National Park has developed a cutting mix specifically for use with heather:

2 perlite

1 peat

1 vermiculite

note: mix is at least 50% perlite, or pumice, or some other well-drained ingredient

Potting mix:

5 ground composted Douglas Fir bark

3-4 peat

1 vermiculite

2 perlite

2 sand

2-3 cups bonemeal

note: can add a wetting agent in place of perlite

North Cascades National Park has successfully propagated plants using commercial soil mixes purchased from local nurseries.

Transplanting

At some point the seedlings and cuttings will be large enough to transplant from flats into pots. Periodically look under the flats to see if there are any roots showing. When roots are visible, gently lift up a few plants to check their root development. When the roots are well developed the plants are ready to be transplanted into small plastic pots. The pots come in standard sizes, generally 2 1/4 inch square and 2 1/2 inch deep, or 3 1/2 inch square and 3 1/2 inch deep. The root balls of the plants to be transplanted should be no greater than half the volume of the pot to allow plenty of room for root growth.

After transplanting, water the plants once with Plant Starter or another fertilizer with the formula of 9-45-15 diluted to half- strength to help root growth. Place the pots back on the misting bench for one week, then move to a cool, shaded spot in the greenhouse, or outside if there is no chance of frost. Check the root development of the seedlings, rooted cuttings, and divisions; when the roots have filled out to the edges of the pots the plants are ready to be transplanted to the field.

Rotation To Yard

It is important that seedlings and rooted cuttings be moved gradually from the protected environment in which they were propagated (high humidity, low light intensity) to outdoor conditions (low humidity, high light intensity, drying winds). If they were rooted under mist, they should receive special attention to ensure that they do not dry out. Before placing any of the

seedlings or rooted cuttings outdoors in full sun they should be hardened-off for a week or two in a lath house or in a shaded area.

Fertilization

Appropriate amounts of fertilizer will encourage healthy growth of roots and foliage. Too much fertilizer can over stimulate plants and cause problems with the damping-off fungus. In general, feed plants every two weeks with fertilizer diluted to half-strength, rather than once a month full-strength, to give the plants a slower, more consistent flow of nutrients. Organic fertilizers derived from ocean material have more trace elements than chemical fertilizers.

Seedlings: Fertilize after they have formed two or three true leaves. There can be problems with damping-off if the seedlings are fertilized too early. Any kind of fertilizer will work, but do not use fertilizers high in nitrogen. Diluted Peters Plant Starter or fish fertilizer (1/4 tsp. : 1 quart of water) work well.

Cuttings: Do not fertilize until they are in pots.

Transplants: Water once immediately after transplanting with Peters Plant Starter or another fertilizer with the formula 9-45-15 diluted to half strength to encourage root growth. After the plants are established in pots or in the ground, fertilize as potted plants below.

Potted plants: a fertilizer mixture consisting of :

50% Alaskan fish fertilizer

25% Maxicrop (liquid seaweed)

25% 9-45-15 fertilizer

Some greenhouse workers have had success using a general 20-20-20 fertilizer.

Integrated Pest Management

The National Park Service has an extensive Integrated Pest Management (IPM) program. The goal of IPM is to use the most environmentally sound techniques in the eradication and control of pest species. The IPM decision-making process is used to determine when control of pests is necessary, and the means to do so. The IPM program controls pests indirectly by modifying the habitat, or human behavior; and directly by physical/mechanical techniques, biological control, or chemical treatment. When pests become a problem, consult with your park IPM coordinator to find an appropriate solution.

Overwintering

The first rule of thumb is to overwinter as few plants as possible-- most of the plant stock should be transplanted into the field in the autumn, so there will be less to overwinter.

Most native plants are dormant in the winter as an adaptation to cold weather. To encourage dormancy in plants that are to be overwintered, stop watering plants a week or two before the plants are to be stored in the autumn. Trim grasses and sedges back to about one inch. Unheated greenhouses, and flats or pots, give little protection from winter cold. Plants overwintered in these conditions will go through periods of freezing and thawing, which may damage or kill them. North Cascades National Park reported a 40% mortality of plants overwintered in a greenhouse without a heater.

Damage and mortality will be greatly reduced if the plants are insulated for the winter. The amount of insulation needed will depend on winter temperatures at the greenhouse. Winter temperatures

are usually in the 30's and 40's (degrees F) where the greenhouses are located at Mount Rainier, North Cascades, and Olympic National Parks, although winter temperatures commonly dip into the teens and 20's.

A simple way to overwinter plants is to put them in an insulated box. One winter, North Cascades National Park stored 2000 *Carex* and *Phleum* plants in a 4'x2'x4' box. The box was lined with 3 inches of peat moss on the bottom and sides. The plants were removed from pots and put into the box with peat moss between the layers. In the spring the plants were discolored and deformed, but 95% were still alive and healthy, despite their bedraggled appearance. Repotting the plants was tedious work and took four days. The next winter, the plants were stored in their pots. A larger box was needed, so part of a shed was converted into an insulated storage area with bales of peat moss for walls. The flats and pots were placed within the bales and covered with loose peat moss. In the spring the plants were uncovered and put into the greenhouse in just a few hours, saving much repotting time. Again, 95% of the plants survived the winter.

Olympic National Park has used three methods for overwintering their plant stock, each method providing 80% survival:

The first method is to make a frame on the ground using 6 inch by 6 inch fence posts. Place the plants within the frame and cover with 6 inches of sawdust or woodshaving mulch.

The second method involves covering the ground with black plastic to keep weeds out, and keep the area warmer. Flats are put on the plastic in rows four across, covered with 6 inches of wood shavings (thicker around the perimeter), a layer of landscape cloth, then another 6 inches of wood shavings on top. This creates conditions similar to those under snow. The landscape cloth and shavings are permeable and allow air movement, yet protect the plants from the cold. During a cold spell with temperatures below 20 degrees F, flats on the outside froze, but seemed to thaw

with little damage beyond burning the tips of some *Phyllodoce*. Insulating the perimeter with thick wood, like railroad ties, or peat bales would probably give better protection. Flats of plants that die back over winter can be stacked to conserve space with several inches of wood chips between the flats.

The third method is to keep plants in the greenhouse on the center bench over heating cables set at 50-60 degrees F (10-16 degrees C), and to leave lights on for additional heat.

Mount Rainier National Park has used two methods to overwinter plants:

With the first method, a wooden frame 8 inches tall is built. Excelsior is laid inside the frame to insulate the bottom. Flats and pots are stacked three deep, then covered with plastic sheeting or a large light-colored tarp.

In the second method, a frame is put over raised beds (like a covered wagon) using 2 inch PVC pipe and plastic sheeting. This method is most successful during mild winters when temperatures stay above 25 degrees F (-4 degrees C). During a cold winter when the temperature dipped below 15 degrees F (-10 degrees C) the plants within the frame froze, causing mortality and lowering the rooting success.

Record Keeping

A clear and accurate record of the work you do in the greenhouse is essential. Since this will be a permanent record, use good quality paper and waterproof ink, and keep everything in a hard-bound notebook. Information to document includes: the kinds of plants, seeds, and cuttings you are working with, and where they came from; size of container and type of medium for each method of propagation; temperatures; watering regimes; type, amount, and dates of fertilization;

dates of planting, germination, root formation; and dates and sizes when transplanted. Include any other details of significance. Describe methods and materials that were successful, and those that were not, and why.

This greenhouse log will be used by many others besides yourself in the years to come; they can learn much from your trials and errors. Additionally, through time, patterns may become evident in the log that are not discernable while you are working in the greenhouse. The information can be recorded many ways. Olympic National Park has developed propagation and fertilization tables with rows and columns to keep dates, methods, and numbers all together and available at a glance (Figure 5-1). The narrative format works well for general observations and notes.

Propagation of Plant Material

Seeds

Sowing rates: The species, viability, and type of seed (locally collected seed or purchased seed) affect sowing rates in flats. Species with large seeds and seedlings are planted at lower densities than small seeds. Many subalpine species need to be planted at high densities because they have low germination rates. Viability can also vary from year to year. Purchased seed usually has been more thoroughly cleaned to remove empty seed hulls, and can be sown at lower densities than locally collected seed. Determining the optimum sowing rate for each species is a trial and error process. A basic rule of thumb is that seeds should be visible on the soil after they are sown. Each person working in a greenhouse has a different method for determining the sowing rate: 10-20 seeds/square inch; 130 seeds/square foot; 3/8-1/2 teaspoon of seeds/flat. Experiment with different sowing rates and keep records to determine which method worked best with each species. An example of record-keeping for sowing rates used at Olympic National Park is given in Figure 5-1.

ONP Revegetation. Plant Propagation Record: 19

Batch #	Species	Flat #	Type of Propagation	Collection Date	Treatment Code	Planting Date	Compost Comp. Code	Seed Rate/# Cuttings		Germination Date (approx.)	Fertilization Schedule	1st Transplant Date	Yield #Rooted	#Redone	#Dead	% Rooting Success		Location Code

Plant Propagation Record. Table Codes

Treatment Code

A) no special treatment
B) stratified/refrigerated (moist)
C) stratified/refrigerated (dry)
D) screened/abraded (seeds)
E) pre-soaked (seeds)
F) cut, dipped in 'Hormex' powder, then inserted
G) cut, dipped in "Dip n Grow', then inserted
H) cut, soaked 18-24 hrs. in dilute liquid hormone solution (1 Tbl/ 1 qt. water), then inserted

Compost Composition Code

A) 1 fine sphagnum peat
1 No. 3 vermiculite
1 medium sand

B) 1 fine sphagnum peat
1 no. 3 vermiculite

C) 2 cu. ft. of 1 fine peat/1 vermiculite
1 qt. fine peat
1 qt. vermiculite
1 qt. perlite
2 qt. medium sand

Location Codes

CB Cat Basin
DL Deer Lake
HD High Divide
HL Heart Lake
HaL Haig Lake
HoL Hoh Lake
LC Lake Constance
LL Lunch Lake
ML Morgenroth Lake
SLB Seven Lakes Basin

Figure 5-1. Propagation/fertilization table used in the greenhouse at Olympic National Park.

In the greenhouse, damping-off (a fungal disease) may be a problem if seeds are sown too densely; keep some space between the seeds in each flat. To eliminate allelopathic complications, and to maintain genetic integrity, sow only one species from one location in each flat. Label the flat with the species name, location, and planting date.

Propagation: While many native species may be propagated readily from seed, others grow with difficulty or not at all. *Erythronium*, for example, has been successfully propagated in the field, but not in the greenhouse yet.

Germination of seeds is influenced by several factors: dormancy, a cold period, scarification of seeds, soil and air temperatures, moisture, light, humidity, and day length. With appropriate conditions many seeds will germinate in two to fourteen days.

Stratification encourages germination in some species. The Soil Conservation Service found that *Carex* seeds which were stratified (layered between damp paper towels) and kept in the refrigerator for thirty days showed a 10% increase in germination.

Extensive work with seed propagation at North Cascades National Park has found that a soil temperature of at least 85 degrees F (30 degrees C) is particularly critical for germination of many subalpine species. Here are three successful propagation methods used by North Cascades National Park:

Method #1 (in the spring):

1. Fill greenhouse flat 3/4 full with the propagating medium.
2. Sow seeds over the soil surface, patting them lightly into the soil. Do not cover the seeds with soil.
3. Water well.
4. Cover the flat with clear plastic to seal in moisture and create a humid environment. Keep the plastic off the soil. A commercial product commonly used is called a "HumiDome". Label the flat with the species name and the location from which it came.
5. Place the flat on a propagating mat which provides bottom heat.
6. Maintain soil temperature at 85 degrees F (30 degrees C).
7. Expose flat to sunlight or artificial light for twelve to sixteen hours a day.
8. Remove flat from the propagating mat after most or all, of the seeds have germinated, but keep the HumiDome in place until the plants have grown 1 inch tall.

Method #2 (for seeds that need a cold period):

1. Follow steps 1-4 of Method #1 above, except sow the seeds in late October or November. Seeds planted the same year as they were gathered seem to work best. This method has been used successfully with *Carex illota, Carex nigricans, and Carex spectabilis*.
2. Place the flat in an insulated, but unheated, dark room.
3. Check the flat periodically during the winter to make sure it does not dry out. At most the flat will need to be watered once.
4. In March or April place the flat on a propagating mat.
5. Maintain soil temperature at 85 degrees F (30 degrees C).
6. Seeds should germinate in approximately two days.

Method #3 (cold frame without a greenhouse):

1. Construct a frame out of boards or logs. The frame should be at least 8 inches deep and 4 feet wide. The length can be whatever works well (North Cascades National Park has used a 4 foot x 80 foot frame).
2. Place an insulating material on the ground inside the frame--1 inch foam board works well.
3. Lay heat cables on top of the foam board if you have them, but cables are not essential. The seeds germinate and grow well with no heat.
4. Fill the frame with 3-4 inches of soil.
5. Sow seeds on the soil and pat gently into the surface without covering the seeds.
6. Place a thermometer on the soil.
7. Cover the frame with clear plastic sheeting, keeping it above the soil. Use wood or rope to shape the plastic into an inverted V over the frame so rainwater runs off, instead of pooling on top of the plants.
8. Monitor temperature, and water when needed. Cool soil temperatures are not a problem with this method. On sunny days the soil or air in the frame can get too hot; if this happens vent the plastic tent as necessary.

After the seeds have germinated the flats may be kept in the greenhouse or moved outside under shade. Keep the flats damp. Mount Rainier National Park recommends watering seedlings with lukewarm water that has been allowed to stand overnight to dissipate any salts (this is particularly important with *Anemone occidentalis)*. Olympic National Park and North Cascades National Park have had no problem with salts in the water.

Fertilize every two weeks with dilute fertilizer (see Fertilization section in this chapter). Thin seedlings as needed to give each plant room to grow. Seedlings may also need to be pinched back occasionally to develop bushier, stronger plants. Check root growth periodically; when the seedlings have developed healthy roots transplant them into pots (see Transplanting section in this chapter).

Advantages: Seeds are relatively inexpensive to collect and grow; seed collection and dispersal requires no special equipment. Seeds can be planted directly in the field, which eliminates time-consuming plant transporting; thousands of potential plants can be 'planted' in one season; seedlings of some species grow faster than cuttings; and the genetic diversity of a community is maintained.

Disadvantages: Seed production and viability vary from year to year; seed collection is time-consuming; seedlings are very small and may not be visible at the site for several years.

Cuttings

Although many parts of the parent plant may be used in propagation, stem, root, leaf, and leaf-bud cuttings are the most likely to have successful, rapid growth. Stem cuttings are by far the most useful for vegetative propagation. Root, leaf, and leaf-bud cuttings have a limited application but are useful with specific species.

Root cuttings: are used to propagate many ornamental plants, but only a few native genera can be readily propagated in this manner. Among these are *Agoseris, Aster, Erigeron, Phlox, Phyllodoce, Polygonum newberryi, Populus* (aspen, cottonwood), *Rhus* (sumac), *Robinia* (locust), *Rosa, Rubus sp.* (blackberry, raspberry, salmonberry, etc.). Root cuttings are handled much the same as stem cuttings except that they are usually grown outdoors in nursery beds. Cut

the root or rhizome into segments 2-4 inches long, allow the ends to dry and become calloused, then plant. It is important that correct polarity is maintained when planting; the proximal end (nearest the plant crown) must be placed up. Best results are obtained if the cuttings are taken in late winter or early spring before growth starts.

Leaf cuttings: are of limited use to a land manager concerned with native plants. Two common species of the *Saxifrage* family may be easily propagated in this manner and actually reproduce this way in nature. *Tolmiea menziesii* (pickaback plant) reproduces by forming new plants at the base of the leaf blades which take root upon touching the soil. It is a useful, fast-growing perennial herb of lowland forests. *Saxifraga ferruginea var. macounii*, a plant of the higher elevations of the West, develops bulblets in place of some flowers which can be gathered and planted in flats to produce new plants.

Leaf-bud cuttings: consist of a leaf blade, the petiole (leaf stem), and a short piece of stem with the auxiliary bud attached. This limited technique is useful where propagating material is scarce, as each node can be used as a cutting. Blackberry and rhododendron can be grown in this way, and should be treated in the same manner as stem cuttings, with high humidity and bottom heat.

Stem cuttings: are classified according to the maturity and nature of the parent plant. Hardwood cuttings are taken from mature growth of woody plants in late fall and winter when plants are dormant. Semi-hardwood cuttings are taken from semi-mature growth of woody plants in late summer and early fall. Softwood cuttings come from the rapidly growing tips of woody plants in spring and early summer. Herbaceous cuttings are similar to softwood cuttings but are taken from non-woody plants. Heathers require specific treatments and are discussed separately after the information on cuttings. Plants with underground stems (rhizomes) are usually propagated by division, discussed in a later section.

Hardwood cuttings are one of the least expensive and easiest methods of vegetative propagation, but apply only to woody material. They are easy to prepare and require little specialized equipment during rooting. Because they are taken during the dormant season, after leaf fall, they do not need a controlled atmosphere, as do most other forms of cuttings.

Hardwood cuttings are taken from the current year's growth at any time during the dormant season, but succeed best if taken just after leaf fall. If taken before buds break, there is the danger that leaves will form before the roots, and the cuttings will die. At least two nodes should be included in the cutting, with the basal cut just below a node and the top cut 1/2 to 1 inch above a node. Six inches is generally a satisfactory length for a hardwood cutting.

Not many of our native narrow-leaved evergreen trees and shrubs can be propagated by hardwood cuttings. *Thuja plicata* (western red cedar), low-growing *Juniperus sp.* and *Taxus brevifolia* (yew) are exceptions to this rule. Cuttings from young stock plants root more readily than those taken from old trees. Cuttings should be taken from the top of the plant and should consist of rapidly growing leader or lateral shoots from the parent stem. Cuttings 4-8 inches long are usual, and the leaves should be removed from the lower third.

Cornus (dogwood), *Ribes* (currant, gooseberry), *Populus* (cottonwood, aspen), *Rosa, Rubus* (salmonberry, thimbleberry, blackberry, etc.), *Salix* (willow), *Spiraea*, and *Viburnum* (high- bush cranberry) are some of the native deciduous genera suitable for rooting by this method, and others should be tried. Success of rooting may be increased by vigorous pruning of stock plants the year before the cuttings are to be taken. This will encourage the growth of vigorous stems that will root rapidly. Cuttings should be taken from healthy plants growing in full sunlight. The wood should not be taken from rank growth with abnormally long internodes or from small, weakly growing interior shoots.

The tip portions of a shoot on a deciduous hardwood cutting are usually deficient in stored foods and should be discarded.

In the mild climate of the Pacific Northwest, hardwood cuttings may be planted in the fall 3 inches to 4 inches apart in an outdoor nursery bed filled with a rooting mix for cuttings. Dip the lower stems of the cuttings in a rooting hormone of ripewood strength (0.8% IBA). Plant the cuttings deeply enough so that just one bud on a deciduous cutting or the upper two-thirds of an evergreen cutting shows above the surface. The outdoor nursery bed in which the cuttings are to be planted should be in full sun. The bed should be well cultivated before the cuttings are set, and competing tree roots eliminated. Evergreen hardwood cuttings may also be rooted in a greenhouse with high humidity and bottom heat of 75 to 80 degrees F (24 to 26.5 degrees C).

Alternatively, the cuttings may be tied in bunches, dipped into rooting hormone (0.8% IBA) and stored in moist sand or sawdust in an unheated building, and planted in the spring. Some woody plants have hollow or pith-filled stems (*Sambucus* - elderberry). Hardwood cuttings of these plants tend to rot because the hollow or pithy center is exposed and the cuttings die. This may be avoided if the base of the cutting is sealed by being touched to the surface of melted paraffin wax. The temperature of the wax should not be so high as to damage the cutting.

Semi-hardwood and softwood cuttings are the most important types used in revegetation. The two kinds of cuttings are differentiated only by the condition or maturity of the wood. Semi-hardwood cuttings are taken from the partially matured growth of woody plants in late summer or early autumn. Both broad-leaved evergreens and deciduous plants can be grown in this manner. The stems are ready for cutting if they snap when bent with the fingers, instead of bending or crushing. Softwood cuttings are taken

from the rapidly growing tips of plants in spring or early summer, usually from deciduous woody plants or low-growing woody sub-shrubs like *Luetkea pectinata* (partridge foot), *Dryas sp.* (mountain avens) and *Penstemon spp.* Since both types of cuttings have leaves attached, they are equally subject to wilting before roots form and thus require similar conditions of high humidity. Bottom heat is usually beneficial to both types, especially softwood cuttings.

Collecting and propagating the cuttings: Carry along plastic bags, twist ties or rubber bands to close the bags, a clean sharp knife or sharp pruning shears (preferably not anvil type), plastic labels, and a soft pencil or waterproof marking pen. Take cuttings from a number of plants of the same species to increase the chances of obtaining cuttings of the proper maturity and hormone level. Cuttings should preferably be made in the morning when the stems are fully turgid. On clear afternoons the plants are under water stress, and the cuttings may not root successfully.

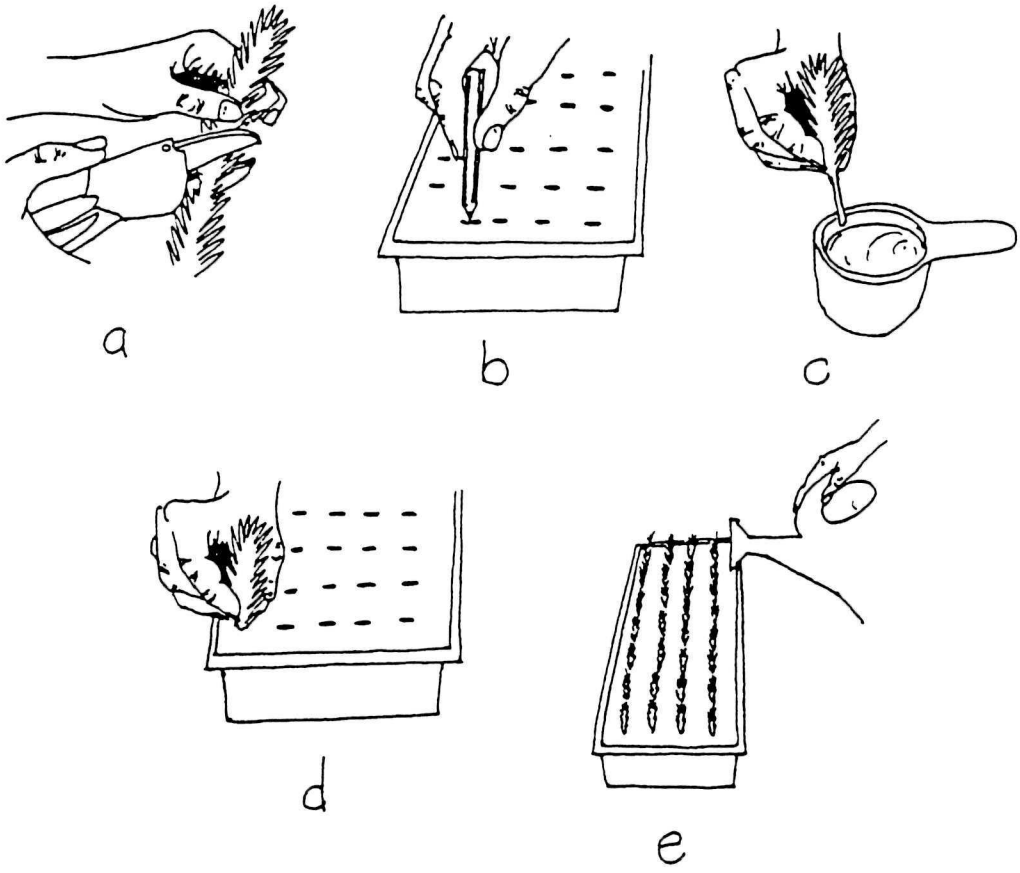
Some propagators recommend taking cuttings from healthy, vigorous branches growing in full sun. Others contend that the spindly, etiolated shoots from the shaded interior of the plant actually contain more of the root-inducing hormone and should be used for cuttings. With either sunwood or shadewood, take the cuttings from the ends of the branches. There should be at least three nodes on the finished cutting. The length of the cutting will depend on the distance between nodes, but it should be long enough to prevent wilting, and to permit making a fresh basal cut back at the propagating facility. Heel cuttings may be taken of woody material which is more difficult to root. Small lateral twigs with at least three nodes are pulled off, not cut, from the leader shoot, leaving a piece of older wood or "heel" at its base.

Place the cuttings immediately in wet plastic bags to prevent wilting. Keep species separate and label each bag with the name of the plant and location. In order to maintain genetic integrity, do

not mix cuttings from different geographic locations. Keep the bags of cuttings cool and shaded from the sun. The bags can be placed in light-colored garbage bags for carrying from the field, and should be carried in an ice chest in a vehicle. If the cuttings cannot be handled promptly upon reaching the propagating facility, they should be refrigerated. The length of time cuttings can be refrigerated varies by type of cutting; softwood cuttings may last up to a week, while semi-hardwood cuttings may last for several months.

Flats or pots should be filled with cutting medium before the cuttings are brought in. The type of container is somewhat dependent upon the size of the cuttings to be made. Cuttings of low growing plants like *Luetkea pectinata* (partridge foot) or *Arctostaphylos uva-ursi* (kinnikinnik) can develop adequate root systems in shallow plastic flats holding at least 2 inches of mix. Cuttings of more upright plants like *Cornus stolonifera* (red-osier dogwood), *Pachistima myrsinites* (Oregon box), or *Rhododendron macrophyllum* (Pacific rhododendron) will need a deeper flat containing 4 inches of medium to permit sufficient root development.

Re-cut the end of the stem of the cutting with a single-edge razor blade, or sharp knife, leaving at least three nodes. If the cutting is a heel cutting, trim the old wood and cut the "tail" to 1/4 inch. Remove the bottom leaves with the razor blade so that none will touch the surface of the mix when inserted, leaving at least three leaves at the tip (Figure 5-2). If the cutting has many large leaves, like *Rhododendron macrophyllum*, cut each leaf in half crosswise to reduce water demand and keep the cuttings from touching in the flat. This will not be necessary with small-leaved plants. The cut surfaces of the cuttings may be dipped in a rooting hormone before being inserted into the mix. These chemicals are not a shortcut to success in propagation and will not cause rooting if the cutting is not physiologically able to produce roots. They do increase the ability to produce roots more quickly and in greater abundance.



(a) removal of terminal shoot (b) preparing flat into which cuttings will be planted (c) dipping cutting into rooting hormone--note that leaves have been removed from lower stem (d) planting cutting (e) watering cuttings in, after all have been planted

Figure 5-2. Preparation and Planting of Cuttings (From Davis 1991)

The mix in the flats must be moist when the cuttings are ready to be inserted. Make holes in the mix with a pencil or nail and insert cuttings so as not to wipe off the hormone. Bury the stems in the mix up to, but not touching, the leaves. Leave about 1 inch of space between each cutting. Firm the soil with fingers as you work and spray with a fine mist to settle the soil. Label each set of cuttings with the species name, date, and location. To prevent an allelopathic reaction between species, and to maintain genetic integrity, put only one species from one geographic area in each flat.

Handling the cuttings during rooting: Portions of plant material (cuttings) have been detached from the parent plant and deprived of nutrient and water uptake; therefore the cuttings must be given assistance to grow into usable stock for transplanting back to the wild. For all types of cuttings, except hardwood or root cuttings planted outdoors, some environmental control is necessary. The ideal environmental control will prevent the loss of moisture from the cuttings, provide adequate light for photosynthesis, and maintain correct temperatures, both in the atmosphere surrounding the cuttings and in the rooting mix. Structures used to provide the necessary control vary from simple polyethylene tunnels over flats, to cold frames and elaborate greenhouses. Propagating structures are discussed later in this chapter.

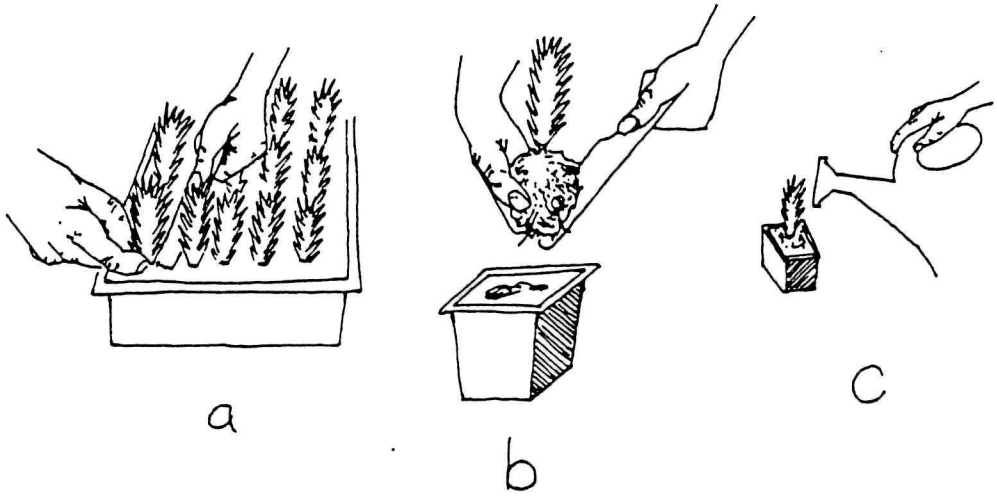
Leafy softwood or semi-hardwood cuttings need high humidity when rooting. Place the flats on a misting bench that has been covered with a plastic tent to maintain the humidity. On cool, cloudy days, misting the cuttings once may be adequate. On hot days they may need misting at least three times a day. If the misting system is automatic, check it to prevent overwatering. The rooting mix should be damp, not waterlogged. The cuttings will require close attention during the rooting period. They must not be allowed to wilt at any time. Temperatures in the cutting medium should be maintained between 65 and 75 degrees F (18 and 24 degrees C). Sanitation should be maintained by promptly removing dead leaves and cuttings. If hygienic practices have been followed throughout, including the use of clean flats, tools, and newly mixed cutting media,

pathogens should not be a problem. Disease problems under mist conditions have not been severe, probably because the frequent watering of the leaves keeps spores from germinating. If necessary, the cuttings may be watered occasionally with a dilute solution of one of the fungicides registered with the Environmental Protection Agency. Proposals for fungicide use must be submitted through the Park Integrated Pest Management Coordinator for Regional and Washington approval.

Every so often gently lift up a few cuttings to look for roots. It takes about three weeks for *Luetkea pectinata* to develop roots and at least two more weeks before the root system is strong enough for the cuttings to be transplanted. Heather cuttings, on the other hand, may take two and a half months to develop roots and another two to three months before transplanting may be attempted.

Transplanting the cuttings: Rooted cuttings should never be taken directly from the cutting medium for planting in the field. Because the cutting mixture provides no food, the cuttings should be potted in a growing medium as soon as they have developed a vigorous root system. This allows the tops and leaves to recover their stored nutrients that helped initiate rooting and growth.

Lift the rooted cuttings gently from the rooting medium with a fork, spoon, or trowel, taking care not to break the roots (Figure 5-3). Try to retain a ball of the medium still adhering to the roots. The cuttings are ready for potting when the roots are 1-2 inches long and well branched. Partially fill the 2 inch or 3 inch pots with the potting mix and set the cuttings into them. Hold the cutting upright with one hand while filling the pot with a trowel. Tamp the soil gently around the roots, leaving 1/2 inch to 1 inch from the soil level to the top of the pot for watering. Settle and thoroughly moisten the soil by watering with a fine spray. Water the transplanted cuttings once with Peters Plant Starter (9-45-15) diluted to half strength. Put the pots back on the misting bench



(a) removing rooted cutting from flat--note support provided by fingers (b) transplanting cutting into previously prepared container (c) fertilizing transplanted cutting with shock-reducing fertilizer

Figure 5-3. Transplanting Rooted Cuttings (From Davis 1991)

for one week, then move to the shade, either in the greenhouse or outside, for several weeks. Gradually the plants may be moved into sunlight.

Propagation Of *Cassiope* and *Phyllodoce*

The heathers, *Cassiope sp* and *Phyllodoce spp.* are the backbone of many subalpine plant communities in the Pacific Northwest. The branches of these small woody plants are easily damaged by trampling and slow to recover. Because of their abundance, heathers are important components when reconstructing native plant communities in disturbed areas, yet have been difficult to propagate. Heathers are propagated with semi-hardwood cuttings but are discussed here in a separate section because they require specialized treatment.

Olympic National Park uses the following steps to successfully propagate *Cassiope* and *Phyllodoce*:

1. Collect the cuttings in mid-September. Look for lateral, spindly, etiolated branches from the bottom or interior of the plant, not densely-branching sunwood. The vegetation should not be flowering or fruiting. The branches should have a soft, green tip (current summer's growth), then a semi-mature section (not soft like the tip, but not woody). Below this area, the foliage will be fully mature and woody. Heather cuttings must be taken from the semi-mature growth between the green and woody. Take cuttings that are 3-4 inches long. It is best to propagate heathers soon after collecting the cuttings. If the cuttings cannot be propagated right away they may be stored in the refrigerator in a moist plastic bag with the top folded over, not sealed, to allow some air exchange. Stored properly the cuttings should last all winter.

2. Strip the leaves off the lower 1 inch of the cuttings; then, using long twist ties, tie them into bundles of fifty (an 11x22 inch flat holds fifty cuttings). Pre-soaking the bottoms of the cuttings in a hormone solution for a day before propagating may increase rooting. The hormone solution is 1 tablespoon Dip and Grow to 1 quart of water.

3. The next day, plant the cuttings in the peat/sand/perlite cutting medium discussed in the section on soil mixes, and place on a misting bench.

4. The heat and humidity need to be monitored carefully. During the summer do not use bottom heat. Protect the cuttings from the sun. Hang shade cloth over the plastic humidity tent at the misting bench to make the microhabitat darker. This will reduce the heat and potential for desiccation, and increase rooting. During the winter use bottom heat at 45 to 60 degrees F (7 to 16 degrees C). Heathers have very fine roots and need good drainage, complete shade, and coolness when rooting.

5. Heather cuttings will develop roots after two and a half months. Check under the flats periodically for roots. Because the roots are very delicate the cuttings should be left to develop in the cutting medium for at least three to four months.

6. Transplanting the rooted cuttings out of the cutting beds into pots can be very difficult. This is the stage where the tender roots may be damaged, causing the plants to die. Start transplanting as early in the spring as possible (February through June). Transplant only on cool, cloudy days. Handle the cuttings gently and as little as possible. It may be best to use white or green pots, rather than black pots which absorb more heat. The potting mixture, discussed in the soil mix section earlier, contains ground fir bark as the primary ingredient. Nursery growers of rhododendrons, plants in the same Ericaceous family as heathers, have had greater success using ground fir bark rather than peat in the

soil mixes. After transplanting, water the cuttings once with Peters Plant Starter, diluted to half strength. Put the pots back on the misting bench for one week, then move them to the coolest, darkest part of the greenhouse for two to four weeks to reduce any transplanting shock. If it is well into spring, with no chance of a frost, the pots may be moved outside into full shade after being on the misting bench.

7. Keep the pots in the shade for most, or all, of the summer. By the fall the plants may be in half sun/half shade. Fertilize regularly. These heather plants may be overwintered at the propagating facility and planted in the field the following autumn, two years after taking the cuttings. Heathers plants that were propagated early in the fall may have developed a strong enough root system to be planted in the field the following fall, one year after the cuttings were taken.

Advantages: Propagation of some species is easier or faster by cuttings; cuttings produce larger plants initially, making them more visible at the revegetation site.

Disadvantages: Plants are bulky and heavy; getting them to the site can be difficult. Some species spread very slowly after being transplanted. Cuttings are cloned from the parent stock, which reduces genetic diversity.

Divisions

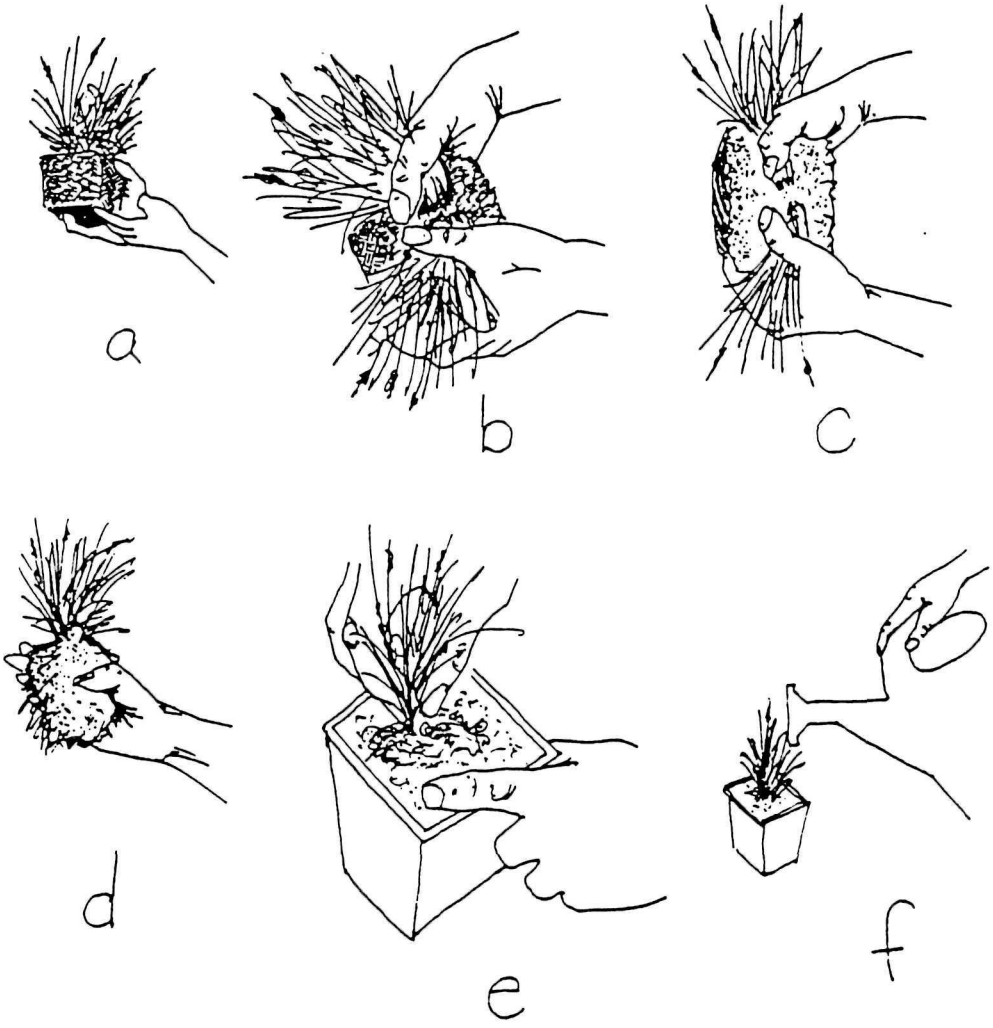
A large number of our native plants multiply by underground stems or rhizomes (Appendix 3). At various distances from the parent plant, nodes on these rhizomes send up aerial stems, and roots down, into the soil. If the rhizomes are thick and fleshy, it is possible to cut off pieces of them and bury them in flats until they have initiated roots and shoots. Another practice is to cut off sections of the rhizomes, including roots and shoots, and plant these sections in flats (if the divisions are

small) or pots (for larger divisions) of potting mix. Bottom heat and rooting hormones are generally unnecessary when propagating plants by dividing the rhizomes. The potted divisions should be kept moist and shaded for two to four weeks to allow the roots to recover from the transplanting. After this the plants may be in partial sun and shade. The plants may be kept in a propagating facility or outdoors. When the plants have developed a substantial root system they may be transplanted into pots, if they are in flats, or transplanted into the field.

A lesser number of native plants multiply in the wild by stolons or prostrate aerial stems that root at the nodes to form new plants (Appendix 3). The nodes, with some stem, may be detached from the parent plant and propagated by pressing them into flats of potting soil. The stems may be covered with soil but keep the node uncovered. A hairpin works well to hold the node firmly against the soil. Keep the soil moist. These plants may be kept in a propagating facility or outdoors. After substantial roots have developed the plants can be transplanted into small pots. The plants are ready to be planted in the field when the roots have filled the pot and are growing through the bottom.

Propagation by divisions is not practical for herbaceous plants with tap roots (lupine, columbine) or single stems.

Some of the most valuable plants for revegetation are the sedges and grasses, particularly those that form sods by their rhizomes or stolons. Clumps of sod may be dug in the field (care being taken to fill the divots!) and brought back to the propagation facility for division. The clumps should be teased apart with the fingers and small pieces or "sprigs" containing some roots and one or more aerial stems planted in shallow flats or small square plastic pots. A clean razor blade or sharp knife may be helpful in cutting through the rhizomes or runners holding the clump together. They should be planted in a potting mix. Grasses and sedges may be divided again and again throughout the growing season (Figure 5-4).



(a) large, healthy plant removed from container (b) finding location of "natural" division (c) dividing plant at location of "natural" division (d) portion of divided plant ready for transplanting (e) planting division--note upright position of plant and soil being slightly tamped in around roots (f) fertilizing newly transplanted division with shock-reducing fertilizer

Figure 5-4. Dividing Existing Stock Plants (From Davis 1991)

Advantages: Propagation is rapid because the divisions already have roots and shoots; produces larger plants initially, making them more visible at the revegetation site.

Disadvantages: Plants are bulky and heavy; getting them to the site can be difficult; some species spread very slowly after being transplanted; divisions are cloned from the parent stock which reduces genetic diversity.

Layering

Layering is a process of inducing roots to form on a stem that is still attached to the parent plant, in contrast to forming roots on a detached stem (a cutting). Some native plants naturally reproduce by layering; others can be encouraged to form roots by the layering process (Appendix 3).

Methods used to layer plants are described in detail in the on-site (field) propagation section of this chapter. The field methods can be modified to use with plant stock at a frontcountry facility.

Facility Management

Types Of Facilities

Polyethylene tunnels: The simplest form, and one quite adequate for rooting small quantities of semi-hardwood cuttings, is a polyethylene tunnel over a flat supported by loops of wire at the ends. In moderate Pacific Northwest climates these simple cutting boxes can be placed outdoors in late summer or fall in places receiving good light but no direct sun. The flats should be examined periodically to see that the soil moisture is adequate and to assess root development. To examine the roots, dig down and under a stem with a small spoon or fork and lift the cutting from the mix. If there is a well developed root system, it can be transplanted into a pot; if not, it should be gently replaced and the mix settled with a spray of water.

Cold frames: Considerably more elaborate, and suitable for rooting large numbers of cuttings or growing divisions, are cold frames. The usual form is a box, without a permanent top or bottom, which is covered with a moveable lid of glass or other transparent material. The frame may be of any size. The old standard dimensions used by generations of horticulturists are 6 feet x 12 feet, designed to hold four 3' x 6' sashes of window glass. With the development of good plastic materials, it is more common to make the covers of 6 mil clear polyethylene, or 8 or 12 mil UV resistant polyvinyl chloride film. The back side of the frame, to which the covers are hinged, should be 6 inches higher than the front to permit water run-off.

The decision as to where to locate the frame involves a compromise between obtaining good light for photosynthesis and the possibility of over-heating from the sun. A location on the north side of a one story building with no overhanging eves or tree limbs is perhaps the best overall for rooting cuttings. Exposure to the south will provide better light for photosynthesis, but it will be necessary to monitor the frame daily and raise the covers on sunny days to keep from killing the

plants by excessive heat build-up. If desired, an electric heating cable may be placed on the ground under the flats to provide bottom heat and hasten rooting.

Cold frames are capable of producing large numbers of plants very economically. North Cascades National Park grew 10,000 plants during 1991 in their cold frame.

Greenhouses: For really large scale propagation of plants a greenhouse is necessary. Greenhouses can be of many shapes and sizes and can be built of both wood or metal (usually aluminum). Glazing may be of either glass, fiberglass, or Filon, a UV resistant rigid plastic material. Adequate ventilation is the one most important prerequisite of the design, and roof vents and exhaust fans are essential. There are numerous publications available which discuss greenhouse designs.

The greenhouses at North Cascades National Park and Olympic National Park are 20'x40'; both produce 10,000 to 25,000 plants each year. Mount Rainier National Park produced 16,000 plants during 1991 in their 13'x24' greenhouse.

Shade houses: Before plants can be moved from an environmentally - controlled facility (greenhouse, cold frame, etc.) outdoors into full sun, they need to adjust to the lower humidity and changes in air movement and temperature. A shade house works well as an interim facility for plants before they are planted out in the field. It is a wooden frame structure covered with shade cloth or lath, which blocks approximately 50% of the light. The shade house also adds bench space for growing plants that do not need the high humidity and controlled environment of a greenhouse, such as older seedlings and potted plants.

Physical Layout of a Greenhouse

Commonly, greenhouses have three benches running the length of the greenhouse, one on each side and one down the middle. One of the benches is a misting bench and two are open benches. The benches are usually built to hold 11x22 inch flats, with one row of flats on the side benches and two rows down the center bench.

The misting bench is for plants that need mist propagation--primarily cuttings and recently transplanted plants. The bench has a system of water pipes 2-3 feet above the bench which release mist periodically. The misting system can be manually or automatically activated, depending on the type of operation. To keep humidity high, plastic is draped over the misting system pipes, forming a tent over the bench. The misting bench may be set up without bottom heat. Frequently, the bench will be divided into two or three sections, each with its own heating coils and thermostat. When heating coils are used, lay them on the wooden bench then cover them with 3 inches of sand which helps disperse the heat.

The open benches are used for propagating seeds and growing plants that have already rooted. The seed flats may get covered with a plastic dome when they are first planted to increase humidity; the dome is removed after the seeds have germinated.

Gravel is a common material for the floor of the greenhouse, although soil, sand, or concrete can be used.

Environmental Conditions in the Greenhouse

Light: Greenhouses, by the nature of the materials they are made of and their locations, absorb daylight. To supplement natural light, propagating lights may be used. Placing the lights above the center bench will probably illuminate the greenhouse adequately. The lights are particularly useful to begin propagating in early spring when the days are still short. The lights can be kept on for 16 hours a day to encourage plant growth. During the growing season some plants (heathers and recently transplanted plants for example) may need lower light; these plants can be placed below the benches on lower shelves, or on the ground. An alternative is to drape part of the greenhouse, or part of a bench, with shade cloth to create more shade. Intense summer light can scorch plants and overheat the greenhouse, so shade cloth, lathe, or some other shading material may need to be used.

Temperature: Temperatures in the greenhouse will vary between day and night, and by season. In summer the greenhouse will absorb heat and need to be cooled down; the rest of the year temperatures inside the greenhouse will be a little warmer than outside ambient temperatures. In general, temperatures in the greenhouse should range between 45 and 80 degrees F (7 and 27 degrees C). Greenhouses can be designed with built-in heaters, and portable heaters may be used in an existing structure, to keep the temperature above freezing in the winter. Using a heater in the early spring will lengthen the growing season, allowing plants to be propagated earlier. A system of fans and vents is necessary to circulate air and lower the temperature in the greenhouse.

On hot days, cool the greenhouse with fans, and by wetting down the benches and gravel (or other floor material) in the morning. The gravel may be wetted down again during the day if necessary to keep the temperature down. Watering the plants mid-day on very hot days could inadvertently damage them. When the air is humid, plants open their stomata for gas exchange; when it is hot, the stomates close to preserve plant moisture. When the air is hot and humid (such as after wetting

down the benches), the stomates open with the humidity, but as the humidity decreases during the afternoon, plants lose critical moisture and may die the next day.

Humidity: Proper humidity is important for optimal plant rooting and growth. Keep the greenhouse humidity between 50-70% with the misting system, and additional hand watering if necessary.

Ventilation: The greenhouse must be well-ventilated to reduce mildew and other fungal problems. The doors, skylights, and vents should stay open whenever the outside temperature is over 40 degrees F (5 degrees C) to allow adequate air movement.

Sanitation

The greenhouse, tools, pots, and flats must be kept clean. Wash equipment between uses with a chlorine bleach solution. Replace the sand on the misting bench each year. There are differences of opinion regarding routine greenhouse cleaning. Some recommend emptying and cleaning with a chlorine bleach solution annually. Other greenhouses have gone without cleaning for years without problems. Clean the algae off the outside of the greenhouse every few years as needed.

Propagation and Procurement in the Field

Transporting plants from a frontcountry greenhouse to the field is time- consuming and stressful to the plants; propagating or procuring the plants on-site puts the plants where they are needed, and eliminates this time and stress. There are several methods that can be used: seeding, layering, plant salvage, and raised beds for seeds and cuttings.

On-Site Seeding

Sowing rates: The amount of seed needed to be sown in the field is affected by the species, viability, site topography, and type of seed (locally collected seed or purchased seed). Species with large seeds and seedlings are planted at lower densities than small seeds. Many subalpine species need to be planted at higher densities because they have low germination rates. Sloping sites, where rain and snow creep affect seed dispersal, will need more seeds than flat sites. Purchased seed usually has been more thoroughly cleaned to remove empty seed hulls, and can be sown at lower densities than locally collected seed. Broadcast seeding, which is done by scattering the seed across the ground by hand or with a mechanical spreader, is a common method to sow the seeds.

There is little information on seeding rates using native seed in natural areas of the Pacific Northwest. We can extrapolate from specifications for developed sites, and studies from other areas. Seeding rates are frequently measured in pounds/acre or number of seeds/square foot. Lawns are sown at 40 pounds/acre. Subalpine sites in Montana required 25-100 pounds/acre for adequate revegetation (Brown et al. 1978). The Soil Conservation Service recommends broadcasting 80 seeds/square foot on erodible sites. Taking into account the lower germination rates of subalpine plants, Mount Rainier National Park has estimated at least 133 seeds/square foot. A 100 square foot site requires 2 cups of *Lupinus latifolius*, 3 cups of *Erythronium sp.*, or 40 cups of *Aster ledophyllus* for adequate germination (Rochefort 1990). As a general rule the seeds should be clearly visible on the soil surface after they have been sown.

Propagation: North Cascades National Park has developed a method of direct seeding *Carex spectabilis, C. nigricans,* and *C. illota.*

1. Prepare the soil at the site by spading, and mix in peat moss to add organic matter if needed.
2. Sow the seeds in the fall. The seeds should have been collected from the same location. Press the seeds into the soil without covering them.
3. Cover the site with an excelsior blanket, after first removing the plastic netting on the excelsior.
4. When the snow has melted the following spring or summer cover the excelsior with clear plastic sheeting. Anchor the plastic around the edges.
5. Place a thermometer in the soil to monitor the soil temperature. The soil temperature should be 85 degrees F (30 degrees C).
6. Check soil temperature and moisture daily, if possible. When the temperature gets too high vent the plastic to cool.
7. Water the site if it gets dry. A backpack fire pump works well.
8. After germination, remove the plastic sheeting, but leave the excelsior over the seeds. The excelsior will eventually decompose. Keep watering the site through the summer until the fall rains arrive. Fertilize the seedlings to promote root growth. The seedlings need to go into the winter with well-developed roots.

Mount Rainier National Park has developed a similar method of seeding in the field using 5'x10' raised beds. The beds can be filled with a soil mix, or local soil. The beds have been seeded with a mixture of species that are at the site, including *Anemone occidentalis, Aster ledophyllus, Erigeron perigrinus,* and *Festuca viridula.* When the seedlings have a substantial root system they can be transplanted to a revegetation site nearby.

Layering

Layering is a process of inducing roots to form on a stem that is still attached to the parent plant, in contrast to forming roots on a detached stem (a cutting). Some native plants that naturally reproduce by layering include: juniper, subalpine fir, heather, blackberry, and willow; other species can be encouraged to form roots by the layering process (Appendix 3). Three methods may be used to propagate native species: tip, simple, and mound layering (Larsen undated). Layering can be done at any disturbed site and is very effective when revegetating trails.

Tip layering: Blackberries are one example of plants that can be reproduced by tip layering. In the summer when the new canes have grown to 24-30 inches tall cut off the cane tip. This encourages the lateral shoots of the canes to grow. In late July or early August, when the lateral shoots have small, curled leaves at the tip, and have grown long enough to touch the ground, they are ready to propagate. Dig a 4-6 inch hole in the soil near the parent plant. Put a lateral shoot tip into the hole, vertically up-side-down, and firmly pack soil around the tip. The soil must stay moist. Once a well-developed root system has formed, usually by autumn, the lateral cane may be cut from the parent plant 6-8 inches above the soil where it was inserted. The new plant can be replanted the same autumn or later in the spring. Each new layered plant will have a stub of cane from the parent plant, and a well-developed root mass on the buried tip. The rooted tip contains a terminal shoot bud which, when growth starts again, will turn up and push out of the soil forming a new shoot oriented right-side-up.

Simple layering: Deciduous and evergreen plants can be reproduced by simple layering. Deciduous plants are layered in the spring using branches produced the previous year, or in the summer using the current year's growth. Evergreens are frequently layered in the spring and summer using branches from the current season, although shoots from the previous year will also work. The shoots are ready to use when they are long enough to lay on the ground, and will break

when they are bent sharply. Dig a hole or trench 6 inches deep near the parent plant. Bend the branch sharply into a 'U' shape about 12 inches back from the tip, remove any leaves that will be buried, and insert the bottom of the 'U' into the hole or trench. Leave 6 inches of the tip sticking up out of the hole. You may need to place a stake or rock on the branch at the bottom of the curve to keep it down in the hole. Firmly pack the hole with soil. Stake the tip if necessary to keep it upright. Rooting can be stimulated in several ways:

1. cut a shallow notch or slice on the underside of the branch at the lowest point (also makes bending easier);
2. apply a rooting hormone to the cut;
3. twist the stem where the bend is to loosen the bark;
4. girdle the shoot by twisting a wire tightly around the shoot, right behind the bend, between the bend and the parent plant.

Keep the soil moist. Evergreens growing low to the ground with narrow leaves can often be encouraged to form roots simply by covering a branch with 3-4 inches of soil 12 inches back from the tip.

Branches that were layered in the spring will have a well-developed root mass in the autumn. When they are dormant, cut them from the parent plant. The new plants may be transplanted the same autumn, or later the next spring before they begin growing. Plants layered in the summer should not be transplanted until the following spring.

Mound layering: This method of layering works well with stiffly- branched plants not suitable for simple layering, and with well- established shrubs. If well-established shrubs are not available a plant that has been grown in the ground for one year can be used. Cut the shrub almost to the ground early in the spring before growth begins, leaving 2-3 inch branch stubs sticking up. Many

new shoots will be produced on the cut stubs when growth begins. When the new shoots are 3-4 inches long, mound soil around the established plant and the base of the shoots, leaving 2 inches of shoot tip above the soil. Mound more soil around the shoots two to three times throughout the growing season to a final depth of 8-10 inches. Always leave several inches of tip above the soil. The soil used for mound layering must be well- drained and kept moist. By Autumn the shoot bases will have well- developed roots. The shoots can be cut from the parent plant and replanted that same season or later in the spring. If the shoots are cut from the parent plant in the autumn, replace the soil over the established plant to protect it from winter damage. This same parent plant can be used to propagate more plants by the same process for several more years.

With plants that are difficult to root, follow the same process except that after the parent plant has been cut back to 3 inch stubs, cover the stubs completely with 1/2 inch of soil over the stub tips. The new shoots will have to grow through the soil to reach the light. Keep adding soil as outlined above. The new shoot bases, which have never been in the light, will not turn green from chlorophyll production, allowing the stem tissue to form roots more easily. Other techniques to encourage rooting include:

1. girdle the base of the new shoots by wrapping a piece of wire tightly around the shoot one or two months after they have started to grow,
2. cut a shallow notch or slice on the parent stem,
3. cut off a ring of bark around the parent stem.

Advantages: Some species will produce plants by layering more easily than by seeds or cuttings. Layering can be done at the revegetation site, eliminating plant transporting. Produces larger plants initially, making them more visible at the revegetation site.

Disadvantages: If layering is done at the greenhouse you have the same disadvantage of transporting bulky, heavy plants to the site; and plants are cloned from parent plants which reduces genetic diversity.

Plant Salvage

The construction of trails, campsites, structures, and roads provides a supply of plants to be salvaged that would otherwise be destroyed during construction. Salvaged plants are removed from the construction site, and transplanted into trenches at storage sites located in the vicinity of the construction area. When the work is finished these plants can be used to revegetate the construction scars, or transplanted to other sites in need of revegetation. Salvaged plants have the advantage of being healthy, well-established plants whose large size will make them visible at a revegetation site. Some species, such as swordfern, tolerate having their root mass divided two or three times, allowing more plant stock to be produced. Occasionally there are limitations, such as plants that do not transplant well due to their size or species, and potential salvage sites where access is so difficult that salvaging plants is not feasible. In most cases, plant salvaging is an inexpensive way to recycle many large (and small) plants for restoration work that would otherwise be lost. Plants species that are 'salvageable' are listed in Appendix 3.

As an illustration, Olympic National Park was involved in a large-scale plant salvage project when the Soleduck Road was reconstructed. They identified several factors that made the salvage operation more efficient and feasible:

Salvage site selection: The site should have an ample supply of salvageable plants, and be readily accessible to make the project feasible. Remember that the plants will be transported to planting sites, storage sites, or a road by backpack, gurney (i.e. stretcher), or vehicle when considering logistics and site selection.

Storage sites: It is rare for plants to be dug from the ground and immediately replanted; more commonly the plants are salvaged, then held in storage sites until they are replanted. The storage sites must be chosen after evaluating several factors: transportation distances, suitability of the storage site location, availability of water, possibility of noxious weed infestation, length of time plants will be out of the ground before being planted in storage sites, the need for potting if plants are moved to a greenhouse, and the availability and cost of trucks for moving plants. Storage sites must be near the salvage project to minimize the time spent transporting plants, but outside the construction clearing limits to ensure that equipment does not inadvertently damage the salvaged plants. Getting to the storage site should not require going up or down a steep slope; it makes transporting and watering plants too difficult. Environmental conditions at the storage site must match the needs of the plants to be stored there.

Olympic National Park used thirty-one small, shady storage sites to hold plants salvaged from 45 acres. The storage sites were only 10-50 feet from where the plants were dug up. Shallow trenches 10-15 feet long and 2 feet wide were dug to hold the plants. The plants were stored for two years, until construction was completed. It took two or three people one day a week to water the plants for twelve weeks during the first summer; the plants received no care the rest of the time they were in storage. Most species had a survival rate of over 90%.

Mount Rainier National Park used salvaged plants for restoration work at Paradise Meadows. Instead of using trenches, 5'x10' raised beds were built to hold plants.

Species selection: Select species that tolerate transplanting, are native to the area, and are adapted to the environmental conditions at the restoration site (Appendix 3). Post- construction environmental conditions may be quite different from the pre-construction conditions. A cool and shady slope may become hot and sunny after a road is built across it. The species used to

revegetate the site must be adapted to the new environmental conditions, and still be native to the area.

Advantages: Salvageable plants are often abundant at construction sites. The large plants can cover a revegetation site rapidly; and some species can be divided two to three times to make more planting stock.

Disadvantages: You are limited to the plants on hand which may not be the appropriate size or species to transplant. Salvage site may be hard to get to which will make transporting plants difficult.

Propagation and Procurement by Contract

Agencies such as the Soil Conservation Service (SCS) and private nurseries have been contracted to grow plants for restoration sites in National Parks. When revegetating in natural zones and wilderness areas, maintaining genetic integrity is a high priority; contracted propagation should use native seeds and cuttings collected near or at restoration sites. When revegetating along roadsides, genetic integrity may be a lower priority than procuring a large quantity of seeds and plants to stabilize the slopes, thus allowing a wider range of plant material to be used.

Plant Material

Seeds and cuttings: can be collected near disturbed sites in the National Park, and propagated by a private greenhouse or the Soil Conservation Service. Plants grown from the seeds or cuttings can be used directly for revegetation, or they may be kept at the greenhouse and used to produce quantities of seeds for revegetation in the park.

For the Soleduck road project, Olympic National Park contracted with a private greenhouse to grow lowland, understory plants for revegetation from seeds and cuttings collected by park personnel. Trees for the road project were grown on contract by the U.S. Forest Service from seeds collected near the park.

Mount Rainier National Park has contracted periodically with the Soil Conservation Service for seeds and plants to use on road construction projects, and restoration projects at Paradise and Sunrise.

Bareroot stock: refers to deciduous trees and shrubs that have been grown in nursery beds, and are dug and transplanted while they are dormant 'bare root'—with no ball of soil around the roots, although the roots may be packed with damp sawdust. The propagation of bareroot stock can be contracted out to private nurseries or agencies, using plant material collected near or at restoration sites. Bareroot stock is commonly planted in the fall and winter, but can be held over for planting in the spring by keeping the plants dormant in a cooler, not a freezer. Olympic National Park was planting bareroot stock until mid-May on the Soleduck Road project, and it has survived well.

Advantages: Bareroot stock is relatively inexpensive. The bare roots and dormancy make the plants lightweight and easily transported. The dormancy and cool weather provide ideal transplanting conditions.

Disadvantages: Plant materials limited to species that can be transplanted bareroot.

Chapter 6. Site Preparation

Campsites and social trails that have been heavily used often have compacted soil and erosion problems. Frequently these sites have eroded below the surrounding grade, which changes the habitat and channels more water through the eroded troughs. Plants have difficulty surviving on sites where organic matter and soil are continually washed away. Water and roots cannot penetrate the compacted soil. These site problems must be corrected before the site can be revegetated. Site preparation typically involves: 1) scarifying the site to break up the compacted soil, 2) stabilizing the soil to minimize or prevent erosion, and 3) filling and contouring the site to approximate the original grade, if there is extra soil available to use. At this stage, soil additives can be worked into the soil to approximate the original soil conditions. Examples are peat moss and sterile cow manure which may be substituted for lost organic matter and will increase the water-holding capacity of the soil.

Scarifying the Site

Compacted soil should be broken into small particles about 1/4 inch in size with a loose, granular consistency. This will allow plant roots and water to penetrate into the soil. A spading fork, shovel, or pulaski work well to break the soil into large chunks. These chunks can be broken into small particles with a rake or your hands. It is difficult to determine the depth of soil compaction since we usually cannot see it. You may be able to estimate it by digging around with your hands or a small shovel. Generally, soil scarification is influenced by the depth of the soil, the depth of the compaction, the depth to a rocky soil layer or bedrock, and the presence of plant roots. As a general rule, scarify the site 6-12 inches deep when small shrubs or herbaceous plants are to be planted because most of them root within that depth. Sites that will be planted with tap-rooted herbs such as lupines, and larger shrubs and trees, will need deeper scarification because these roots go deeper into the soil. Alpine sites tend to be very rocky, allowing only a few inches to be scarified.

While scarification is generally helpful, there are some cautions. Scarification done improperly can invert the soil profile. Clumps of soil should be lifted up and loosened or broken apart, not turned completely over, to keep the soil and organics on the surface.

On steep sites, soil loosened by scarification may have greater erosion potential. Olympic National Park recommends little or no scarification when the slope is greater than about 20% to minimize potential erosion. Steep sites can be filled with rock and debris, rather than soil, to reduce erosion. If backfilling with soil is necessary, silt bars, discussed in the section below, can be used.

The soil at an impacted site commonly appears barren, but may contain live roots that will resprout given time and protection from trampling. Because scarification can damage or destroy these live roots, the site should be examined for the presence of roots before being scarified. Live roots will probably be flexible rather than brittle, and show green color under the surface when scratched. When live roots are present, the site should be scarified only in spots or not at all, depending on the density of roots.

Stabilizing the Site

Both subsurface and surface methods can be used to stabilize soil and prevent erosion. When resources—personnel, materials, funding— are available, soil may be imported to restoration sites that are eroded below the surrounding grade. In these cases, subsurface silt bars are used to stabilize the soil. More commonly, restoration projects are limited to surface treatments with materials available on-site (rocks, logs, minimal amounts of soil), or relatively inexpensive imported materials (excelsior blankets).

Surface Stabilization

Check dams, or surface silt bars, are commonly used to stabilize gullies and social trails at restoration sites. Rocks or logs can be used to build the check dams. Rocks may be available on the site, or can be retrieved from nearby talus slopes; diameters of 10-18 inches work well. Usable logs are sometimes generated by trail work.

The rock or log material for the check dam should be dug into the sides and bottom of the eroded gully or trail to anchor the check dam to the site, preventing it from blowing out in a storm (Figure 6-1). Use the excavated soil to fill in behind the dam, as well as local gravel and soil generated by the trail crew. There are no hard and fast rules about the number of check dams to use at a site. A general guideline is to have the top of one check dam even with the bottom of the next higher check dam. Start at one end of the gully and work up its length. When the check dams are completed there will be a series of small terraces along the length of the gully, with the risers being the check dams, and the treads being the backfilled soil and gravel. The treads may be somewhat concave because of having little soil with which to backfill; over time more silt will be deposited in the treads. Plants along the edge of the gully or trail can often be layered in the tread area to increase the stability.

Bare soil at a restoration site must be protected from surface erosion. Excelsior blankets (wood shavings held together by a photodegradable netting) can be spread across large areas. If available, large rocks can be partially buried in the soil and dead trees and branches can be strewn on top of the site. Rocks and logs should be placed randomly to match the natural occurrence in adjacent areas. Keep the moss and lichens on rocks facing up when burying them in the soil. The rocks and logs help in several ways. They shade the soil, creating favorable microhabitats for plants with cooler soil and air temperatures, and greater soil moisture. They may discourage use of a site,

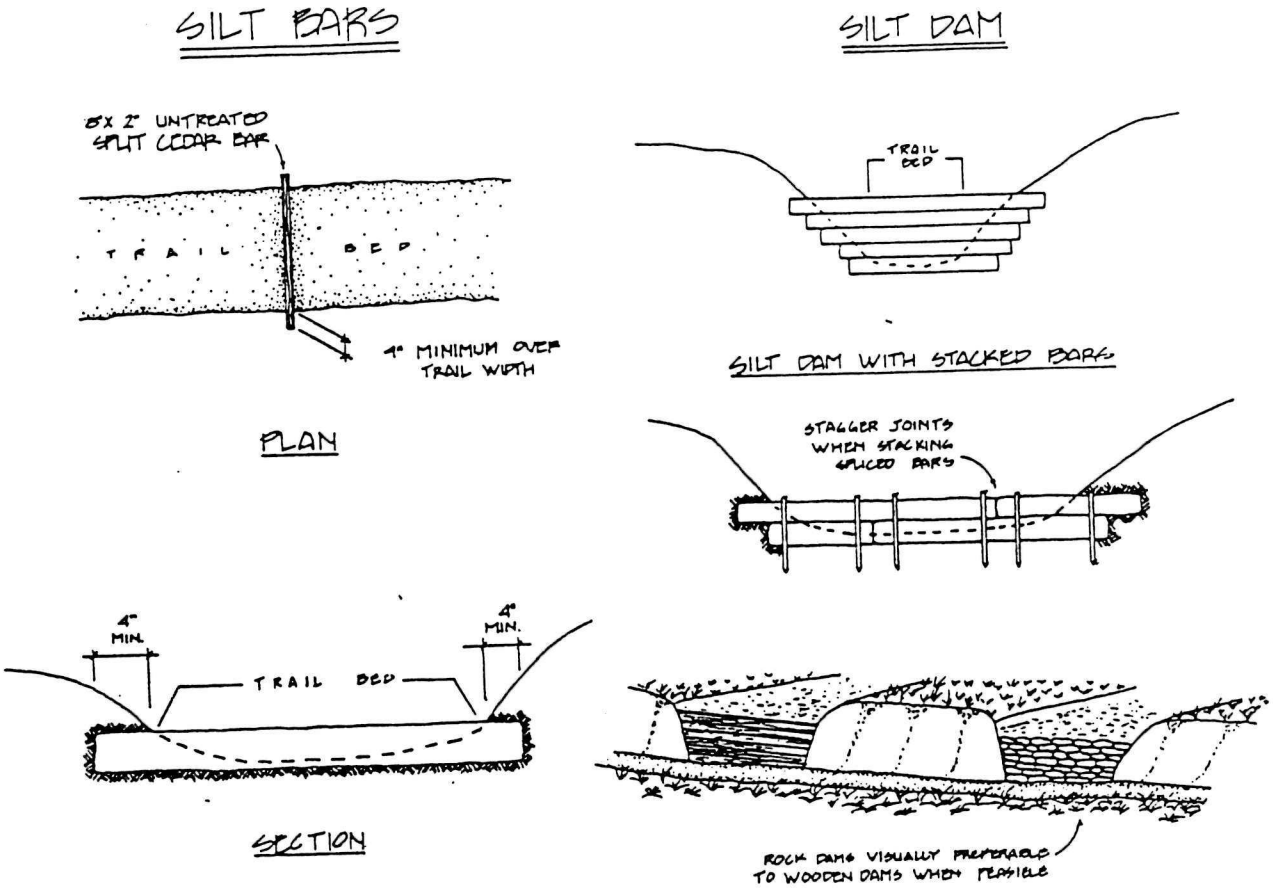


Figure 6-1. Installing Silt Bars and Silt Dams (From Rochefort 1990).

particularly for camping. And in time, they give the site a more natural look similar to adjacent areas.

Subsurface Stabilization

When large quantities of soil are needed to fill an eroded site, subsurface silt bars made of wood or rock can be used to stabilize the soil. Silt bars are placed across the eroded area perpendicular to the hill slope and parallel to the contour. Once the silt bars are in place the area is filled to grade (level with the surrounding ground) with soil. When the filling is completed the silt bars will be covered with 1- 2 inches of soil.

Silt bars may be made of wood or rock. Wooden bars made from cedar rails have been used on many restoration projects because their light weight makes them easy to transport, and the wood is not difficult to cut and fit to the site. At a rocky site wooden bars may be difficult to place in the ground, and with its natural abundance rock may be an easier material to use. When collecting rock for a project it is important to remember that rock is an integral component of many plant and animal habitats in the mountains. Gather a few rocks here and there over a wide range so that no one place is impacted too heavily. If a large quantity of rocks is required for a particular project, it is recommended to bring them in from an outside source.

Installing silt bars: (after Rochefort 1990) Below are the steps for placing silt bars in a social trail. The number of silt bars needed and the distance between them will vary with each situation. Start at one end of the trail and work your way along the length of it. A rule-of-thumb for spacing the bars is to have the top of the lower bar even with the bottom of the next higher bar. Dimensions of cedar rails are usually 12 feet long by 8-12 inches high and 4-8 inches wide when purchased. Each bar will need to be split lengthwise to conserve materials and because it is not necessary for the width to be greater than 2 inches. Wooden bars will decompose over time which may cause the

soil to slump. To minimize potential slumping, extend the spacing guideline to put in as few bars as necessary. Well-established vegetation will also reduce future slumping. Some of the problems that may be encountered will be discussed later.

1. Measure the width of the area to be stabilized.
2. Cut a bar 8 inches longer than the width of the impacted site.
3. Determine the location of the bar and cut a narrow slot through the berm on either side of the trail into which the bar will be placed. (Save the vegetation cut from the berms to replant over the ends of the bars after they are in place.) Dig a trench on the bottom of the social trail, between the slots so that the bar can be anchored into the bottom of the social trail. The trench should be 2-4 inches deep, and the width of the bar. The objectives of both the slots and the trench are to firmly anchor the bar into the social trail.
4. Drop or hammer the bar into the trench slots and make sure it is secure.
5. If the social trail is deeper than the first bar, add additional bars to make a silt dam until the top of the silt bar is 1-2 inches below the adjacent berms. Ideally there should be no gap between the upper and lower bars, but if the bars do not meet exactly try to keep the gap to less than 1 inch. The addition of bars to approximate the depth of the impact may mean you will have to split a bar lengthwise since the depth of most impacts will not be a multiple of 8 inches.

Problems And Special Considerations: Sometimes it may be difficult to obtain a snug fit of the bar into the adjacent berm. Consider using stakes or rocks in front of the bar or in the berm slots to add stability.

Bars may be shorter than the width of the trail, requiring two bars to span the width. In this case, overlap the ends and stabilize the middle with stakes. Successive bars in a dam should be overlapped at different points so all the weak spots are not in the same area (Figure 6-1).

Often a social trail is in the middle of an undulating slope so that the undisturbed berm is higher on one side of the trail than on the other. In this case, cut the bar at an angle or install the bar at an angle so that the filled trail will slope gradually from one side to the other.

Rocks, tree roots, or clumps of vegetation may be where the bar is to be placed; cut or rearrange the bar to fit the situation. Salvage any plants removed to place bar, and use for transplant material later.

Filling and Contouring the Site

After the site has been scarified and stabilized it needs to be filled and contoured to match the adjacent undisturbed soil. The amount of soil required may vary from only a few inches in minor situations to several feet in severely eroded areas. While we would like to fill a site with native soil and recreate the original soil profile, there are several reasons why this usually is not feasible. We frequently do not know much about the soils in the parks because few of the soils have been mapped. Commercial soils developed from different parent materials than park soils so they are not identical. And we can not take large quantities of native soil from within the park to supply restoration projects. However, when we understand the basic processes and materials that are developing our native soils we can approximate the soil profile, and add amendments to recreate any specific local condition that is lacking and encourage plant growth. Through time and weathering the soils will modify into something more similar to the native soils and be able to sustain local plant communities (Rochefort 1990). Our knowledge of park soils is continually, albeit slowly, expanding as more of the soils are mapped and analyzed in labs, and as we observe the results of our own soil work on plant growth and site restoration.

When the resources are available, sites that have eroded at least 2 inches deep should be filled to grade with a fill that approximates the original soil profile of rock, gravel, and soil. The soil, as the A horizon, should be 6-12 inches deep because this is where most rooting occurs. The gravel, as the B horizon, underlies the soil to a depth of 18 inches below the surface, and below 18 inches is the rock horizon. Although it may be possible to use rock from within the park, the soil and gravel usually must be purchased.

Mount Rainier National Park has had several revegetation projects that have involved soil restoration work and has set forth the following guidelines concerning the use of rock, gravel, and soil (Rochefort 1990).

Rock which is collected within the park will be collected from sites where removal will not markedly disrupt adjacent plants and animals. Talus slopes are frequently used as places to collect rocks. Rock collecting should occur only when the rocks are still large and unstable and no plants are present. Any removal of rocks may effect pikas and marmots; to minimize this disturbance collect rocks over a large area and take no more than 5 cubic yards of rock from any one site. Because the rocks will be carried and positioned by people they should be less than 25 pounds and less than 2 feet in diameter.

The **gravel** layer should be well-drained and contain different sized particles, but all within the parameters of being larger than sand and much smaller than rocks. Gravel will usually be purchased from a source outside the park. Over the years, Mount Rainier National Park has tried different sizes of gravel in restoration projects: rock crushed in the park (1986), 1.5 inch crushed aggregate (1988 at Paradise), and 1.25 inch crushed rock (1989). While all the gravel worked, the crushed rock (1986) and the 1.5 inch crushed aggregate (1988) were easier to work with, because the gravel was more uniform in size and not sharp-edged. The 1989 crushed rock varied from fines to large, sharp-edged pieces. When the gravel was transported in plastic bags to the restoration

sites and dropped from the helicopter net the sharp edges caused some of the bags to split open. Formerly, burlap bags had been used to transport gravel and had not split open.

Soil usually is purchased from a source outside the park. Mount Rainier National Park tries to buy soil with approximately the same texture, pH, and organic matter content as the native soil in the area in which they are working. Soils in the subalpine areas of Paradise Meadows are predominantly sandy loams with a pH of 4.6-5.2, and an organic matter content ranging from 1.8-8.0% at 10 cm below the soil surface. Soil has been purchased in the same ranges, then amended with peat to add more organic material, and fertilizers to encourage plant growth. Purchase orders must specify "sterilized soil". Steam pasteurization, where the soil temperature is heated to 160 degrees Fahrenheit, is a less expensive sterilization process. Occasionally bags of "sterile" soil have had plants growing in them, indicating they were not properly sterilized. If this happens, talk to the Contracting Officer before using or paying for the soil.

Rock, gravel, and soil need to be packed into the eroded area. The rocks should be packed by hand to get a close fit, while the gravel and soil may be packed by walking over the site periodically as it is being filled. Filled sites frequently settle and slump within the first year. Careful packing, and even mounding the soil 1-2 inches above the surrounding grade, will minimize settling.

Site Preparation for Seeds

Preparing a site where seeds are going to be planted is the same process as has been described so far in this chapter, but more care needs to be taken with the final soil surface to make sure that it is ready for seeds. The surface should be fine-textured and even, not lumpy. Rake the top 1/2 inch of the soil surface so that it is slightly rough, which encourages the seeds to imbed in the surface more

easily. Adding peat will increase the water- holding capacity of the soil, creating a more favorable condition for seeds to germinate.

Transporting Materials

Some materials such as rocks, logs, and small quantities of soil may be collected locally. Large quantities of soil, gravel, cedar rails, peat and other materials will have to be brought into the site. They can be packed in with backpacks, horses, wheel barrows, improvised litters, and helicopters. The volume and weight of soil and gravel may necessitate the use of helicopters, but many wilderness areas have restrictions about their use. Check with park policies when planning this phase of a restoration project. Burlap bags have worked better than plastic when transporting soil and gravel by helicopter.

Chapter 7: Planting Methods

Planting can begin once the site has been stabilized, scarified, and filled. Seeding, transplanting, and layering are common revegetation methods. Planting is usually done in September for several reasons. Plant growth is slowed in preparation for winter dormancy. Combined with cooler weather, the lessened growth rate reduces the chance of transplant shock. Cool autumn weather and approaching winter snows also reduce the water needs of the plants. Fall seeding follows the natural cycle of native plants which drop their seeds in late summer and fall. In the autumn there are usually still people around to help with the planting—an essential component of successful planting are the numbers of NPS permanent staff, seasonals, and volunteers who can be recruited to help. Sites can be planted at other times during the year, but will probably need constant watering throughout the summer and into the fall. While seeds are easily transported to the field for planting, plants in flats and pots must be packaged carefully. After planting, a mulch is usually applied to conserve moisture, reduce erosion, and keep seeds on the site.

Planting Strategies

Restoration sites have differing amounts of disturbance; some sites have most of the original vegetation intact, with only a few species missing, while other sites have large expanses of bare soil. Revegetation needs will vary with the physical and environmental conditions at each site.

There are several criteria to follow when choosing the species to plant at a restoration site. The planting plan must be in accordance with the NPS Management Policies for the specific zone. Each species should be a natural component of the plant community at the restoration site, or would be a component had the site not been damaged. The plants must have been propagated from species growing at, or near, the restoration site (there are exceptions to this, such as when

contracting out for plants or seeds). When revegetating a site after construction, plants must be chosen that are appropriate for the habitat at the site. This is of particular importance when the post-construction environment is different from the earlier, pre-construction environment (for example, a shaded forest slope that changed to a hot, dry slope after road construction).

Management plans for the site must be evaluated. Whether a site remains open to hiking and camping, or is closed to use, will influence the revegetation plan. There are several revegetation strategies to consider in conjunction with management plans. Species that have been eradicated from a site because of low tolerance to trampling can be replanted. Species that are more resilient to trampling can be planted, with species which are less tolerant interplanted later to restore a more natural community. Or, only species which tolerate trampling can be planted. The later approach changes the original composition of the plant community, but creates a hardier community that can withstand continual trampling. These revegetation strategies should be discussed with NPS resource managers, botanists, and field rangers to determine the most appropriate strategy for each site.

When a restoration site continues to be used for camping, picnicking, or hiking, revegetation will be more successful if species that tolerate trampling are planted (grasses, sedges, low herbs with small leaves and basal rosettes). A restoration site with limited use can be planted with a greater variety of plants, including those with little tolerance to trampling (tall herbs, woody shrubs, dense cushion plants). Over time, additional species from the surrounding area may become established on the site

Tools

Most planting projects involve digging small amounts of soil, and working among other plants and roots. For these, hand tools work well. Olympic National Park uses a hand mattock (Appendix 1) which is of great value for scarifying and planting in subalpine and alpine sites. The mattock, consisting of a pick and a hoe (adz) mounted on a 14 inch handle, combines versatility and portability, making it useful in many situations.

Bigger tools are necessary for large planting projects that involve moving quantities of soil. These include shovels, picks, pulaskis, rakes, and spading forks.

Transporting Plants and Supplies

Plants can be transported to the revegetation site by backpack, rescue litter, stock, and helicopter. Regardless of the method, the plants must be packaged carefully to survive the trip. There are many methods for packing plants. Species with an upright stem, such as heathers and other woody plants, need to be packed more carefully than grasses, sedges, and *Luetkea,* which have a more flexible stem.

Small cartons can be lined with a garbage bag and filled with plants, with or without their pots. Keeping the weight about 20 pounds will make it easier to move the cartons. The same method can be used, substituting a backpack for the carton. The weight should be comfortable to handle.

Another method is to fill boxes with a 1:1 mixture of vermiculite and peat which has been slightly dampened. Place the plants in the mixture; plants with a firm root ball can be taken out of their pots, but plants with a loose root ball should be packed in their pots to protect the roots. Depending on the size of the box, it may hold 150-200 plants. Olympic National Park uses boxes that are 18-

24" square and 24" deep. All vertical and horizontal corner joints must be reinforced on the outside with fiber strapping tape; the boxes still fall apart eventually, but this slows it down. These boxes are put into fish totes (plastic bins), which are then loaded into helicopter nets for transporting to the site. After the plants are flown into the backcountry, open the boxes so they have air circulation (unless the temperature is below freezing). The plants can remain in the boxes for a couple weeks.

North Cascades National Park has successfully transported thousands of grasses, sedges, and *Luetkea* by emptying the plants out of their pots into large plastic garbage bags, which are loaded into helicopter nets. The weight of the bags should be 20-30 pounds. One year it started to snow before all the plants could be planted. Plants were dumped out of the remaining bags into a large pile and left to overwinter. The following spring, after the snow had melted, the plants in the pile were planted. Most had survived the winter, and many showed signs of new spring growth.

Heather can be transported by inverting an empty flat over the top of the planted flat and taping them together. To keep the top flat from sliding or crushing the plants below, remove the soil in the corners of the planted flat and place 1x1 inch pieces of wood, approximately 4 inches tall, into the corners to support the top flat . The flats should be transported upright.

Planting Techniques

Planting Seeds

Methods for seeding a site are given in Chapter 5 (Plant Propagation) in the section on field propagation.

Planting Plants

Greenhouse plants (also called plugs) to be transplanted into the field will usually be in 2-3 inch pots or in flats with many plants in each flat. Begin by digging a hole that is twice the size of the plant's root ball. The soil on the sides and bottom of the hole should be loosened and uneven to allow the roots to grow into the native soil more easily. Place the root ball into the hole and backfill with soil. Pack the soil down firmly. Frost heaving, during the freeze/ thaw cycles in the mountains, often forces plants up out of the ground; plants should be planted about 1 inch below the soil surface to minimize problems. Planting below grade also creates a basin around each plant which collects water for the plants. Water the transplants with Vitamin B-1 or Peters Plant Starter to reduce transplant shock. Planting during periods of cool, overcast weather will minimize stress to the transplanted plants and ensure the greatest survival.

Spacing: Plants should be planted in irregular, clumped patterns to imitate the patterns of natural landscapes. Clustering the plants creates a microhabitat; the clump provides protection from wind and creates shade—both of which reduce moisture loss. Plant two to five plugs of herbaceous species in a cluster, with 2-3 inches between the individual plants. Space clusters 6-8 inches apart (Figure 7-1). Plant woody shrubs and small trees in clusters 1-3 feet apart, taking into account their size and growth form. Intermixing species will help the area look more natural. If there are not enough plants to cover the site, plant the areas that are the most visible, or the areas that are closest to a trail or campsite, to screen the site and discourage use.

Timing between seeds/plugs: When a site is to be revegetated using both seeds and plants, plant the plugs first, then scatter the seeds across the site. The process of digging holes and walking across the site to plant plugs will disturb newly-planted seeds. This is particularly important when seeds and plugs are to be planted in different years.

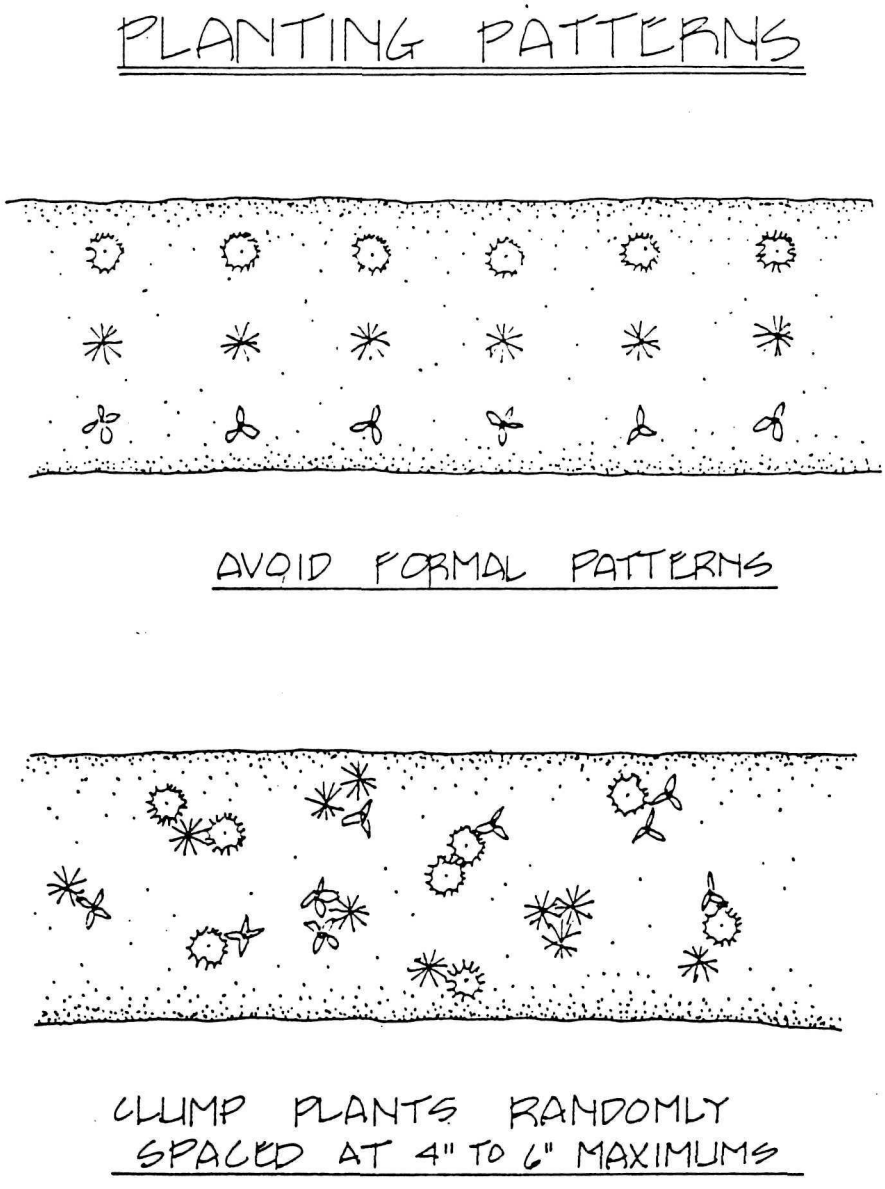


Figure 7-1. Planting patterns (from Rochefort 1990)

Layering

Layering is a process of inducing roots to form on a stem that is still attached to the parent plant. It is both a propagation technique and a method for planting on-site. Layering works well along social trails and the periphery of campsites, to move the naturally-growing plants inward and revegetate denuded areas. General techniques for layering are described in Chapter 5. When layering in a social trail, lay the long branches of the parent plant, frequently heather, in the trail behind a check-dam (silt bar) which collects soil and water. Bury a section of the branch in the soil, and lay rocks on top of it to keep the branch under the soil. Plants that propagate by layering are listed in Appendix 3.

Mulches

After plants and seeds are planted a mulch is laid down over the site to provide protection. The mulch shades the vegetation and soil, reducing soil temperatures, moisture loss, and erosion. The mulch also protects the site from wind damage. As the mulch decomposes organic material is added to the soil. Frost heaving may be reduced by the pressure of the mulch over the plants and soil.

Numerous commercial mulches are available (Table 7-1, 7-2). Most consist of a blanket of mulch fiber (straw, wood shavings, paper) held together by netting on one or both sides of the blanket. Most mulches decompose in one to five years, depending on material and climate. The netting is made of string or photo-degradable plastic. Plastic netting frequently does not decompose completely, and should be removed when the mulch is applied or after a few years. Curlex and Excelsior, both made of aspen shavings, are frequently used for revegetation projects.

Table 7-1. Types of Mulches

Mulch	Manufacturer	Description	Advantages	Disadvantages
Curlex	American Excelsior Company	Aspen wood shavings with photodegradable plastic mesh	Easy to install, promotes seedling survival, decomposes in 2-5 years; netting UV sensitive, decomposes in 1-2 years	Heavy
Hi-Velocity Curlex	American Excelsior Company	Aspen wood shavings with black heavy-duty plastic netting on both sides	Very effective on steep slopes, promotes seedling survival	Heavy; black netting visible for years
ESC Straw Blanket	Erosion Control Systems	Straw blanket with photodegradable netting on one side, sewn on 2" centers	Lightweight, sewn together for easier installation, promotes seedling survival	May decompose too quickly
ESC Excelsior Mat	Erosion Control Systems	Excelsior blanket (aspen shavings) w/ photodegradable netting, sewn on 2" centers	Promotes seedling survival, may be easier to install than Curlex since it is sewn	
High Impact Excelsior Blanket	Erosion Control Systems	Excelsior blanket w/ photodegradable netting on both sides and sewn on 2" centers	Easy to install since it sewn together	
Native Plant Materials	Gathered on site	Usually sedges, but can be grasses, Newberry's fleece-flower, litter and duff, etc.	Native seed source, inexpensive, looks more natural	Time-consuming to collect, must be worked into soil or will blow away
DS75	North American Green			
DS150 Straw Blanket	North American Green	Straw blanket with quick degrading photodegradable netting	Lightweight, faster decomposing netting	Netting may decompose too quickly
S75 Straw Blanket	North American Green	Straw mulch with photodegradable netting on one side	Lightweight, promotes seedling survival	Decomposes quickly (1-2 years), may not prevent erosion long enough

S150 Straw Blanket	North American Green	Straw blanket w/ photodegradable netting on both sides	Lightweight, promotes seedling survival	Decomposes quickly
SC150	North American Green			
C125	North American Green			
P300	North American Green			

Table 7-2. Mulch Dimensions and Costs (after Rochefort 1990, updated 4/93)

Mulch	Width	Length	Area	Weight	Cost/Roll
Curlex	4	180	720	78	
Hi-Velocity Curlex	4	100	400	72	
ESC Straw Blanket (Standard)	7.5	120	900	50	$52.00
ESC Straw Blanket (Hi-Velocity)	7.5			55	$77.00
ESC Excelsior Mat (Standard)	7.5	96	720	68	$45.00
ESC Excelsior Mat (High Impact)	7.5	60	450	50	$36.00
Native Plant Materials	N/A	N/A	N/A	N/A	N/A
DS75 Straw Blanket					
DS150 Straw Blanket	6.5	83	540	30	
S75 Straw Blanket	6.5	83	540	30	
S150 Straw Blanket	6.5	83	540	30	
SC150 Straw Coconut Fiber Blanket	6.5	83	540	30	
C125					
P300					
Box of Staples (1000)					

Mulches can also be made from native material. Sedges, Newberry's fleece flower, mosses, duff, rotten logs, and plant litter are some materials that have been used successfully. Native mulches have the advantage of being inexpensive, occur near the site (do not need to be transported), and are natural looking. They are also a potential seed source. However, native mulches may decompose too rapidly to give adequate protection to a newly planted site. Native material should always be collected out of sight of trails and camps. The material should be abundant so that collecting will not damage the plant community. The mulch material should be appropriate for the habitat being revegetated—subalpine sedge mulches in subalpine sites or rotten logs from forested areas broken up and scattered over wooded sites.

Applying The Mulch: Roll the mulch out and lay it over the site with the netting on top. The mulch can be left on top of the plants without damaging them. By the next season the plants will have started growing through the mulch. Alternatively, two slices can be cut in the blanket, forming an X above each plant, and the plants pulled through the mulch. Anchor the mulch with U-shaped staples (designed for this use) around the edges. Anchoring is important; steep slopes and snow creep pull mulches downhill. Rocks and logs placed on top of the mulch will visually break up the large expanse of excelsior, help anchor it, and provide stepping stones for later watering and maintenance. Use materials that are naturally found at the site. The bright yellow or tan color of excelsior can be darkened and made less noticeable by spraying with a solution of humagro (a commercial product made of decomposed peat or humic acid) and water.

Special Situations

Planting amid live roots: Sites where heathers and huckleberry were the dominant plant frequently have live roots in the soil, although the above-ground vegetation may be gone. Scarify the soil shallowly (4 inches or less) with a hand mattock to minimize damage to existing roots.

Plant in the spaces between the roots. Planting density will depend on the type of site and density of roots.

Planting social trails: Frequently there are still some plants and extensive mats of live roots in social trails. Scarify the soil shallowly, and work in peat or sterile manure. Plant densely, 2-4 inches apart, in the spaces between roots and plants. Leave small basins around each plant for water to pool. Put small checkdams and rocks between the plants to slow runoff water. *Luetkea pectinata* frequently spreads quickly, collecting silt and forming little soil pockets that can be planted the following year with other species.

Fire rings: The soil in an illegal fire ring frequently has been damaged by the heat of the fire, making it difficult for plants to re-establish on the site. Take the fire ring apart and remove any burned wood and ash. Scarify the soil at least 12 inches deep. Adding organic material to the soil by mixing in generous amounts of peat or manure will improve the chemical balance and increase the moisture-holding capacity of the soil. Then plant and mulch the site as usual.

Record-keeping

Document site preparation, seeding, planting, and mulching done at each site to facilitate monitoring later. The records will provide valuable information to determine the success of various restoration treatments. Figures 7-2, 7-3, and 7-4 are examples of record forms used at Olympic and Mount Rainier National Parks.

REVEGETATION PROJECT RECORD SHEET GENERAL AREA _____

DATE	PLANTING AREA	# PLANTS	SPECIES	BATCH #	# EMPL	TOTAL HRS	# VLNTRS	TOTAL HRS	COMMENTS

Figure 7-2. Revegetation Project Record Sheet used at Olympic National Park.

REVEGETATION PROJECT DATA SHEET

Area:_____ Trail:_____ Season:_____
Dates of Rehab. Work Begin:_____ End:_____
Average crew size:_____ Were photos taken of work: _____

WORK COMPLETED (Enter your estimate of the % completed)
trail stabilization_____ filled_____ mulched_____
seeding_____ planting_____ fertilizing_____

STABILIZATION were erosion bars installed?_____
number of wood bars_____ number of silt dams_____
number of rock bars_____ total work hours on stabilization:____

SCARIFICATION was the area scarified?_____
depth of scarification_____(inches) total workhours_____
equipment used_____

FILL enter cubic yards used
rock_____ gravel_____ fill_____ topsoil_____ peat_____
total workhours_____ method of transportation_____

PLANTING/SEEDING were plugs planted?_____
source of plugs (enter number from each source)
greenhouse_____ other_____ where?_____

total workhours (transporting plugs & planting)_____
Species planted:_____
_____
was the area seeded?_____ volume_____(gallons if possible)
Species:_____

Methods of collection: vacuum_____ hand_____ other_____
total workhours seeding & collecting_____

FERTILIZER
was B-1 used?___ amount_____
was other fertilizer used?_____ composition:_____
application rate:_____ lbs/acre
Application dates begin:_____ end:_____

MULCH type used:_____ amount:_____ rolls
Application dates: begin:_____ end:_____ total workhours_____

Comments on project _____
_____
_____

Has work on the trail been completed?_____
Work to be completed next year_____

Figure 7-3. Revegetation Project Data Sheet used at Mount Rainier National Park.

TALLY SHEET FOR REVEGETATION PROJECT DATA

Area:_____ Trail:_____ Season:_____
Date work begun:__/__/__ ended:__/__/__
Average crew size:_____
tally rolls film taken; Slide:_____
Print:_____

Tally of Data for Each Phase, per Trail:

Stabilization:
Number of wood bars:

Number of rock dams/walls (specify):

Number of silt dams:

Number of work hours for stabilization:

Scarification:
Depth of scarification:_____inches
Tools used:_____
Number of work hours for scarification:

Fill:
Method of transportation:_____
Rock (cubic yards or # helicopter nets - specify):

Gravel (cu. yards or # bags - specify. ~50 bags/yard^3):

Fill (specify), cu. yards:

Topsoil (cu. yards or # bags - specify. ~40 bags/yard^3):

Peat, cu. yards:

Number of work hours for filling trail:

Planting/Seeding:
Source of plugs (tally number from each source):
Greenhouse:

Other (specify source(s)):

Species planted:_____

Number of work hours for transporting and planting plugs:

Methods of seed collection (check all that apply):
vacuum:_____ hand:_____ other(specify):_____

(Continued)

Total volume of seeds, in gallons:_____

Species:_____

Number of work hours for collecting and seeding:

Fertilizer:
Using B-17____ Amount:_____
List names and compositions of other fertilizers used:

Application rate: _____lbs/acre
Application dates; Begun: __/__/__ ended: __/__/__
Number of work hours for fertilization:

Mulch:
Type:_____ Begun:__/__/__ Ended:__/__/__
Number of rolls:

Number of work hours for mulching:

DIRECTIONS FOR TALLY SHEET

These sets of data-gathering sheets are to be used on a daily basis throughout the season to keep a running tally on work hours and materials used for each trail worked on. Used daily they should facilitate thorough record keeping and save you hours of work at season's end, as these sheets consolidate all the data needed by the NRPs; final totals can be transferred directly onto the final reveg. project data sheet.

For continuity's sake definitions are included for two terms which may be unclear:

1) "Wood bars" vs. "silt dams": a silt dam may contain one or more wood bar(s); a stack of 2 or more bars is still one dam. Likewise, a rock wall or rock bar will create one silt dam.
2) "Work hours": work hours constitute the total number of hours of work for the given component. Thus if four people fill a trail for one full ten-hour work day, 40 work hours have been spent filling that trail. In keeping a tally, you may want to just tally the number of days spent at a task, then multiply by hours/day at season's end. (Five people working one day - five work days. Be sure to note any days divided into separate tasks, and calculate total hours accordingly — such as three hours spent barring and five spent filling, etc.) *NOTE*: subtract travel time from your figures, unless you're transporting plants (keep a tally on plant transport time). For example, a crew working on Panorama Point will spend an average of two hours daily hiking to and from the site; therefore the average work day on Pan. Pt. will be eight hours (assuming a ten-hour day), and so forth.

Remember: creating a standardized method of data collection for yourself at the season's start will prevent loss of information and save you headaches later on!!!!

Figure 7-4. Tally Sheet For Revegetation Project Data used at Mount Rainier National Park.

Chapter 8. Site Maintenance and Protection

Plants at a restoration site require watering at the time of planting, and until steady autumn rains begin. Plants generally become established after their first winter and need no further maintenance. Restoration sites, on the other hand, need maintenance and protection for many more years. Short-term strategies for site protection include barricades, signs, ranger patrols, and periodic physical maintenance. Long-term strategies focus on education of the public, as well as permanent and seasonal NPS employees.

Barricades and Camouflage

Barricades are used to visually camouflage restoration sites and discourage human use. They are made of natural materials that occur at the site, such as rocks, downed logs, and dead branches or brush. Forest litter and decomposing logs and stumps can be scattered over sites to help them blend in with the rest of the area. Excelsior may not work as a barrier; visitors often mistakenly assume it indicates a path on which to walk.

Social Trails

Barricade social trails at each point where the trail intersects a maintained trail, campsite, or viewpoint, and at places where its visibility will entice visitors to use it. Brush and logs work well as physical barriers to discourage use. Rocks piled at the intersection of a social trail and a maintained trail can be effective to discourage use; but rocks scattered in the social trail may be perceived as stepping stones by visitors. Small social trails may be easily concealed scattering litter and brush. This may have to be repeated on large or obvious social trails to provide a physical

impediment until the area revegetates naturally, or until the greenhouse plants have grown large enough to provide camouflage.

Large Sites

Large impacted areas, such as campsites, are challenging to barricade and camouflage. These sites frequently have many access points, and the large denuded areas contrast sharply with surrounding natural vegetation. Block the obvious access points, and scatter rocks, litter, and brush across the site to camouflage it as much as possible. If access to the site is limited, or only part of the site is visible, concentrate the brushing and camouflaging on access points and areas of the site that are most visible.

Signs

Several different signs are used to limit human use at revegetation sites and educate visitors about restoration processes. Signs can be effective tools to educate people. They must be used sparingly so visitors are not overwhelmed, and begin to ignore them. An abundance of signs also clutters the landscape and detract from the visitor's experience. Some of the common signs used in the parks are described below.

Bootprint Sign

North Cascades and Olympic National Parks have successfully used a small wooden stake showing a slash through a bootprint to indicate areas where walking is not allowed (Figure 8-1). Place these bootprint no-walk stakes at junctions where social trails intersect main trails. The small size of this sign does not clutter the natural landscape, but to be effective the meaning of the

bootprint symbol must be understood. Rangers, interpreters, and restoration program displays at campgrounds and visitor centers, need to explain the symbol.

Revegetation Site Sign

Mount Rainier National Park uses small brown waterproof signs to identify revegetation sites (Figure 8-1), and to discourage people from camping or hiking there.

Heather Sign

Olympic National Park has a sign to encourage people to stay off the heather in meadows in the subalpine lake basins (Figure 8-2).

Trail Sign

North Cascades National Park uses a sign that is effective along trails. The sign encourages hikers to continue hiking to the next campsite (identified with mileage on the sign) rather than camping at the revegetation site adjacent to the trail (Figure 8-2). Frequently, the next campsite is closer than many tired hikers realize; the information on the sign gives them the incentive to go on a little further.

Interpretive Signs

Mount Rainier National Park has developed interpretive signs for Paradise Meadows that combine interesting information about natural resources with the problems of resource damage and methods of protection. The format of the text is: THE RESOURCE...THE PROBLEM...THE SOLUTION...(Figures 8-3, 8-4, 8-5).

Figure 8-1. Bootprint and Revegetation Site signs.

Figure 8-2. Heather and Trail signs.

APPENDIX 9A

INTERPRETIVE SIGNS

Wayside Location: "Dance Floor" area at Alta Vista facing toward Golden Gate area.

Title: Alta Vista

Purpose: 1. discuss adaptation factors for surviving in the subalpine
2. promote individual responsibility to protect the subalpine environment

Text:

THE RESOURCE...

From this viewing area you see one of the most intriguing environments found in nature - the SUBALPINE. It is a land of contrast with lush, colorful displays of flowers and the stark whiteness of snow. The average winter snowfall is approximately 630 inches a year. All living organisms which survive here have to adapt to this contrast.

Survival techniques include; 1. hibernation - marmot, 2. camouflage - snowshoe hare, 3. insulating factor of snow-plants, 4. structural adaptations - flexibility of trees.

THE PROBLEM

Life is maintained close to a thin line of margin for survival. Anything that unnaturally disturbs the subalpine environment can have major consequences. From this viewpoint you can also notice erosional scars and a reduction of aesthetic quality of the area caused by walking off constructed trails. The Golden Gate area across the drainage show an example of the problem and a solution. Erosional scars were caused by people cutting across switchbacks instead of staying on the trails. Restoration work was done, consisting of filling/ stabilization, mulching and planting of native vegetation.

THE SOLUTION

Restoration work, such as at Golden Gate, is extremely important, but harmony between nature and us is one of the key factors for the ongoing survival of the subalpine meadows. Just as plants and animals must adapt to their environment, we must do our part by staying on maintained trails and treating the environment with respect. Let us leave the natural cycles to survive without undue influences from man, which after all is one of the main reasons maintaining for a national park like Mount Rainier.

APPENDIX 9B

WAYSIDE LOCATION: GLACIER VISTA AT LARGE OVERLOOK

Title: Glacier Vista

Purpose: 1. explain the major glacier features of the area
2. promote visitor protection of fragile subalpine resources

Text:

THE RESOURCE...

Stretched out before you is the Nisqually Glacier, one of six which originates from the summit of Mount Rainier. It covers 1.8 square miles and is 4 1/2 to 5 miles long. Glaciers are moving bodies of ice and snow which form when more snow accumulates in an area than melts away each year. The slope of the land and weight of the mass of ice/snow causes the glacier to move, carving out the landscape in its path. Movement is illustrated by cracks called crevasses. Crevasses are caused when the middle of the glacier moves faster than its edges, and from irregularities of the glacier terrain it flows over. Listen carefully and you can hear cracking sounds of glacier movement along with ice/snow avalanches and rockfalls.

Text:

THE SOLUTION...

Glaciers will continue to shape the landscape for years to come. Some glaciers, such as the Nisqually, have aided man by providing sources of water for domestic use and indicating trends in climate by patterns of advance or retreat. Meanwhile, our human effect on the environment can be greatly improved by staying on maintained trails and preserving the area for future generations.

Figure 8-3. Examples of interpretive signs used in subalpine habitats at Paradise Meadows, Mount Rainier National Park.

WAYSIDE LOCATION: FELLFIELDS ALONG TRAIL TO CAMP MUIR

Title: Fellfields

Purpose:1. to interpret the fragile nature of Fellfields, especially the importance of retaining the stone layer and related plants
2. to identify problems caused by removing rocks and hiking off the established routes
3. to promote visitor responsibility toward resource preservation

Text:
T-1 (large type)
THE RESOURCE...

T-2 (medium type)
FELLFIELDS ARE ROCK-STREWN AREAS ABOVE TIMBERLINE AND BELOW THE ICE CAP ON MOUNT RAINIER. OF THE 42 PLANT SPECIES THAT GROW IN THIS ARCTIC-LIKE ENVIRONMENT, 20 DO NOT OCCUR BELOW 7,000 FEET ELEVATION AND 30 HAVE GEOGRAPHIC RANGES LIMITED TO THE PACIFIC NORTHWEST.

T-3 (smaller type)
STONES ARE ESSENTIAL. Fellfields are made of a tight mosaic of gravel set between larger stones. This effectively protects the underlying soil particles against frost-heaving and erosion. Stones provide shelter and allow plants to establish next to them by deflecting meltwater, modifying temperature and moisture, and altering wind and snow deposition patterns.

PLANTS ARE ESSENTIAL. The visible part of a fellfield plant is only a small part of its total mass. Roots may extend more than five feet beyond the visible plant to stabilize the upper two to twelve inches of soil. The relationship between alpine plants and their rocky soil is critical to the survival of both components.

T-4 (large type)
THE PROBLEM...

T-5 (medium type)
ANYTHING THAT REMOVES OR ALTERS THE PLACEMENT OF THE STONES OR DAMAGES THE PLANTS WILL DESTROY THE FELLFIELD.

T-6 (small type)
EXCEPT FOR A VERY RARE NATURAL DISASTER, FELLFIELD DESTRUCTION IS CAUSED BY HUMAN ABUSE. Walking off the snow or outside the established route alters soil compaction and scuffs the rock mosaic surface, creating conditions unfit for plant growth. This subtle disturbance too often goes unnoticed. Moving stones to create a tent pad for even a single night's stay destroys their sheltering effect on both gravel mosaic and plants, causing serious, longterm effects. This is a drastic disturbance - a lost resource irretrievable in several lifetimes.

T-7 (large type)
THE SOLUTION... ...YOU AND ME!
T-8 (medium type)
THAT'S RIGHT, WE ARE THE SOLUTION.

T-9 (small type)
We must all resolve to:

- restrict travel through the fellfields to the snow or major, established routes.
- avoid shortcutting or walking off the route onto what might appear to be a mere rocky slope.
- leave rocks and stones of all sizes in place.
- camp only on the snow above the fellfields and not on the fellfields themselves.
- encourage others less considerate than we to join in preserving the fellfields.

Protecting the park resources is everyone's responsibility.

Figure 8-4. Example of an interpretive sign used in a fellfield habitat at Paradise Meadows, Mount Rainier National Park.

APPENDIX 9D

WAYSIDE LOCATION: PANORAMA POINT ALONG THE SKYLINE TRAIL

Title: Heath Meadows

Purpose: 1. to interpret the fragile nature of Heath Meadows on-site
2. to identify the problems created by off-trail travel
3. to promote visitor responsibility toward resource preservation

Text:
T-1 (large type)
THE RESOURCE...

T-2 (medium type)
HEATH MEADOWS ARE OLD PLANT COMMUNITIES GROWING IN PROTECTED SOIL FORMED FROM THE ASH LAYERS OF MANY VOLCANIC ERUPTIONS. HEATHER SPECIES THAT DOMINATE THE MEADOWS HAVE A STABILIZING EFFECT ON THE DELICATE SOIL.

T-3 (small type)
Heath Meadows extend up to 8,000 feet elevation on Mount Rainier, much higher than any other location in the region. These heathers are native to the Pacific Northwest and grow very slowly. They apparently require special conditions to sprout and have not established seedlings in these old meadows in recent times.

T-4 (large type)
THE PROBLEM...

T-5 (medium type)
DECLINE OF THE HEATH MEADOWS ON MOUNT RAINIER IS DIRECTLY RELATED TO HUMAN TRAMPLING. ONCE THE PLANT COVER IS LOST, ANCIENT SOILS QUICKLY ERODE DOWN TO THE STONY PAVEMENT. ONCE A HEATHER IS DAMAGED, ITS DECLINE SEEMS TO CONTINUE TO DEATH.

T-6 (small type)
All off-trail activity, regardless of the season, causes conspicuous erosion and plant damage, but trampling during spring melt causes the most damage when water-saturated soil and snow-covered trails stimulate people to use direct routes across the heathers.

T-7 (large type)
THE SOLUTION...

T-8 (medium type)
HEATH MEADOWS NEED STRICT ADHERENCE TO THE OLD PARK ADMONITION, "STAY ON THE TRAILS". THE HARD FACT IS THAT THE IMPACTS MUST BE STOPPED BEFORE ANY RESTORATION OR NATURAL RECOVERY CAN OCCUR.

T-9 (small type)
We must all resolve to:

- carefully follow the marked route over snow-covered trails.
- not shortcut switchbacks or other use routes that will start or perpetuate erosion
- encourage others less considerate than we to join in preserving the Heath Meadows.

Protecting park resources is everyone's responsibility.

Figure 8-5. Example of an interpretive sign used in a heath meadow habitat at Paradise Meadows, Mount Rainier National Park.

Other Forms of Education

Many impacts occur because increasing numbers of visitors and inappropriate activities overly strain the resiliance of natural resources. Large parties, too many parties for the number of camping sites, fire rings in subalpine areas, and social trails are some of the causes of impacts we are currently restoring. Most people are unaware of the damaging effects of walking through heather meadows or cutting switchbacks, and of the slow recovery of mountainous environments due to the short growing seasons and slow plant growth. When people understand the causes of impacts and the inherent difficulties in restoration work, they can help the restoration process with their actions, and teach others to touch the wilderness gently.

Visitor Center

Visitor centers, or information centers, are often the first and most important contact a park visitor has. Minimum impact information can be given out along with wilderness permits and other information. Photographic displays of restoration work (discussed later in this chapter), as well as pamphlets to take home, provide an opportunity to educate visitors about the causes of impacts and the necessity of restoring National Park lands.

Interpretive Talks

NPS interpreters are a tremendous resource; their evening programs, nature hikes, and casual talks reach a large audience. Work with the interpreters in your park so they know about restoration processes, and the park revegetation program, and share this information with the public.

Roving Interpreters

A sociological study of visitors at Mount Rainier National Park found that, while some signs worked adequately to stop visitor use, the most effective deterrent was a person wearing the NPS uniform (Swearingen and Johnson 1988). Mount Rainier National Park has roving interpreters in some of their high-use areas such as Paradise Meadows to answer questions, explain restoration processes, and to discourage off-trail hiking.

Backcountry Rangers and Trail Crew

Backcountry rangers should plan patrols in areas where restoration efforts are occurring, and in areas that have the potential for impacts. Restoration can not operate independantly. Prevention is much cheaper than repair

Rangers and trail crew frequently are working in natural zones where many revegetation sites are located. With training, they can disseminate information and answer questions about the revegetation program to the many visitors they come in contact with. Some of the most rewarding visitor contacts occur in the backcountry when rangers or trail crew are working on a revegetation site. The lessons they share with visitors at this time often lead to a new understanding of the work necessary to restore damaged landscapes, and the importance of minimum impact recreational use.

Displays

Displays should be developed for campgrounds and visitor centers providing information about the causes of impacts, the work the park is doing to reduce impacts and restore natural areas, and the ways visitors can help the restoration process. It is important to ask for help from the visitor, so

that they feel an essential part of the process, and become empowered to share their knowledge with others.

Photographic displays, showing restoration work give park visitors a different perspective on the fragility of natural ecosystems to human impacts. Before and after photos show the intensity of damage that can occur to the land, while affirming the success of restoration work. Photos of the work in progress show the amount of effort and supplies needed to restore the natural landscape, and the commitment the National Park Service has to being caretakers of our natural lands. This, in turn, encourages visitors to see their own responsibility as caretakers of the land while they are camping and hiking.

Physical Maintenance

Restoration sites should be inspected regularly to ensure barricading and signs are intact and there are no new damages to natural resources. Early in the season worn signs and barricades that may have shifted during the winter should be replaced. At subsequent visits look for new natural or human impacts, do any restoration maintenance needed, and replace missing barricades and signs. The later inspections will indicate whether the site protection and visitor education strategies are adequately protecting the site, or need to be improved.

Chapter 9. Monitoring

Monitoring is the process of assessing changes in vegetation and soil conditions at a site over time. Monitoring methods can be quantitative or qualitative, depending on the type of site and level of information needed. Qualitative monitoring describes and estimates changes in conditions at a restoration site, while quantitative monitoring measures how much conditions have changed over time. Repeated monitoring is essential to determine whether or not restoration work is successful. To document recovery, and plan for future projects, resource managers must learn the recovery rates of different species under various environmental conditions. This is essential for future resource management planning.

Quantitative Monitoring

Quantitative monitoring measures different parameters or variables at the restoration site. Methods are objective to minimize personal bias, and can be repeated with similar results by different people. Examples include measurements of site conditions (ie: length and depth of erosion gully), and measurements of vegetative percent cover, frequency, and density using transects or plots. Quantitative methods are used when specific measurements are needed, such as seedling and transplant survival rates, vegetative growth at an impacted site over time, or comparisons of different mulches on plant growth. Because collecting and analyzing field data for quantitative methods is time-consuming, it is usually done on selected sites, or at intervals of several years, rather than annually at every site.

Qualitative Monitoring

Qualitative monitoring describes and estimates conditions. Examples include descriptions of site conditions (ie: vegetation, mulch, erosion), and photo-monitoring (information in the photographs are estimated, not measured). Because qualitative methods are relatively quick and easy to do in the field, they are useful for annual revegetation site inspections. A standardized data form will ensure that the same conditions are evaluated at each site.

Specific Monitoring Methods

Plots

Plots, or quadrats, are frequently used to sample the vegetation in a plant community. The size and shape of plots varies in relation to the size and shape of the vegetation being sampled. Plots are frequently 0.25-1.0 meters square for small or herbaceous vegetation, and up to 0.1 hectares (0.25 acre) for forest stands.

Mount Rainier National Park uses 0.25 meter square plots to measure transplant survival and growth rates, seeding success, and the effects of different types of mulches on seeding. Plots are permanently established by marking two corners with pencil rod rebar or small pieces of angle iron slightly protruding from the soil. Plots are measured twice during the growing season by placing a grid frame over the plot, photographing the plot, mapping the plants, and recording density and frequency of seedlings (Figure 9-1).

Olympic National Park has established plots in restoration sites to assess revegetation success. Detailed records are kept of the number of plants planted at a site; the plants are recounted in later years to determine survival rates (Figure 7-2, p.).

INITIAL MONITORING

Transplant Monitoring

	A	B	C	D	E	F	G	H	I	J
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										

Plot #:
Date established :
Date monitored:
Location:
Mulch type:
Seeding
spp & quantities:
Comments:
Plant condition:
vigorous,green ___
chlorotic ___
broken stems ___

	A	B	C	D	E	F	G	H	I	J
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										

Plot #:
Date established:
Date monitored:
Location:
Mulch type:
Seeding
spp & quantities:
Comments:
Plant condition:
vigorous,green ___
chlorotic ___
broken stems ___

FOLLOW-UP MONITORING

Area:

Transplant Monitoring

	A	B	C	D	E	F	G	H	I	J
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										

Plot#:
Location:
Date established:
Date monitored:

General Condition Plants:

__ flowering __ vigorous __ chlorotic grazed __ seed heads present

Seedlings:

spp:										
frequency										
density										

Mulch:

type of mulch: Mulch color:

Mulch condition: __ like new __ moderately decomposed __ almost gone

Netting: __ intact __ broken __ raveled

Figure 9-1. Initial and Follow-up Monitoring Forms used for plots at Mount Rainier National Park.

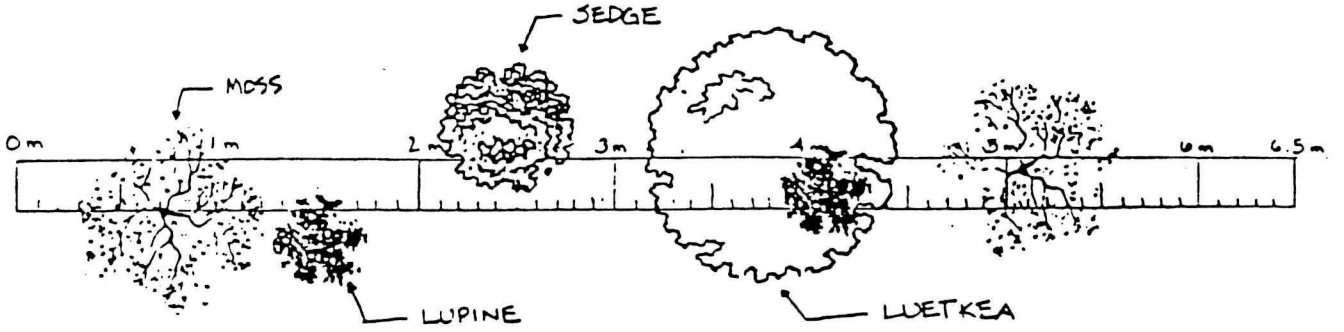
Transects

Transects are quadrats that have been reduced to a single dimension—a line. They are as accurate as traditional plot methods, and can be less time-consuming to carry out.

North Cascades National Park uses line-intercept transects to measure changes in vegetation and bare ground at revegetation sites, and changes in vegetation at cross-country sites in wilderness zones (Figure 9-2). Transects are permanently established using mapped reference points, and are monitored every two to five years.

Line-intercept transect methods: Choose an axis of the site and lay the metric tape across the site along that axis. It can be the longest axis of the site, or a north/south axis, or some other consistent variable. The vegetation will be measured along the edge of the tape with the centimeter marks; if the tape has marks on both edges choose one side, such as the right side when standing at the 0-meter end facing up the length of the transect, and use it consistently. Imagine that there is a sheet of glass along the measuring edge of the tape, extending from the soil up toward the sky. Any plants, rocks, logs, and bare soil that extend through that vertical plane are measured.

Measure the extent of vegetation, bare ground, rock, etc. that occur along the tape edge to the nearest centimeter (Figure 9-2). When plants are above the tape, mentally extend vertical lines down from the edges of the plant clump until they intercept the transect. Plants will also overlap each other, as with the Lupine and *Leutkea* in Figure 9-2; the data on the transect paper will show the overlap. As shown in Figure 9-2, the transect will intercept different parts of each plant. Theoretically, all the variation averages out and the end result is a representative sample of the site. Ignore gaps in the plant clump; they also average out.



LINE-INTERCEPT TRANSECT

Location SULPHIDE RIDGE
Date 7/14/86
Researcher

0 m — 6.50 m
azimuth 16° T

Undisturbed vegetation 0 - 100 , 550 - 650
Disturbed vegetation 100 - 550

moss 30 - 121
490 - 550

Lupinus latifolius 136 - 162
388 - 421

Luetkea pectinata 319 - 439

* NOTE: these numbers are the centimeters of coverage; the data gets entered into the computer in this format, not a mixture of meters and centimeters (as in 4.90).

Figure 9-2. Line-intercept Transect Data Form used at North Cascades National Park.

Record the plant species and the corresponding centimeters "intercepted" by the transect (Figure 9-2). This data will be converted into percent cover for each species along the transect. A separate list of all plant species occurring at the site, even though not part of the transect, will be informative for future monitoring and understanding of site recovery.

When unknown plants are encountered label them Species A, Species B, etc. and continue the transect. Write a description of the plants or, if the species are plentiful, collect a small part of the plant to identify later.

To get a more representative sample of the vegetation, run two or three transects at the site when possible. Small sites (less than 2 meters square) may be adequately covered with one transect. The transects can be parallel, one to three meters apart, or in a V-shape using the same starting point .

During data analysis the percent of the transect occupied by each plant species and bare ground is calculated. From these calculations the percentages of each species and bare ground across the entire site are extrapolated. To calculate percent cover add up the number of centimeters where "Species X" occurs along the transect, divide by the length of the transect (6.5 m = 650 cm in the previous example), then multiply by 100. The resultant number is the percentage of the transect occupied by "Species X". Please note that the vegetation total can be greater than 100% cover because plants may overlap each other, occupying different strata. As in any transect or plot sampling method, the more data collected (ie. the more transects run in this case) the closer to reality the extrapolation is. In the previous example (Figure 9-2) the percentages of each species along the transect are:

moss	23.1%	*Leutkea*	16.9%
bare ground	55.4%	lupine	7.7%

The location of these permanent transects must be documented on a site map (Figure 9-3), discussed below.

Reference points, used to locate the starting point of the transects, must be identified, measured, and mapped if transects are to be located next time the site is monitored (Figure 9-4). Reference points should be objects like trees, boulders, or other distictive features that are not easily moved or removed. The bearings **FROM** the reference points lead **BACK TO** the transect starting point. At least two reference points are needed for a transect so that lines can be projected from the reference points back toward the transect and the point where the lines intersect marks the starting point of the transect. Reference points are not needed for the end of the transect because the starting point and length are known.

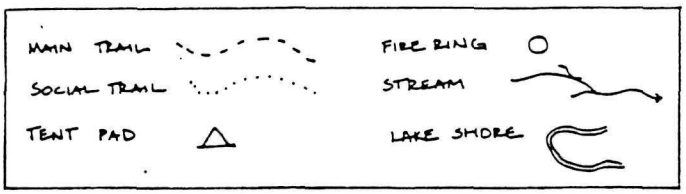
Site Maps and Measurements

Maps are an important visual tool to evaluate conditions at a site. There are many methods of drawing maps and recording site information. The critical factor is to have map-drawing standardized. Maps should be based on true north (generally with the north arrow pointing to the top of the page), drawn to scale, and have the legend, scalebar, topographic and vegetative features, creeks, bare ground, and trails clearly marked.

Circular grid map: Olympic National Park uses a circular grid map (Figure 9-5) to monitor campsites. All identifying features at the site (vegetation, rocks, logs, etc.) are drawn along the eight cardinal directions and in the spaces between. From the maps, the area of bare soil at each site is calculated, enabling resource managers to determine if the campsites are within the standard for the Limits of Acceptable Change (LAC). When campsites are larger than LAC standards, the optimal boundaries of the site are identified, and the area outside the boundary revegetated. Revegetation success is evaluated by periodic monitoring.

LINE-INTERCEPT TRANSECTS

SITE MAP



Location_____

Date_____ Your Name_____

Notes:

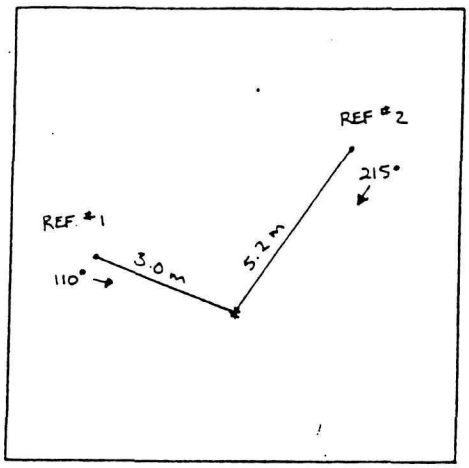
Sketch:

Figure 9-3. Line-intercept Transect Site Map Form used at North Cascades National Park.

REFERENCE POINT FORM

Camp Sulphide Ridge Date_____ Investigators_____

Transect A



REF #1 : Mtn hemlock, 2 m tall, 7 cm dbh, REF. PT. measured from center base of trunk

REF. #2 = Mtn hemlock, 3.5 m tall, 20 cm dbh, blaze on SW side of trunk ~2m above ground. REF. PT. measured from center base of trunk.

Figure 9-4. Reference Points Form used at North Cascades National Park.

Camping Area/Site # _____ Mapper _____ Date __/__/__

16) Bare ground measurements: cm _____ (inches _____) check one

Line	Length	Description
N		
NE		
E		
SE		
S		
SW		
W		
NW		

17) Site Map Cm ___ (Inches ___) Check one. Scale: _____

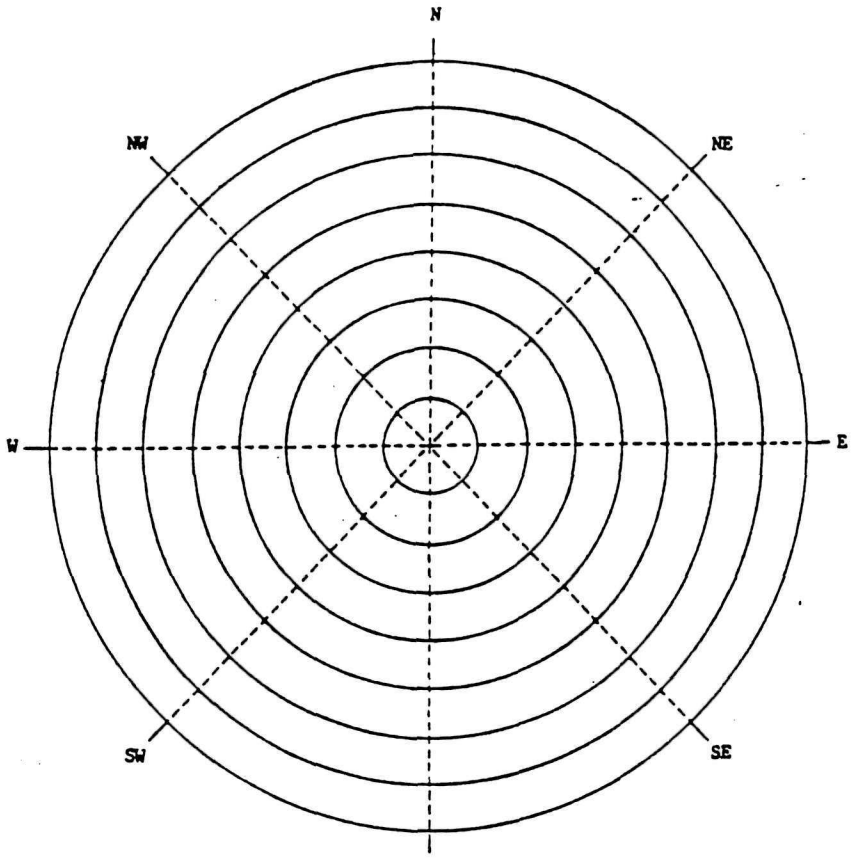


Figure 9-5. Circular Grid Map used at Olympic National Park.

Bare ground measurements: The area surrounding the campsite frequently is unevenly vegetated, with gaps of bare soil between plant clumps. To standardize the methods of calculating bare soil at a campsite, workers at Olympic National Park created the "2-meter rule". According to the 2-meter rule, if two or more plants are encountered in a 1-meter segment and two more plants are in the next 1-meter segment, the official bare ground measurement stops at the first plant encountered along the line. If there are two or more plants in a 1-meter segment, but fewer than two plants in the next 1-meter segment, the measurement continues over the plant clump until the 2-meter rule is encountered.

Restoration Site Evaluation Forms

Restoration site evaluations should assess the condition of four elements: soil, vegetation, mulch, and human use. A standardized form will ensure that the same information is assessed each year. This type of monitoring is usually qualitative, to describe general trends from year to year. Site forms used by Mount Rainier and Olympic National Parks are shown in Figures 9-6 and 9-7. Examples of evaluation forms for social trails are shown in Figures 9-8 and 9-9. The following list shows the information to assess:

Soil: erosion (length, depth, origin)
condition of water bars or check dams

Vegetation: condition of plants (healthy, new growth, stressed, dead)
percent cover of plants on site
phenology (flowering, seeds, seedlings)
exotics present?

Mulch: type of mulch

condition and color of mulch, netting

estimate size of area covered by mulch

Human use: signs of use?

description of impact

reason for use (camping, water, etc.)

Photo-monitoring

Changes in conditions at a site can be documented with photographs. Slides or prints may be used. Color photos may fade slightly over time, but show vegetation and bare soil clearly. It can be difficult to differentiate vegetation, bare soil, and shadows in the longer-lasting black and white photos.

To assess changes in site conditions over time, the photos must be taken from an established location, height, and direction. Photo-monitoring should be done at the same time of year, or the same phenologic stage of the vegetation each year. Several photographs should be taken at each site. Photographs taken at different angles and in different lighting conditions will show the site to better advantage. It is essential to keep an accurate photo log of the location of each roll and exposure in order to compare photos taken over a period of many years (Figure 9-10).

REVEGETATION MONITORING DATA SHEET

Area:_____ Trail:_____

Monitoring date:_____ Observer:_____
Were photos taken?___ office where filed:___ photo number:_____

MULCH
type of mulch used:___ Excelsior ___Hold-gro ___Rollite _____
___Native sedges ___Straw Other:_____
Color: ___bright yellow ___cream/white ___grey
___bright green ___dull green ___brown
Physical condition: estimate of %cover of ground by aspen shavings (excelsior), paper (Hold-gro, Rollite), straw, or native sedges:
___0-5% ___6-25% ___26-50% ___51-75% ___76-100%
Condition of netting: ___complete ___broken, but in place ___raveled
___ >75%gone

PLANTS
Condition: estimate percent which are:
___vigorous species:_____
___stressed species:_____
___dead species:_____

Percent cover of area by plants:
___0-5% ___6-25% ___26-50% ___51-75% ___76-100% _____
Phenologic stage: were any flowers present?___ species:_____
seeds present?___ species:_____
seedlings present?___ could you identify the species? (y or n)___
list species:_____
Exotics: did you notice ___clover ___scotch broom ___red fescue
___other species:_____
Could you notice new growth on plants?(y or n)_____
species:_____
Comments:_____
_____
_____

EROSION

Are bars visible?:(y or n)___ number___ What portion of the bar(s) is visible? ___just the ends ___entire length of the bar
Evidence of erosion:
gullies down the rehabbed area:(y or n)___ depth: ___0-4" ___>4"
undermining of bars (y or n): ___
sheet erosion (y or n): ___

Are repairs needed? ___yes ___no Explain in comments.
Comments:_____
_____
_____

Figure 9-6. Revegetation Monitoring Data Sheet used at Mount Rainier National Park.

Backcountry Resurvey - Initial Survey Addendum Sheet Date ___/___/___
Surveyor _____

Camping Area _____ Site # _____

Site Description _____

Ground Vegetation Species _____

Overstory Species _____

Crown Cover _____ % Average Overstory Height _____ ft. # of Dead Trees _____

Distance of Site to Main Trail _____ ft. # of Adjacent Sites with 200 ft. _____

Site Origin

	Shelter
	Resting Place
	Horse Camp
	Trail Crew
	Fishing
	Scenery
	Climbing
	Official
	Other

Elevation _____ ft

Vegetation Zone

	Alpine
	Subalpine
	Montane
	Lowland
	Coastal

Nearest Water Form

	Lake
	Spring
	Stream
	Pond
	Snow

Soil Texture

	Sandy
	Loam
	Clay

Slope _____ %

Aspect _____

Landform

	Beach Area
	River Valley
	Slope
	Side Stream
	Basin
	Ridge Top
	Other

Horse Trample Areas _____ Horse Forage Present _____ Visible Erosion _____

7/91

Figure 9-7. Initial ~~and Resurvey~~ Campsite Monitoring Forms used at Olympic National Park.

OLYMPIC NATIONAL PARK CAMPSITE RESURVEY SHEET

Subdistrict_____ Drainage_____ _____ Date__/__/__
Camping Area_____ Surveyors' names_____
Site Number_____ Perm Plot?_____ Year of area map used_____

1) Campsite development: FR____ Interior dia._____ Dist. to BW?____
   # Sitting Items_____ (type) _____
   HP?____ Shelter?____ Other (specify)_____
   _____

2) # signs present on site_____ describe_____
   _____

3) Organic material: absent _____ part cover _____ total cover _____

4) Visible erosion: (describe)_____
   _____

5) # trees/% circ. exposed roots within bare area: total # _____
   _____/1-15% _____/16-25% _____/26-50% _____/51-75% _____/76-100%
   # mutilated trees_____ # non-natural stumps_____

6) Stock feces?____ other stock evidence_____
   _____

7) Distance site to water_____ ft. Dist to closest site _____ft.

8) Type toilet: Pit____ Vault____ Other_____
   Full structure_____ Half structure_____ No structure_____
   Privy in view of camp?_____
   Dist to privy _____ft. Dist of privy to water_____ft.
   # of discernible cat hole areas _____

9) # adjacent sites within sight/sound _____ / _____

10) Site within view of main trail? _____

11) Social Trails (#/destination): Total # _____
    _____/water _____/privy ___/catholes _____/main access trail
    _____/view _____/campsites _____/other (describe_____)

12) Photos? _____ Roll # (recorded on photo log sheet)_____

13) Site delineated? ____ Natural border ____ Artificial border ____
    Description of delineation _____

14) Location of center point and permanent markers _____
    _____
    _____

15) Comments _____
    _____
    _____ RS 4/91

Figure 9-8. Resurvey Campsite Monitoring Form used at Olympic National Park.

BASELINE DATA SHEET

PARADISE SOCIAL TRAIL SURVEY

Date:_____ Observers:_____

Elevation (ft):_____ Aspect:_____

Area:_____ Border Trails:_____

Trail Code:_____ Photo Number:_____

Trail Segment	1	2	3	4	5
Slope (deg):	_____	_____	_____	_____	_____
Length (m):	_____	_____	_____	_____	_____
Width (m):	_____	_____	_____	_____	_____
Depth (m):	_____	_____	_____	_____	_____

Dominant plant community bordering the impact site:
____heath-shrub (HS)____lush-herbaceous (LH) ____low-herbaceous (LO)
____dry-grass (DG) ____wet-sedge (WS)
____fellfield (FF) ____% bare

Erosional condition. (check one or more)
____No erosion (i.e. stabilized with plants) ____Erosion evident
____Soil compacted throughout site
Comments:

Estimate % of area which is bare:
____5% ____6-25% ____26-50% ____51-75% ____76-95% ____95-100%
Is loss continuing? ____Y____N
Comments:

Evidence of prior trail or rehab. work.
____Transplants ____Jute netting ____Water bars
____Others

Indicate current trail use:
____Footprints ____Trampled plants
____Observed visitor walking on trail ____Unknown use level
____Other:

Probable cause for the formation of the trail:
____(1) Attain better view ____(2) Shortest distance between two points
____(3) Avoid snowy or wet spots in the established trail
____(4) Get to a shady or rest spot ____(5) Drainage ____(6) Other:

Estimate number & length of water bars needed:

Suggested rehab. strategy and rationale:

Figure 9-8. Baseline Data Sheet for Social Trail Surveys at Paradise Meadows, Mount Rainier National Park.

SOCIAL AND WAY TRAILS INVENTORY AND RATING FORM

Study Area: _____ Survey Date: _____ Wilderness Zone: _____
Observers: _____ Trail Code: _____
Low Elevation: _____ High Elevation: _____ Soil "k" value: _____
Closest Access Trail: _____ # Rock Cairns: _____

Physical Characteristics

Segment Number										
Slope										
Aspect										
Veg. Type										
Tread Length										
Bare Width (in)	0 12-18 25-36	<12 19-24 36+	0 12-18 25-36	<12 19-24 36+	0 12-18 25-36	<12 19-24 36+	0 12-18 25-36	<12 19-24 36+	0 12-18 25-36	<12 19-24 36+
Tread Width (in)	0 12-18 25-36	<12 19-24 36+	0 12-18 25-36	<12 19-24 36+	0 12-18 25-36	<12 19-24 36+	0 12-18 25-36	<12 19-24 36+	0 12-18 25-36	<12 19-24 36+
Tread Depth (in)	<2 >6-12 25-36	2-6 13-24 >36	<2 >6-12 25-36	2-6 13-24 >36	<2 >6-12 25-36	2-6 13-24 >36	<2 >6-12 25-36	2-6 13-24 >36	<2 >6-12 25-36	2-6 13-24 >36
Multiple Treads #										

Vegetation Type Codes: HS (heath shrub), HH (heath lush herbaceous), DG (dry grass), LH (lush herbaceous), WS (wet sedge), LO (low herbaceous, LS (lush streamside), TS (tall shrub), KF (krumholz), FF (fellfield), AM (alpine meadows), FO (subalpine woods, forests)

Administrative Considerations

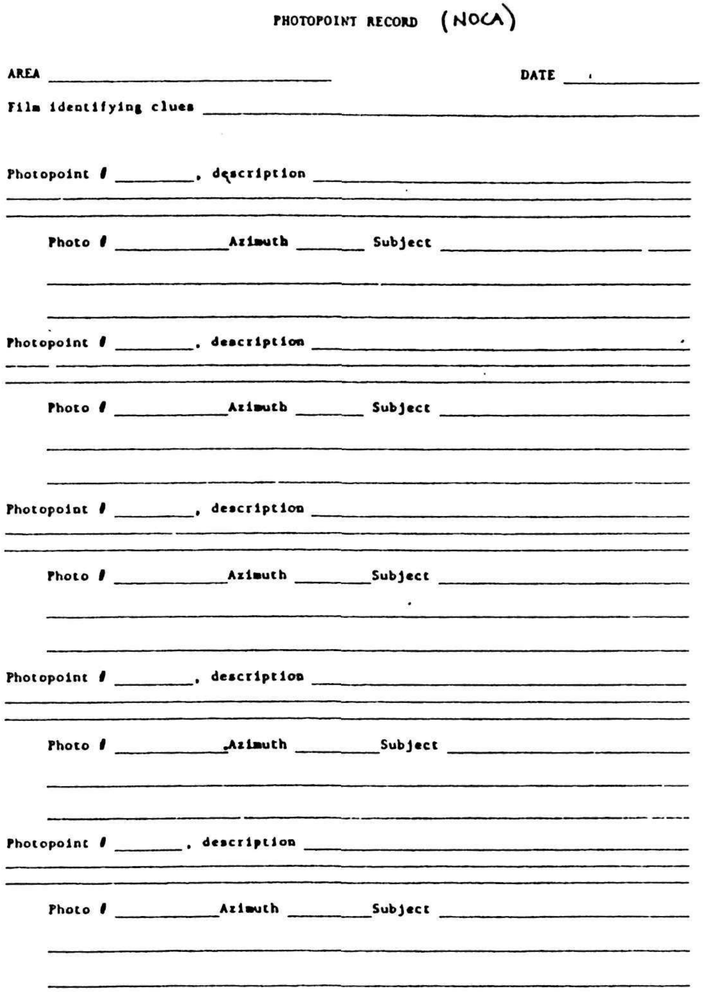
Check all that pertain:
_____ Laws/Regulations which would affect or mandate action at this site
_____ Safety/ Life Threats caused by the impact
describe: _____
_____ Presence of rare or endangered species
list species: _____

Observed Use of the Site

Did you observe visitor use of this site? ___ yes ___ no
estimate number of people _____
describe the time over which you observed this site (number of days, days of week, weather, length of each observation time) _____
_____

Why do you feel this impact developed? _____

Figure 9-9. Social and Way Trails Inventory and Rating Form used at Mount Rainier National Park.



PHOTOPOINT RECORD (NOCA)

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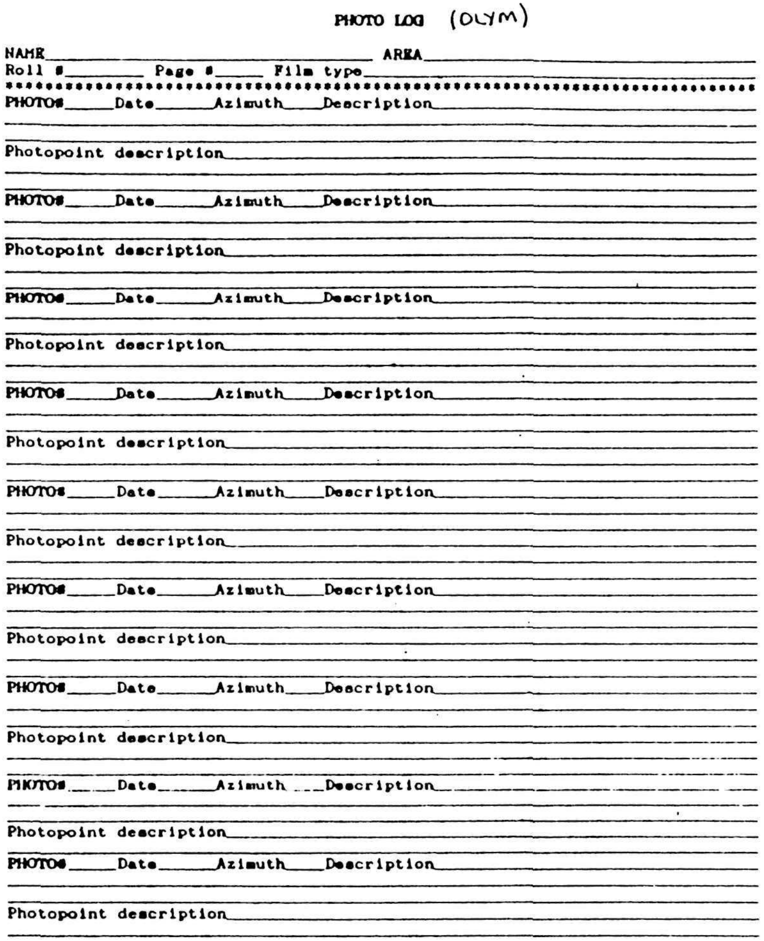

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Photopoint description ____________

Figure 9-10. Photomonitoring Forms used at North Cascades National Park and Olympic National Park.

Computerization

The process of monitoring sites generates a lot of data; computers can store the data in an organized way and keep it easily accessible for analysis.

Olympic National Park uses a data base to store restoration data and calculate the area of bare soil at each campsite from the circular grid map.

North Cascades National Park has a program that calculates percent cover of vegetation and bare ground along the line-intercept transects. Another program, used in monitoring campsites, calculates the area of bare ground and draws a schematic outline of the site. The size and shape of the campsite can be compared between successive years of monitoring to determine if the site is enlarging and, therefore, in need of restoration work.

Mount Rainier National Park uses a data base program (dBASE) to store baseline inventory information, completed revegetation work data, and qualitative post revegetation monitoring data. The program also calculates the restoration rating for the site (Appendix 2), species and supplies needed for restoration work, and produces summary reports of work accomplished and monitoring results.

Chapter 11. Research Needs

As demonstrated by the recovery of many impacted sites, we have learned many successful propagation and revegetation techniques in the last 20 years. There continue to be many challenges ahead. There is much more to learn about the art and science of restoration ecology, specifically in the areas of propagation, genetics, mycorrhizal relationships, and soil treatments. There is also much information to share between practitioners in the field. Many on-going experiments are underway in greenhouses, lowland forests, and along windswept ridges. All of this knowledge must be shared if we are to increase the successful restoration of impacted lands in the National Park Service system.

Before initiating research we need to know what has already been done. Cole and Schreiner compiled an annotated bibliography of impacts and rehabilitation in 1981; an updated bibliography would greatly expand our knowledge and prevent redundant research. Important topics to be addressed include seed storage and viability, propagation of woody species, the effects of mycorrhiza on plant growth, the importance of genetics, and general restoration techniques.

Recent popular works, such as *Helping Nature Heal: An Introduction to Environmental Restoration* (Nilsen 1991) show the extent of work going on throughout the United States and around the world. Many recent scientific compilations, such as *Environmental Restoration* (Berger 1990) have also recently addressed some of the need for more technical research. There is also much to learn from the related fields of wetlands and stream restoration, and the wealth of information gained by the reclamation of mine sites and highways throughout the west. Restoration and Management Notes, a journal published by the Society for Ecological Restoration (University of Wisconsin Arboretum) is the single best source for recent restoration news.

Propagation

The most important need is to perfect methods of direct seeding. It is the most economical means of restoring large backcountry areas. Direct field seeding saves valuable resources, time, and money. Other methods, while effective, are labor intensive and logistically costly. Currently, field seeding experiments have been done with few species. Research into methods which increase the success and application of direct seeding will enable us to restore larger areas more quickly.

Woody Species

Propagation and revegetation techniques for many herbaceous species are very successful but they are only the one part of the natural plant community. Along with herbaceous plants, woody species are an integral component of natural plant communities. For restoration to successfully reestablish native communities we need to learn more about propagating and planting techniques of woody as well as herbaceous species. Species of immediate concern include huckleberries and heathers, as well as larger shrubs and trees.

Genetics

The National Park Service has a mandate to preserve the genetic integrity of native plant communities. Current methods of collecting and propagating seeds and plants are based on genetics, and care is taken to insure genetic integrity within and between plant communities. New information may provide answers to questions about the interrelations of plant genetics with seed dispersal, parent plants, and habitat, allowing us to more accurately, and easily, preserve the genetic integrity of propagated native plants.

Mycorrhiza

While it is well known that mycorrhiza are necessary for plant growth, little is known about interactions of native woody shrubs and herbaceous species with specific mycorrhiza. Most of the

current research focuses on mycorrhizal relationships with timber species; more work needs to be done with herbaceous plants and woody shrubs. Greater understanding of these relationships will lead to successful revegetation, especially with more difficult woody species. This may be particularly important in harsh subalpine conditions.

Exotic Species

Research on how to avoid and eliminate non-native and exotic species from greenhouse propagation and restoration sites will allow slower-growing native species to revegetate without competition from quick growing exotics.

Soil Treatments

Impacted sites frequently have soil problems of erosion, compaction, low nutrient levels, and poor water-holding capacity. More research into soil dynamics will encourage better germination and growth of seeds and plants. Short and long-term monitoring will enable us to see the success of various kinds of transplants in soils treated with a variety of different soil amendments.

Site-Specific Practices

Each piece of land is different and has different needs as a restoration project. Site-specific problems (erosion, soil type, availability of native species, etc.) pose specific challenges. Along with continuing to refine our tools and techniques (waterbars, check dams, slope stability) we must remain alert for what the land has to teach us. Many solutions to local problems can be applied elsewhere with a little experimentation, thought, and care.

The handbook *On-Site Restoration Methods for Mountainous Areas Of The West* (Hanbey 1992) focuses on site-specific restoration techniques, and is a helpful resource.

Monitoring

Monitoring is a crucial step in assessing the success of restoration projects. The short field season is filled with active revegetation work, leaving little time for follow-up monitoring. More information is needed on the short- and long-term survival of transplants, and evaluating recovery rates of particular species and impacted sites.

APPENDIX 1

Restoration Equipment And Supplies: Sources

Aerial Photographs

Aerial Photo Field Office, ASCS USDA, P.O. Box 30010, Salt Lake City, Utah 84130. FTS 588-5856.

Mattock

Smith and Hawken, 25 Corte Madera, Mill Valley, California 94941. (415) 383-2000.

Mulch Companies

American Excelsior Company, 609 South Front Street, Yakima, Washington 98901. (509) 575-5794, 1-800-228-0729.

Erosion Control Systems, Gulf States Paper Corporation, P.O. Box 3199, Tuscaloosa, Alabama 35404. (205) 759-5151.

North American Green, 14649 Highway 41 North, Evansville, Indiana . (812) 867-7266. Local Supplier: Western Utility Supply, P.O. Box 3524, Seattle, Washington 98124. (206) 762-7025.

APPENDIX 2

Restoration Rating Criteria from Mount Rainier National Park

The restoration rating criteria is the sum of two numeric criteria: soil erosion potential and aesthetic or visual quality. The erosion potential parameter is a local adaptation of the Universal Soil Loss Equation (Fritzke and Ripple 1987) and utilizes seven rating factors: plant community type, soil texture, length of impact, depth of impact, width of impact, slope, and percent of impact which is bare ground. Social trails with the highest erosion potential generally receive the highest numeric values. The aesthetic ranking is composed of three parameters: distance of the impact from a maintained trail, visibility of the impact, and accessibility of the impact. Social trails which are visible, in close proximity to a maintained trail, and are recognizable as a trail receive the highest aesthetic ratings.

In addition to numeric ratings, notations as to safety hazards, presence of rare and endemic species, or laws and regulations affecting the site were made. The presence of one or more of these three conditions is noted on the rating sheet, allowing a subjective prioritization of the impact by management.

A. Erosion Potential Parameter

The parameter was developed based on the Universal Loss equation and utilizes seven rating factors. Each of the seven factors is assigned a range of weighted values and the weighted values are used to calculate the soil loss potential for the impacted site.

The seven factors and weighted values are:

1. Community Type

Fellfield (FF)	3.0
Heath Shrub (HS)	3.0
Lush Herbaceous (LH)	2.0
Low Herbaceous (LO)	2.0
Dry Grass (DG)	2.0
Wet Sedge (WS)	1.0

2. Soil "k" Value or Soil Texture

Numbers have been determined by analysis of soil texture values. Soil texture surveys were completed by NRP staff and analysed by Dr. William Ripple, OSU.

Paradise 0.39

3. Length of Impact

10 meters (32.8')	multiply by	1.0
10-30 m (32.8-98.4')	"	2.0
31-60 m	"	4.5
61-100 m	"	7.5
>100 m (>328')	"	10.0

4. Depth of Impact

<0.05 m (0.19')	multiply by	1
0.05-0.1 m	"	2
0.11-0.15 m	"	3
0.16-0.20 m	"	4
0.21-0.25 m	"	5
0.26-0.30 m	"	6
>0.30 m	"	7

5. Width of Impact

<0.20 m	multiply by	1.0
0.21-0.5 m	"	1.5
0.51-1.0 m	"	2.5
1.1 2.0 m	"	5.0
>2.0 m	"	6.0

6. Slope

<5 degrees (<9%)	multiply by	2
5-9 degrees (9-18%)	"	8
10-19 degrees (19-36%)	"	26
20-29 degrees (37-58%)	"	51
30-40 degrees (59-84%)	"	70
>40 degrees (>85%)	"	80

7. Percent Bare Ground

<5%	multiply by	0.011
6-25%	"	0.043
26-50%	"	0.09
51-75%	"	0.15
76-95%	"	0.24
96-100%	"	0.45

The soil erosion potential rating is arrived at by multiplying each weighting factor by one another.

Soil Erosion Potential = Community Type x Soil Texture x Length x Depth x Width x Slope x Percent Bare Ground

B. Aesthetic Parameter

The aesthetic parameter has three factors:

1. Distance of impact from a developed trail

a. Primary trail which intersects a maintained trail 1.05

b. Secondary social/way trail which does not intersect a maintained trail 1.00

c. Tertiary or greater social/way trail 0.95

2. Visibility

a. Easily recognized as a trail or rest area 1.10

b. Difficult to recognize, such as an area with trampled plants but no bare ground 0.95

3. Accessibility

a. Easily accessible from a maintained trail 1.05

b. Separated from the maintained trail by a barrier such as a steep slope, drainage, tree island... 0.95

This parameter was based on the hypothesis that impacts which are very visible and look like trails or rest stops, are close to maintained trails, and are easily accessible will attract more visitor use and degrade more easily than less visible, inaccessible trails. Each of the factors is multiplied by one another to calculate this parameter:

Aesthetic Parameter = Distance x Visibility x Accessibility

The total rating for an impact is Soil Erosion Potential x Aesthetics.

APPENDIX 3

Native Plants for Propagation

A. Seeds

Abies lasiocarpa	(subalpine fir)
Acer circinatum	(vine maple)
Acer macrophyllum	(bigleaf maple)
Agoseris glauca	(agoseris)
Agrostis spp.	(bentgrass)
Anaphalis margaritacea	(pearly-everlasting)
Anemone occidentalis	(western pasqueflower)
Antennaria alpina	(alpine pussy-toes)
Arnica latifolia	(mountain arnica)
Aruncus sylvester	(goatsbeard)
Aster alpigenus	(alpine aster)
Aster foliaceous	(leafy aster)
Aster ledophyllus	(Cascade aster)
Berberis nervosa	(Oregon grape)
Caltha biflora	(white marshmarigold)
Carex illota	(small-headed sedge)
Carex nigricans	(black alpine sedge)
Carex phaeocephala	(dunhead sedge)
Carex spectabilis	(showy sedge)
Circium edule	(edible thistle)
Danthonia intermedia	(timber oatgrass)

Deschampsia atropurpurea	(mountain hairgrass)
Draba aureola	(alpine draba)
Elymus glaucus	(western ryegrass)
Epilobium spp.	(willow-herb)
Erigeron peregrinus	(subalpine daisy)
Erythronium montanum	(avalanche lily)
Festuca idahoensis	(Idaho fescue)
Festuca viridula	(green fescue)
Hieracium gracile	(slender hawkweed)
Juncus mertensianus	(Merten's rush)
Leptarrhena pyrolifolia	(leatherleaf Saxifrage)
Linnaea borealis	(twinflower)
Luetkea pectinata	(partridgefoot)
Lupinus latifolius	(broadleafed lupine)
Luzula campestris	
var. *multiflora*	(field woodrush)
Luzula parviflora	(small-flowered woodrush)
Mimulus lewisii	(pink monkey-flower)
Oemelaria cerasiformis	(Indian plum)
Phleum alpinum	(alpine timothy)
Polygonum newberryi	(Newberry's fleeceflower)
Potentilla flabellifolia	(fan-leaf cinquefoil)
Ribes spp.	(currant)
Rosa spp.	(wild rose)
Rubus parviflorus	(thimbleberry)
Rubus spectabilis	(salmonberry)
Spiraea spp.	(spirea)

Symphoricarpos albus	(snowberry)
Trisetum spicatum	(spike trisetum)
Vaccinium deliciosum	(Cascade blueberry)
Vaccinium parvifolium	(red huckleberry)

B. Cuttings

1. Root cuttings (late winter/early spring)

Gaultheria shallon	(salal)
Populus spp.	(aspen, cottonwood)
Rhus spp.	(sumac)
Robinia spp.	(locust)
Rosa spp.	(wild rose)
Rubus spp.	(blackberry, raspberry, salmonberry)
Symphoricarpos albus	(snowberry)

2. Leaf cuttings

Saxifraga ferruginea var. *macounii*	(rusty saxifrage)
Tolmiea menziesii	(piggy-back plant)

3. Leaf-bud cuttings

Rubus spp.	(blackberry)

Rhododendron macrophyllum

(Pacific rhododendron)

4. Stem cuttings

a. Hardwood (late fall/winter)

Cornus spp.	(dogwood)
Juniperus communis *	(mountain juniper)
Populus spp.	(aspen, cottonwood)
Ribes spp. *	(currant, gooseberry)
*Rosa spp.**	(wild rose)
Rubus spp.	(blackberry, salmonberry, thimbleberry)
Salix spp.	(willow)
Sambucus racemosa	(red elderberry)
*Spiraea spp.**	(spiraea)
Symphoricarpos albus	(snowberry)
Taxus brevifolia	(yew)
Thuja plicata	(western redcedar)
Viburnum spp.	(high-bush cranberry)

* species may root more readily with semi-hardwood cuttings

b. Semi-hardwood (late summer/early fall)

Abies lasiocarpa	(subalpine fir)
Arctostaphyllos columbiana	(bristly manzanita)

Arctostaphyllos uva-ursi	(kinnikinnik)
Cassiope mertensiana	(white mountain heather)
Cornus stolonifera	(red-osier dogwood)
Dryas spp.	(mountain avens)
Gaultheria shallon	(salal)
Juniperus communis	(mountain juniper)
Linnaea borealis	(twinflower)
Luekea pectinata	(partridge foot)
Oemelaria cerasiformis	(Indian plum)
Pachystima myrsinites	(Oregon box)
Penstemon spp.	(beardstongue)
Phlox diffusa	(phlox)
Phyllodoce empetriformis	(pink mountain heather)
Ribes spp.	(currant, gooseberry)
Rosa spp.	(wild rose)
Rubus lasiococcus	(dwarf bramble)
Rubus pedatus	(strawberry bramble)
Spiraea spp.	(spiraea)
Symphoricarpos albus	(snowberry)
Vaccinium spp.	(huckleberry)

c. softwood and herbaceous (spring/early summer)

Linnaea borealis	(twinflower)
Rosa spp.	(wild rose)
Sambucus racemosa	(red elderberry)
Symphoricarpos albus	(snowberry)

C. Division

a. Stolons

Caltha asarifolia	(marsh marigold)
Fragaria spp.	(wild strawberries)
Gualtheria shallon	(salal)
Linnaea borealis	(twinflower)
Potentilla anserina	(cinquefoil)
Rubus lasiococcus	(dwarf bramble)
Rubus pedatus	(strawberry bramble)

b. Rhizomes

Achlys triphylla	(vanilla leaf)
Adenocaulon bicolor	(trail plant)
Anaphalis margaritaceae	(pearly everlasting)
Arnica spp.	(yellow daisies)
Aruncus sylvester	(goatsbeard)
Asarum caudatum	(wild ginger)
Carex spp.	(sedge)
Dicentra formosa	(bleeding heart)
Epilobium angustifolium	(fireweed)
Gaultheria shallon	(salal)
Iris spp.	(wild iris)

Mahonia spp.	(Oregon grape)
Menyanthes trifoliata	(bog buckbean)
Oxalis oregana	(wood sorrel)
Petasites spp.	(coltsfoot)
Streptopus spp.	(twisted stalk)
Thalictrum spp.	(meadow rue)
Valeriana sitchensis	(Sitka valerian)
Vancouveria sitchensis	(inside-out-flower)

c. Root ball

Polystichum munitum	(sword fern)
Symphoricarpos albus	(snowberry)

D. Layering (method/timing)

Abies lasiocarpa *	
Berberis spp.	(simple, mound/spring)
Cornus spp.	(simple/spring, summer)
Gaultheria shallon	
Juniperus spp.	(simple/summer)
Kalmia latifolia	(simple/summer)
*Pachistima myrsinites**	
Rhododendron spp.	(simple, trench/spring, summer)
Ribes spp.	(mound/spring)

Rosa spp.	(simple, tip/spring, summer)
Rubus spp.	(tip/summer)
Salix spp.	(simple/spring)
Sambucus spp.	(simple/spring)
Tsuga spp.	(simple/spring)
Vaccinium spp.	(mound/spring)

*naturally layers in wild, method/timing not known

E. Salvageable Plants

Anaphalis margaritacea	(pearly everlasting)
Athyrium filix-femina	(lady fern)
Blechnum spicant	(deer fern)
Gaultheria shallon	(salal)
Polystichum munitum	(sword fern)
Pseudotsuga menziesii	(Douglas fir)
Tsuga heterophylla	(western hemlock)

mats of shallow-rooted herbs, especially aggresively rhizomatous species:

Festuca spp.	(fescue)
Linnaea borealis	(twinflower)
Oxalis oregana	(Oregon oxalis)
Rubus spp.	(blackberry bramble)
Tiarella trifoliata	(foamflower)

Glossary

Allellopathy. Inhibition of one species by another with the release of noxious or toxic metabolic by-products into the environment.

Baseline. The starting point for data collection at a particular site; baseline data records the condition of the site at a specific point in time before changes (restoration or more impact) have occurred.

Community type. A collection of all plant populations coexisting in a particular habitat. The same species tend to occur together wherever that habitat occurs (sometimes also called an association).

Cutting. A piece of vegetative material taken from a plant for propagation.

Division. Pieces of underground rhizomes or aboveground stolons cut from the parent plant for propagation. The division may or may not have roots and shoots attached.

Ecosystem. The biotic and abiotic components of a particular region or habitat functioning as an ecological unit.

Exotic species. Plants found outside their native habitat; in particular, species that have been introduced intentionally or unintentionally and become established; many are of Eurasian origin.

Genetic integrity. Preservation of the range of genotypes in an area, including the natural proportions of, and interactions between, genotypes.

Genotype. The genetic composition of an individual plant.

Germinate. When seeds begin to grow roots and shoots.

Habitat. The place where a plant or animal lives, generally defined by environmental characteristics such as a stream habitat, or a forest habitat.

Hardwood cutting. A cutting from mature growth of a woody plant in late fall and winter when the plant is dormant.

Layering. A process of inducing roots to form on a stem that is still attached to the parent plant.

Monitor. The process of measuring, recording, and evaluating restoration sites and revegetation work over time.

Perlite. An inert material originating from volcanic glass; used as a soil amendment, absorbs water, longer-lasting in the soil than vermiculite.

Phenology. The seasonal timing of life cycle events in relation to environmental cues.

Photo-monitoring. Recording conditions over time at a site with photographs.

Plot . A frame of variable shape and size used to measure vegetation (also called a quadrat).

Propagate. The process of growing plants using various methods, such as cuttings, divisions, layering, and seeding.

Scarify. To make small scratches on a seed, or to break up and loosen the soil surface.

Semi-hardwood cutting. A cutting taken from semi-mature growth of woody plants in late summer and early fall.

Softwood cutting. A cutting taken from the rapidly growing tip of a woody plant in spring and early summer.

Transect. A plot reduced to the single dimension of a line. When plots are run continuously along the edge of the transect it is called a belt or strip transect.

Turgid. When plant cells are swollen with water.

Vermiculite. An inert material originating from micaceous minerals; used as a soil amendment, lightweight, absorbs water and nutrients, decomposes more quickly in the soil than perlite.

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