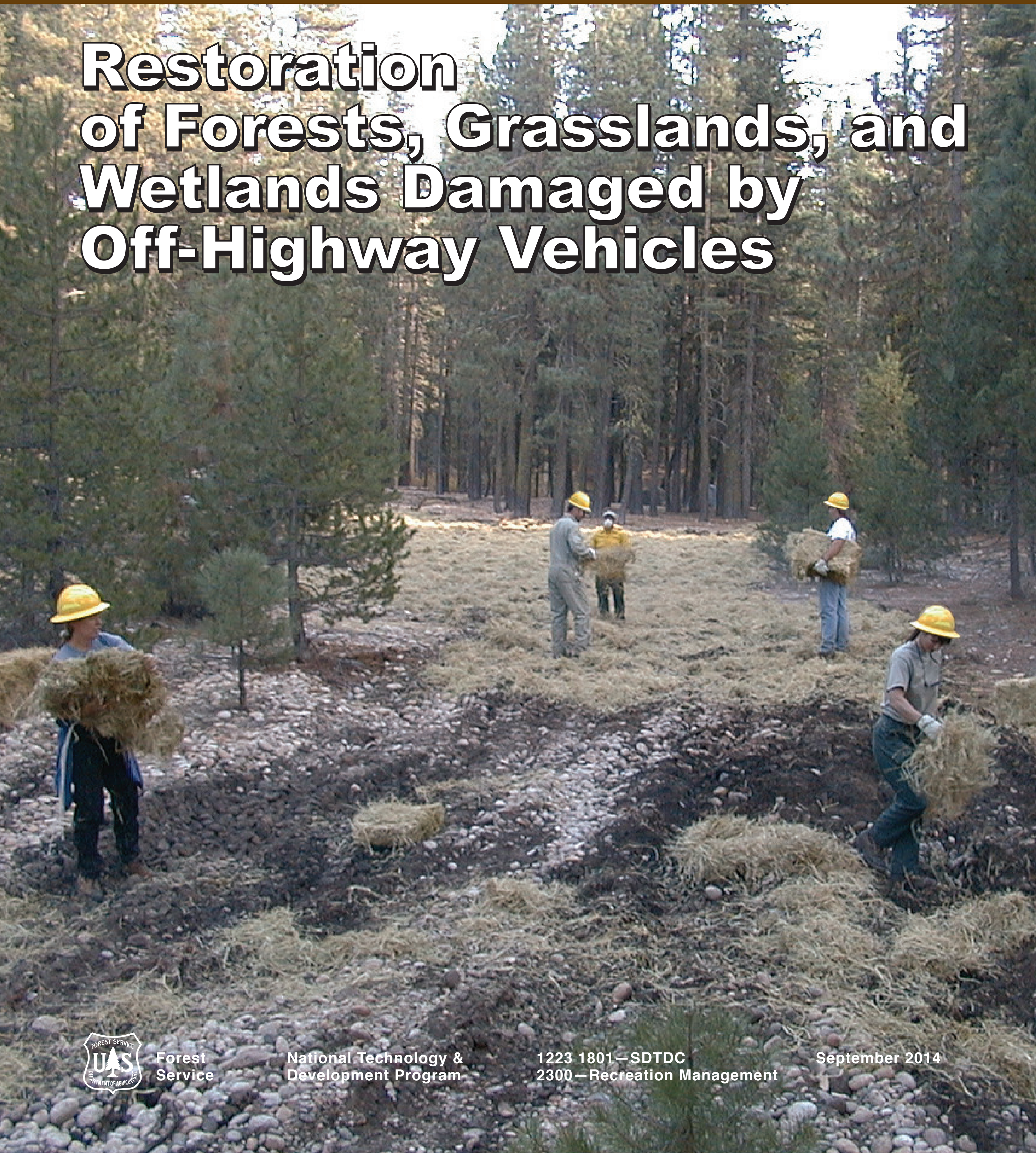
USDA

United States Department of Agriculture

Restoration of Forests, Grasslands, and Wetlands Damaged by Off-Highway Vehicles



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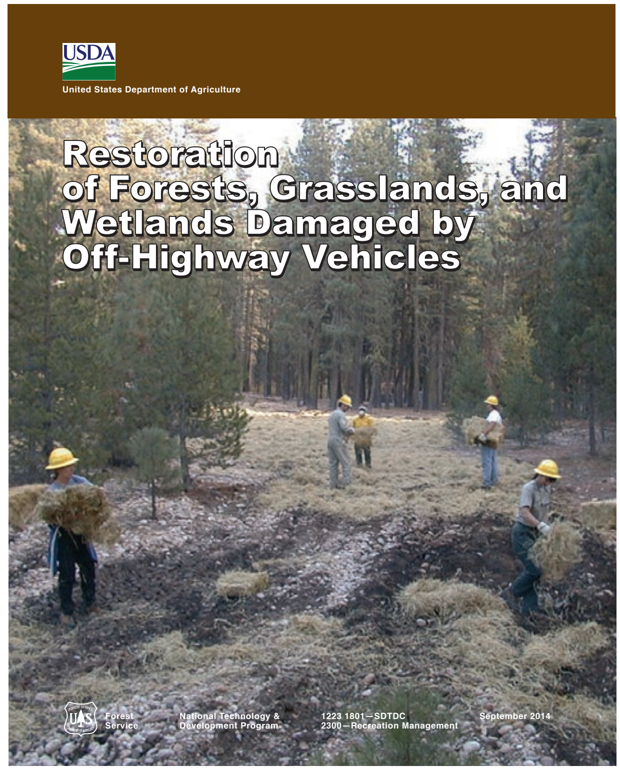

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PURPOSE

The purpose of this guide is to provide information on recognizing damage caused by Off-Highway Vehicles (OHV) to ecosystems. It also provides information on how to restore ecosystems. In this guide damage is defined as the long-term and "acute and obvious changes in an ecosystem" (SER 2004). The desired condition of restoration is the return of a self-sustaining ecosystem.

In this guide, forest, grassland, and wetland ecosystems are commonly referred to as landscapes. The term "trail" refers to a trail or route of any width. The term "area" includes play or concentrated use areas, such as mud holes, hill climbs, and drainage basins, crisscrossed by trails (in some areas called cow trailing). See figure 1.

Figure 1—A sport utility vehicle traveling cross country is stuck in the mud.

This guide was written to be instructional for all readers especially for those associated with trail design, layout, maintenance, and restoration. This includes technicians, recreation planners, landscape architects, engineers, site managers, and resource managers. This guide is divided into three chapters, six appendixes, and a glossary.

Chapter 1, Planning and Signing, is about forming a team, involving the public, and properly signing project sites.

Chapter 2, Forest and Grassland Restoration, is divided into 10 sections. The first section is a discussion of ecological concepts to prepare the reader to identify non-functional landscapes. Restoration methods, the use of mulch and barriers, and planning a project also are discussed.

Chapter 3, Wetlands Restoration, is divided into six sections. This chapter describes the ecological function of wetlands and how their ecosystems are damaged by unmanaged OHV use. It explains how to restore surface and groundwater wetlands. Two case studies are presented.

Chapter 4, Monitoring and Maintenance, is about how to monitor the restoration site for stability, plant growth, litter cover, and human use.

INTRODUCTION

The current Forest Service Strategic Plan FY 2007 – 2012 states that the Forest Service will continue its commitment to reducing threats to the Nation's forests and grasslands. These threats include the introduction and spread of invasive species; the loss of open space and resulting fragmentation of forests and grasslands that impairs ecosystem function; and unmanaged recreation, particularly the unmanaged use of off-highway vehicles. This document is about restoring landscapes damaged by unmanaged off-highway vehicle (OHV) use. See figure 2.

Figure 2—Riders have left the trail and carved a hill climb around a single tree leaving deep ruts and leading to soil erosion.

The "Effects of All Terrain Vehicles on Forested Lands and Grasslands" study supports the premise that unmanaged OHV use is a threat to wildlands. The study concludes:

- All Terrain Vehicle (ATV) traffic can adversely affect natural resources.
- Effects are considered adverse when the natural resources (vegetation, soil, water, and air) have been reduced or changed in a manner that prevents them from maintaining and performing their ecological functions.
- Ramifications of the effects are manifested in the removal or destruction of vegetation, including forest-floor litter, the exposure and destruction of plant-root networks, the exposure of bare soil, soil erosion, and dust migration as a result of bare-soil exposure (Meadows 2008). See figure 3.

Figure 3—Measuring the depth of soil displacement after only 600 ATV passes at a controlled speed. Vegetation is gone, roots are exposed, and the soil is compacted.

Results from high-intensity rainfall simulation tests concluded that soils freshly disturbed as a result of ATV traffic produced on average 10 times more sediment than undisturbed soils (Meadows 2008). Another study done in the Mojave Desert had similar findings (Adams 1982). Numerous studies show that OHV use damages all forms of vegetation. “Vehicles crush, trample and break plants; damage germinating seeds; reduce vegetative cover; and can destroy crucial root systems. These impacts, particularly the stripping of vegetation from the ground, exacerbate other problems, which include soil erosion and sedimentation” (Webb 1982, (Lathrop 1983, Ahlstrand and Racine 1993).

The 2005 Travel Management; Designated Routes and Areas for Motor Vehicle Use; Final Rule (Rule) requires all national forests and grasslands to designate those roads, trails, and areas that are open to motor vehicle use. The Rule effectively eliminates cross-country OHV travel and the establishment and use of unauthorized travel routes. The Rule was adopted to decrease user conflicts, minimize environmental impacts, and to sustain natural resource values (USDA 2005). See figures 4 and 5.

Figure 4—Four-wheel-drive vehicle tracks through a meadow. Wheels have flattened vegetation, and tracks interfere with natural water movement.

Figure 5—Unmanaged OHV use leads to the creation of this unauthorized trail that cuts through an area with a high water table. The consequences of this are the exposure of the subsurface waterflow resulting in mud, exposed roots, and elimination of vegetation.

CHAPTER 1 - PLANNING AND SIGNING

Planning a Restoration Project

This section discusses planning and implementing a successful project. The goal is to restore the area to the adjacent or surrounding landscape so that it becomes part of a functioning ecosystem. A side benefit is an improved recreational experience through restoration of visual quality.

The best restoration efforts attempt to restore the project area's ecology by mimicking the soil density, hydrologic system, and vegetation of the surrounding landscape. As the restoration area vegetation grows back into the surrounding landscape this vegetation becomes part of and meshes with it. Do this by protecting the area from soil erosion, restoring soil productivity, restoring drainage patterns (hydrologic function), and restoring vegetation.

Treat the entire unmanaged off highway vehicle (OHV) area. If the landscape is affected only minimally, then simply closing the unauthorized trail is the treatment. Area grade and damage may dictate the treatment type, which may vary along the length and width of the unmanaged OHV area. Generally, the beginning of the unmanaged OHV area receives greater or denser treatment than a section of an area not visible to the public. This disguises the unmanaged OHV area and unauthorized trail. It also helps to bring costs down. This does not mean that nonvisible trail sections are left untreated.

Define the Problem

Define the problem by taking an area perspective. Define the cause(s) of the problem. This leads to knowing the extent of the damage caused by the unmanaged OHV area's existence and use and which disciplines need to be on the interdisciplinary team.

A Team Approach

Form an interdisciplinary team and use members' expertise to refine the problem and to formulate a well thought-out plan or approach to resolve the problem. Involve professionals, such as biologists, botanists, ecologists, engineers, hydrologists, landscape architects, recreation planners, and soil scientists. These persons have a variety of skill sets and bring useful and different perspectives to a project.

Describe an area's proper functioning condition. For example, state the degree to which natural runoff occurs, the density and type of litter and duff, and the different age classes of the native vegetation (USDI 1999). Check an area's Recreation Opportunity Spectrum classification and to see if the area is a congressionally designated area, such as National Historic Landmarks, National Volcanic Monuments, National Historic Scenic Areas, and so on.

Describe an area's specific desired condition or management objectives, which at a minimum must support the proper functioning condition of the area (USDI 1998). The desired condition can include physical, biological, and cultural/social conditions (USDA 1995) and is descriptive and includes the vegetation type and function of the landscape surrounding the restoration area. For example, the desired condition for this area is 90 percent sedge groundcover 1 year after seeding, and 70 percent coverage in native hardwood seedlings 4 years after transplantation. List the Latin names for all plants.

Understand the Problem and Determine Project Scope

Using the desired condition as a guide, plan to return the unmanaged OHV area to its native state, or at least to a self-sustaining landscape. For example, restoration may redirect and dissipate the source of the concentrated flow; reshape the area to join its contours; and spread duff, seed, and plant native vegetation to match the adjacent landscape. The same is true for restoring a firebreak with an unauthorized trail etched into it. Restore the area by redirecting and dissipating the source of the concentrated flow.

Determine:

- The extent of the damage, such as depth and length of a cut, if there is soil compaction, amount of soil loss, and the amount and types of vegetation lost.

- The source of concentrated flow.

- The size of the unmanaged OHV area that needs restoration, which is likely greater than just the OHV tracks.

- The location of system trails in the area. Having system trails nearby necessitates greater attention to signing and regulation to keep riders off the unmanaged OHV area because the system trails may be open to riding during project work.

Create a restoration plan for the whole area and plan to restore braided unauthorized trails as one restoration site, not as individual unauthorized OHV trails. See figure 6. Be sure to include monitoring and first-year maintenance costs as part of the project cost so that successes and failures are tracked and to increase the likelihood that any repairs are made.

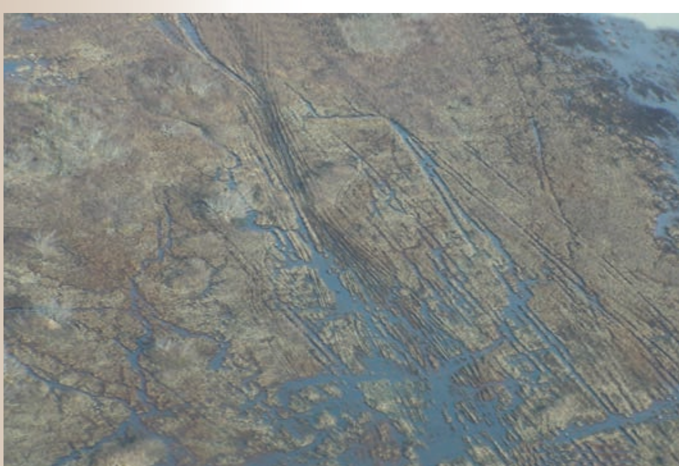


Figure 6—An aerial view of braided unauthorized OHV trails (straight lines). Treat the whole area.

Involve the Public

In the early planning stages, hold public meetings with constituents, including OHV clubs, to explain the purpose and goals of the project and to ask for input. Discuss project strategy, tools and methods, and monitoring. Use the meetings to gain support for restoration. When people are included, they are more likely to feel ownership in the restoration project and are more likely to volunteer.

Create a volunteer program with local users. The San Bernardino National Forest's OHV volunteers adopt-a-trail and peer-to-peer programs are very effective (Santha 2007). After several hours of training, the peer-to-peer volunteers are out on the trails talking to users about safety, stewardship, and respect for public lands. This includes information about Tread Lightly!® See figure 7.

Figure 7—A sign on trail acknowledging partnership with San Diego Adventure Riders.

Signing

Keeping riders off of restoration project areas is critical for a project's success and is one of the biggest challenges in restoration. Install explanatory signs as the restoration begins. Managers report that users are more likely to stay off an area when the restoration activities or efforts are visible and when it is signed and a barrier is in place.

There are two types of signs: larger signs found at trailheads or staging areas that give the reader indepth information, and smaller, succinct signs found at the restoration area. A detailed sign is appropriate at a larger area where the public can see that restoration work has taken place and that the fees they have paid are being used at the area. Include this information:

- State the name of the area.
- Show a map of the area and project area.
- State the name of the project.
- Describe the purpose of the project.
- Outline what behaviors are expected of the visitors.
- Describe how a visitor can help and participate. See figure 8.

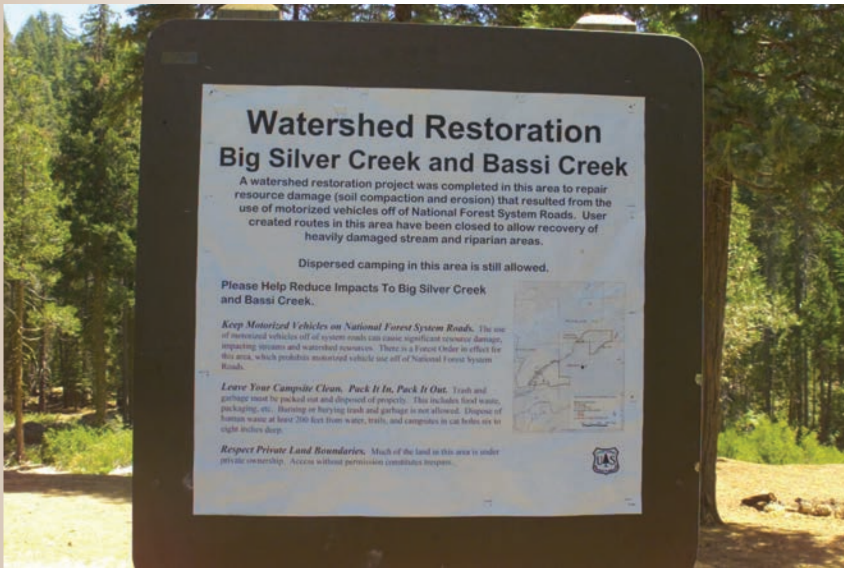


Figure 8—This general area and trailhead sign informs visitors about the watershed. It states why restoration work was needed (because of erosion from unauthorized trails); what was done; what activities are allowed; and the expected user behaviors, such as Pack It In, Pack It Out. It displays a map so there is no mistake about what area is being restored. See appendix B for the text of this sign.

A smaller sign lets the visitor know that restoration is taking place. For example, "XYZ landscape restoration is underway. Please stay on the trail, thanks for helping." This is sufficient in many cases. Do not post long explanations in small font sizes. Post small signs to the side of the unauthorized trail not in the middle of it. The sign is not a barrier. It is more likely to be left in place on the side. See figures 9 and 10.

Figure 9—Welded-wire fence sporting a succinct sign. (Sign text reads "This area is CLOSED. Please stay out of this area so it can recover and return to a natural condition. Thank you." It includes the forest order number.)

Figure 10—This sign, on letter-sized paper, is generally not appropriate because it is too small, has too much information, and one has to bend over to read it.

Vandalism is often a problem. Richard Tull, Cleveland National Forest, found that putting American flag stickers on his signs prevented them from being destroyed. This is supported by similar experiences within the Bureau of Land Management, which uses a flag sticker at the top of Carsonite® stake-signs (GAO 2009). See figure 11.

Figure 11—Note the American flag.

CHAPTER 2 - FOREST AND GRASSLAND RESTORATION

Understanding Ecology

This section discusses how functional components work together and what happens when these components are damaged. One must understand these relationships in order to have the greatest chance of success in restoring the function, structure, and interdependence of ecosystems.

Ecological restoration assists in the recovery of a degraded, damaged, or destroyed ecosystem (SER 2004). Ecosystems are intricate, and understanding ecosystems will help the reader determine what damage has occurred to an area and how to restore its landscape. Restoration focuses on reestablishing composition, structure, and ecological processes to sustain the resilience of terrestrial and aquatic ecosystems.

“Eco-Region-Based Design for Sustainability” defines an ecosystem as “an area of any size with an association of physical and biological components so organized that a change in one component will bring about a change in the other components and in the operation of the whole system” (Bailey 2000). Components (soil, hydrology, vegetation) are an ecosystem’s structure and the interactions between these components are its function(s); they are interdependent.

Ecosystems are not only vegetation at ground level. The vertical influence of an ecosystem extends from underground, below the dry-season water table up through the canopy of mature vegetation. In certain settings, grass may be the native mature vegetation, in others it may be cacti or bald cypress. See figure 12.

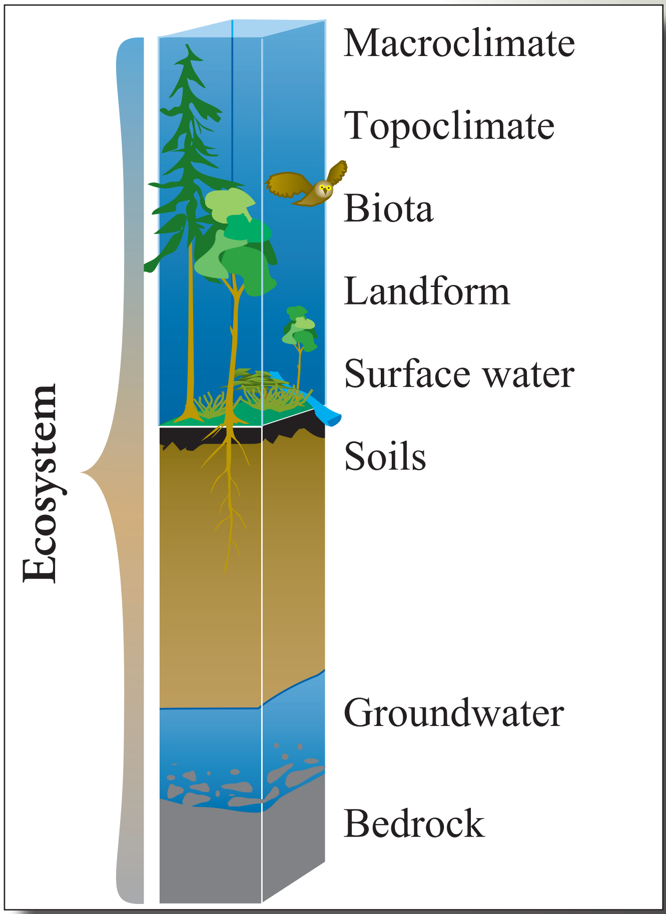


Figure 12—Ecosystem in vertical perspective. (Photo courtesy of Robert G. Bailey 2002, OR)

Soil, hydrology, vegetation, and habitat are discussed here as functional components of ecosystems. These topics were chosen because they are visibly affected by unmanaged off-highway vehicle (OHV) use. Riparian and desert ecosystems are most sensitive to the effects of unmanaged OHV use.

Soil

Soil supports—and is the basis for—all other ecological components. All plant life and most living things are dependent on healthy soil. Soil is a mixture of mineral and organic material that is the result of climate, vegetation, and soil organisms acting on parent material (rock) over time. Soils range from sand to silt to clay, and each has specific biological, physical, and chemical balances that support plant life. The physical, chemical, and biological components of soil support the productive capacity of the land, its ecological processes, and hydrological watershed function. When one component changes, the other components are affected. See figure 13.

Figure 13—Photo shows many soil layers. Topsoil is generally darker, more friable, and supports more roots than subsoil (Steinfeld 2007).

A proper mixture of air (gas component) and water (chemical components) in the soil is essential for plant growth. Typical upland soils are approximately half solid matter (mineral particles and organic matter), and half pore space. Under optimum conditions about half of the pores are occupied by water and the other half by air. The soil's permeability varies by soil type; this ability to absorb water and allow gas exchange is crucial for a healthy soil (Keefer 2000). See figure 14.

Figure 14—Undisturbed soil. Note the vegetation, leaf litter, topsoil, roots, pore space, and mineral soil.

Small pores (physical component) influence water-holding capacity, while large pores facilitate water and air movement and root penetration (Steinfeld 2007). Large pores are created by the biological activity of soil organisms. "The arrangement of large pores is called soil structure. It is qualitatively observed as cracks, channels, aggregates, crumbs, and clods in soils, and described by alternative terms such as friability and tilth" show up as a granular or crumb-like soil structure, such as cracks, macropores, channels, aggregates, and crumbs, and can be described as friability and tilth (Steinfeld 2007).

Although organic matter comprises a relatively small portion of the soil (1 to 8 percent in upland soils), it is very important in supporting soil processes. Soil organic matter consists of two fractions: an active or labile fraction comprised of living microorganisms and macroinvertebrates and recently dead soil organisms and plant roots, and a stable or recalcitrant fraction comprised of humic acids and complexes of humic and mineral matter. It is the recalcitrant soil organic matter that creates habitat for soil organisms and maintains soil structure long term. Soil organisms and their interactions with plant roots maintain the structure of topsoil, which is so important for water infiltration and gas exchange.

Healthy soils contain a variety of organisms, including bacteria, fungi, protozoa, nematodes, arthropods, earthworms, and burrowing animals. For example, soil fungi are divided into three functional groups; one is mycorrhizae or mycorrhizal fungus. Mycorrhizal fungi have a symbiotic relationship with plant roots, living in or on them. The structures and excretions of fungi and plant roots bind the soil to plants (Claassen 2006). This binding enhances soil structure providing “avenues” that facilitate moisture movement through the soil. The fungi take carbon and energy from the plant and in exchange make phosphorus soluble for plant uptake while extracting other nutrients, such as nitrogen, to the plant (Tugel 2000; Therrell 2006). See figures 15 and 16.

There is evidence that nonnative weedy or naturalized plant species adapt to soils faster where there is an absence of the mycorrhizal fungi that natives need for growth (Vogelsang 2004; Claassen 2006).

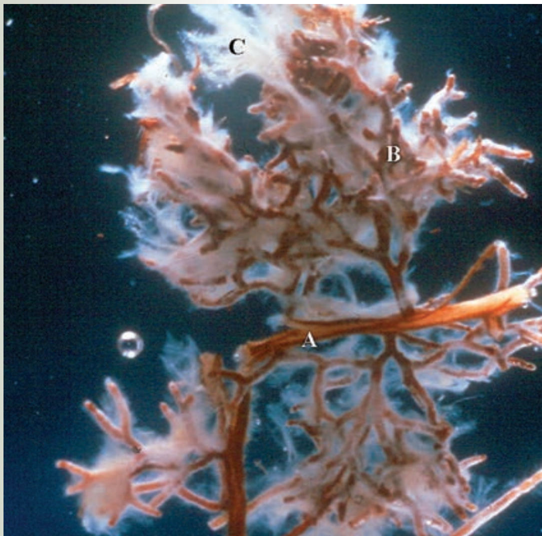


Figure 15—Mycorrhizal fungi can greatly increase the surface area of the root system. The ectomycorrhizal (outside the cells of the host root) fungi attached to the pine root system (A) comprise most of the absorptive surface shown in this photograph. The mycorrhizae include brown branched structures (B) and white hyphae or filaments (C). (Photo courtesy of Mike Amaranthus, Mycorrizal Applications.)

Figure 16—Endomycorrhizal (goes into the host root cell) fungi associated with other vascular plants, including grasses and forbs, link root cells to soil particles. In this photo, sand grains are bound to a root by hyphae from endophytes (fungi similar to mycorrhizae) and by polysaccharides secreted by the plant and the fungi. (Photo courtesy of Jerry Barrow, USDA-Agriculture Research Service Journal Experimental Range, Las Cruces, NM.)

Much of the following, to page 21, was taken from chapter 2 of “Stream Corridor Restoration: Principles, Procedures, and Practices” (Federal Interagency Stream Restoration Working Group [FISRWG] 2001).

Hydrologic Processes Across Landscapes

The hydrologic cycle describes the continuum of the transfer of water from precipitation to surface water and ground water, to storage and runoff, and to the eventual return to the atmosphere by transpiration and evaporation. Precipitation returns water to the earth’s surface. Precipitation is generally thought of as rainfall or storm events. However, snowmelt is also an important source of water, especially for rivers that originate in high mountain areas and for continental regions that experience seasonal cycles of snowfall and snowmelt... Precipitation reaching the earth can return to the atmosphere; move into the soil; or run off the earth's surface into streams, lakes, wetlands, or other water bodies. All three pathways play a role in determining how water moves into, across, [landscapes]. See figure 17.

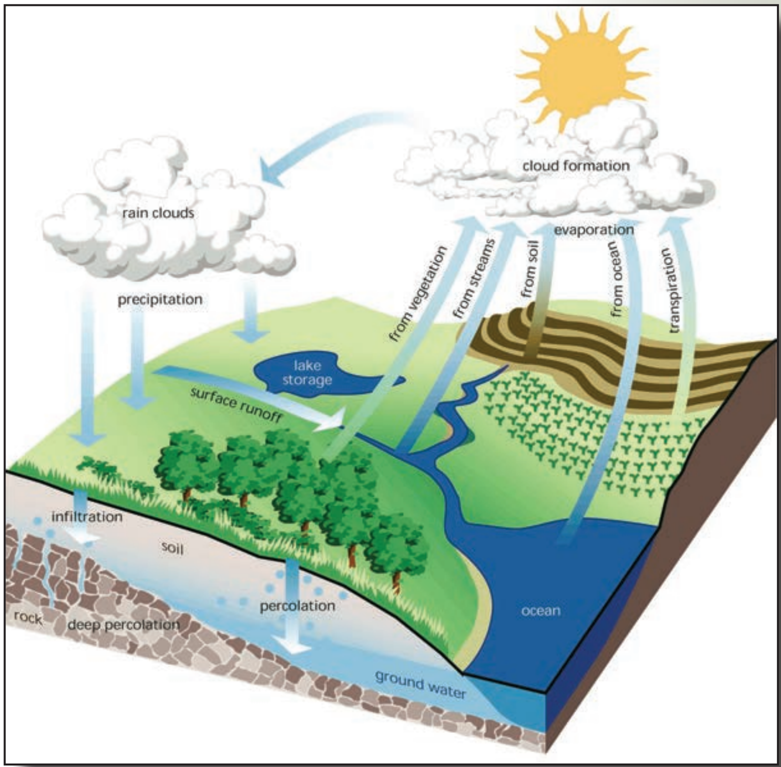


Figure 17—The hydrologic cycle. The transfer of water from precipitation to surface water and ground water, to storage and runoff, and eventually back into the atmosphere is an ongoing cycle (FISRWG 2001).

[The key functions in the hydrologic cycle most affected by unmanaged OHV use are interception, infiltration, soil moisture storage, and runoff.]

Interception

More than two-thirds of the precipitation falling over the United States evaporates to the atmosphere rather than being discharged as streamflow. This "short-circuiting" of the hydrologic cycle occurs because of interception and evapotranspiration.

A portion of precipitation never reaches the ground because it is intercepted by vegetation and other natural and constructed surfaces. The amount of water intercepted in this manner is determined by the amount of interception storage available on the aboveground surfaces. In vegetated areas, storage is a function of plant type and the form and density of leaves, branches, and stems. [Blades of grass are just as important to this function as tree canopies.]

Rainfall at the beginning of a storm initially fills interception storage sites in the canopy. As the storm continues, water held in these storage sites is displaced. The displaced water drops to the next lower layer of branches and limbs and fills storage sites there. This process is repeated until displaced water reaches the lowest layer, the leaf litter. At this point, water displaced off the leaf litter either infiltrates the soil or moves downslope as surface runoff. See figure 18.

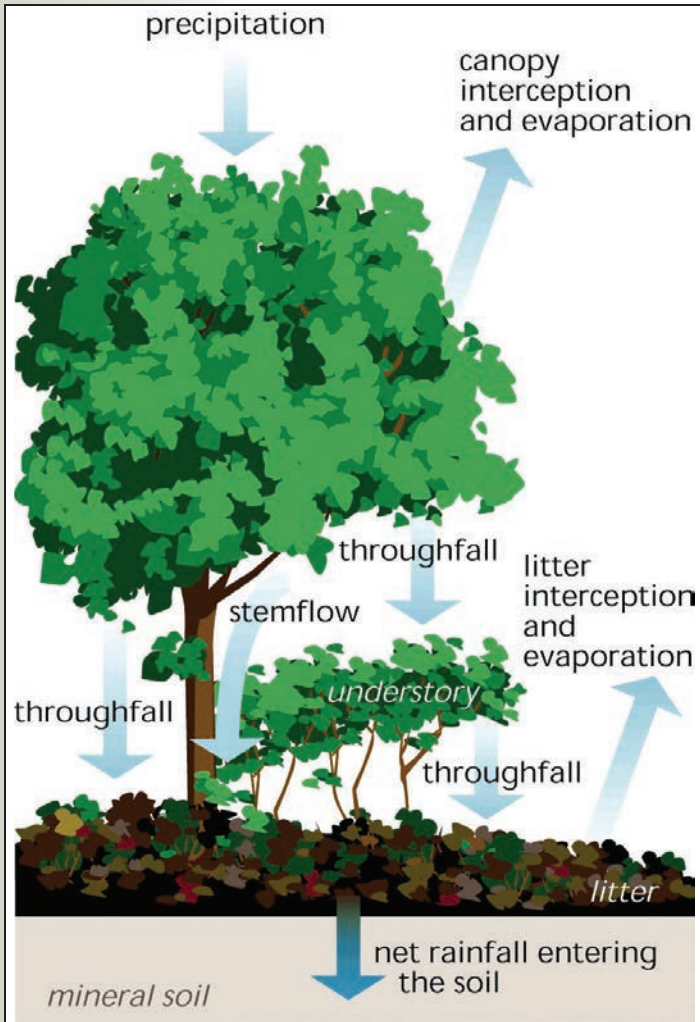


Figure 18—Typical pathways for forest rainfall. A portion of precipitation never reaches the ground because it is intercepted by vegetation and other surfaces (FISRWG 2001).

Antecedent conditions, such as [soil] moisture still held in place from previous storms, affect the ability to intercept and store additional water. Evaporation will eventually remove water residing in interception sites. How fast this process occurs depends on climatic conditions that affect the evaporation rate.

Interception is usually insignificant in areas with little or no vegetation. Bare soil or rock has some small impermeable depressions that function as interception storage sites, but typically most of the precipitation either infiltrates the soil or moves downslope as surface runoff. In areas of frozen soil, interception storage sites are typically filled with frozen water. Consequently, additional rainfall is rapidly transformed into surface runoff.

Infiltration

Precipitation that is not intercepted or flowing as surface runoff moves into the soil... Close examination of the soil surface reveals millions of particles of sand, silt, and clay separated by channels of different sizes. These macropores include cracks, "pipes" left by decayed roots and wormholes, and pore spaces between lumps and particles of soil.

Water is drawn into the soil pores by gravity and capillary action. Gravity is the dominant force for water moving into the largest openings, such as worm or root holes. Capillary action is the dominant force for water moving into soils with fine pores. The size and density of these pore openings determine the water's rate of entry into the soil. Porosity is the term used to describe the percentage of the total soil volume taken up by spaces between soil particles. When all those spaces are filled with water, the soil is said to be saturated. See figure 19.

Soil characteristics, such as texture and tilth are key factors in determining porosity. Coarse-textured sandy soils and soils with loose aggregates held together by organic matter or small amounts of clay have large pores and, thus, high porosity. Soils that are tightly packed or clayey have low porosity.

Infiltration is the term used to describe the movement of water into soil pores. The infiltration rate is the amount of water that soaks into soil over a given length of time. The maximum rate that water infiltrates a soil is known as the soil's infiltration capacity. If rainfall intensity is less than infiltration capacity, water infiltrates the soil at a rate equal to the rate of rainfall. If the rainfall rate exceeds the infiltration capacity, the excess water either is detained in small depressions on the soil surface or travels downslope as surface runoff.

Areas with natural vegetative cover, leaf litter, and duff usually have high infiltration rates. These features protect the surface soil pore spaces from being plugged by fine soil particles created by raindrop splash. They also provide habitat for worms and other burrowing organisms and provide organic matter that helps bind fine soil particles together. Both of these processes increase porosity and the infiltration rate.

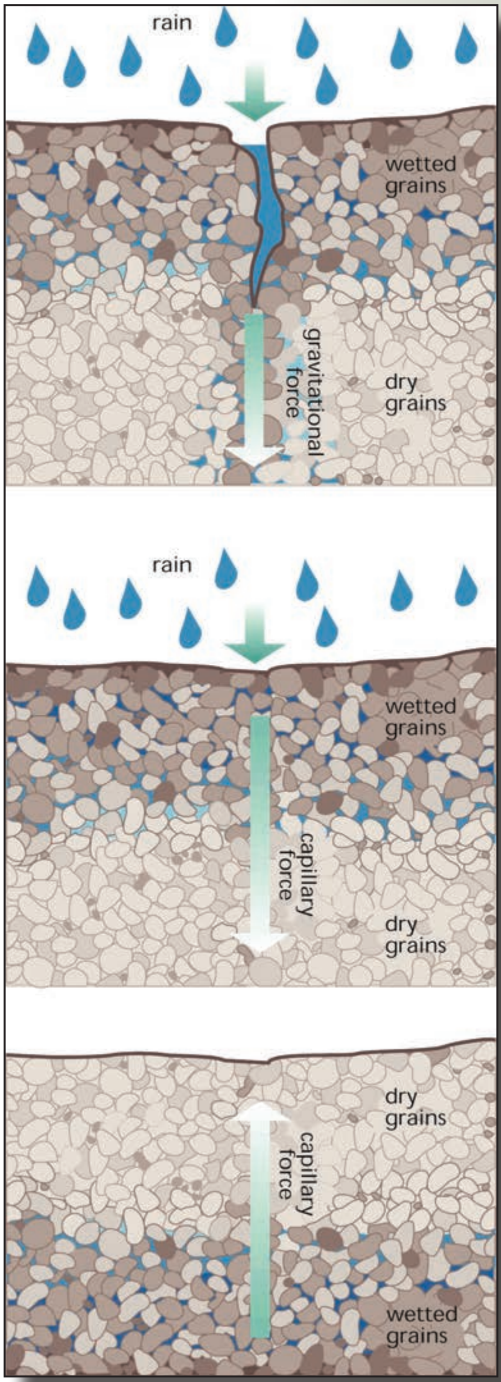


Figure 19—Soil profile. Water is drawn into the pores in soil by gravity and capillary action (FISRWG 2001).

Soil Moisture

After a storm passes, water drains out of upper soils due to gravity. The soil remains moist, however, because some amount of water remains tightly held in fine pores and around particles by surface tension. This condition, field capacity, varies with soil texture. Soil moisture is most important in the context of evapotranspiration. Terrestrial plants depend on water stored in soil. As their roots extract water from progressively finer pores, the moisture content in the soil may fall below the field capacity. If soil moisture is not replenished, the roots eventually reach a point where they cannot create enough suction to extract the tightly held interstitial pore water. The moisture content of the soil at this point, which varies depending on soil characteristics, is called the permanent wilting point because plants can no longer withdraw water from the soil at a rate high enough to keep up with the demands of transpiration, causing the plants to wilt.

Groundwater

The size and quantity of pore openings also determine the movement of water within the soil profile. Gravity causes water to move vertically downward...Capillary forces eventually take over and cause water to move in any direction.

Water will continue to move downward until it reaches an area completely saturated with water, the phreatic zone or zone of saturation. The top of the phreatic zone defines the groundwater table or phreatic surface. Just above the groundwater table is an area called the capillary fringe, so named because the pores in this area are filled with water held by capillary forces. See figure 20.

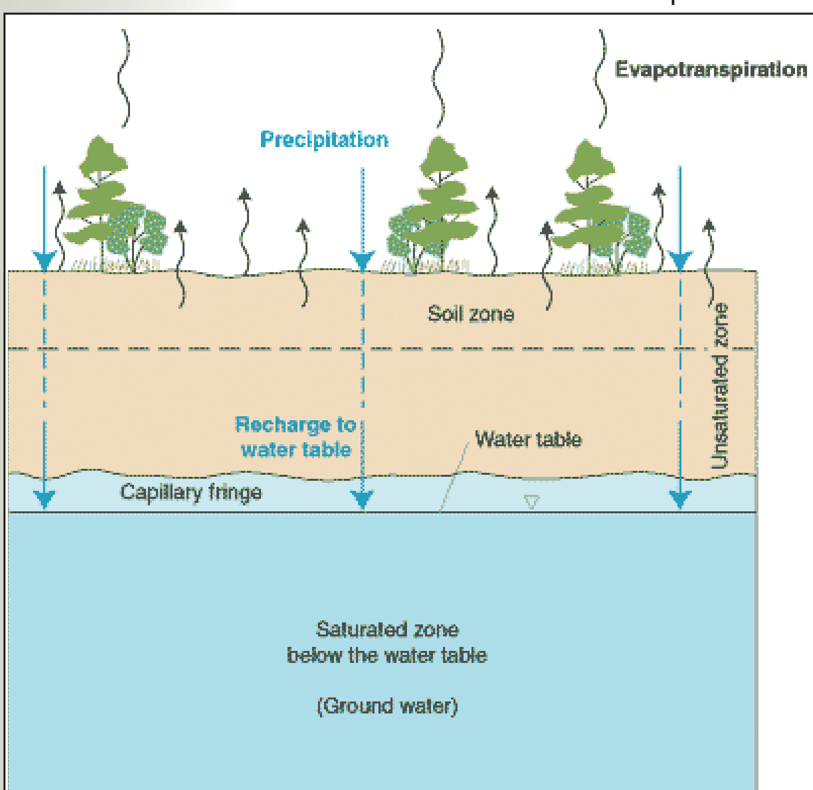


Figure 20—Most of the water absorbed by plants is from the unsaturated zone.

Runoff

When the rate of rainfall or snowmelt exceeds infiltration capacity or when soil moisture storage capacity is full, excess water collects on the soil surface in small depressions (depression storage). [Amphibians, such as frogs and salamanders, and crawfish lay their eggs in these depressions.] Stored water eventually returns to the atmosphere through evaporation or infiltrates into the soil. After depression storage spaces are filled, excess water [runoff] begins to move downslope as overland flow, either as a shallow sheet of water or as a series of rivulets or rills.

The sheet of water increases in depth and velocity as it moves downhill. [This runoff causes erosion. When the flow slows down or stops, sediment drops out. Overland flow eventually runs off into streams, lakes, wetlands, or other water bodies.] See figure 21.

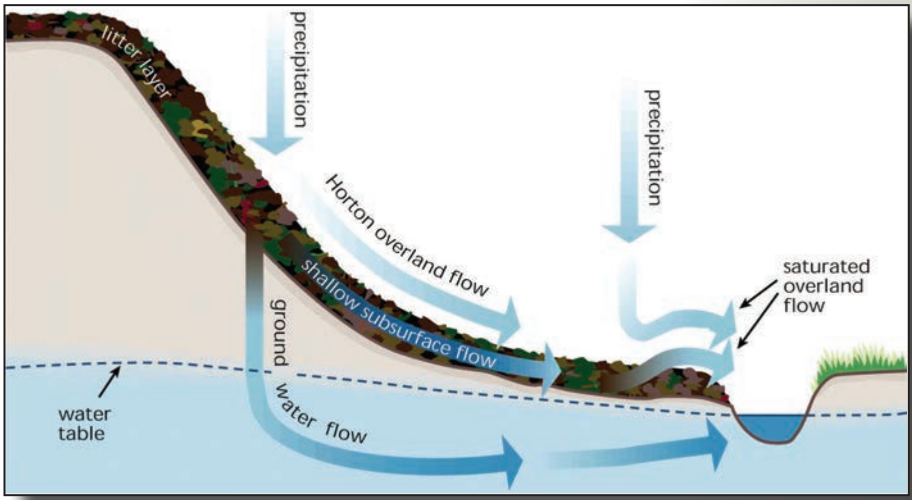


Figure 21—Flow paths of water over the surface. The portion of precipitation that runs off or infiltrates to the ground-water table depends on the soil's permeability rate; surface roughness; and the amount, duration, and intensity of precipitation (FISRWG 2001).

Vegetation

The distribution and characteristics of vegetative communities are determined by climate, water availability, topographic features, and the chemical and physical properties of the soil, including moisture and nutrient content. The characteristics of the plant communities directly influence the diversity and integrity of the faunal communities. Plant communities that cover a large area and that are diverse in their vertical and horizontal structural characteristics can support far more diverse faunal communities than relatively homogenous plant communities, such as meadows.

Plant communities can be viewed in terms of their internal complexity. Complexity may include the number of layers of vegetation and the species comprising each layer, competitive interactions among species, and the presence of detrital components, such as litter, downed wood, and snags. Vegetation may contain tree, sapling, shrub (subtree), vine, and herbaceous subshrub (herb-grass-forb) layers. See figure 22.

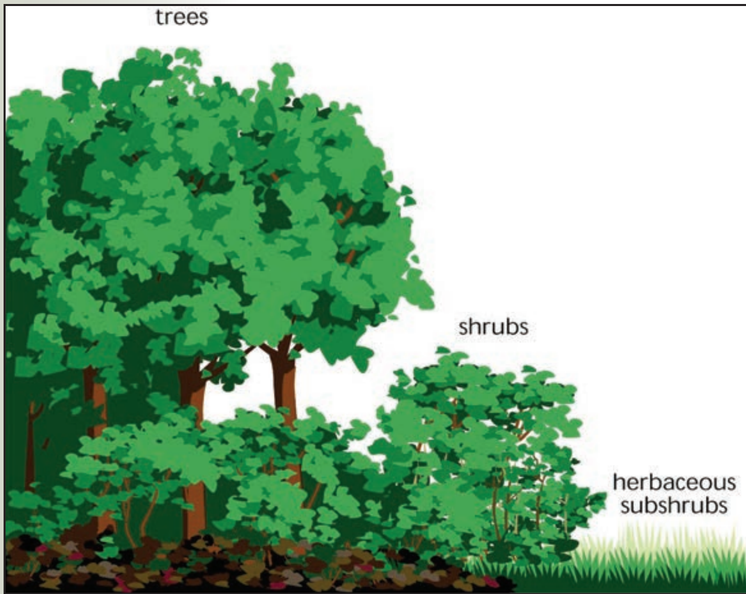


Figure 22—Vertical complexity. Complexity may include a number of layers of vegetation (FISRWG 2001).

Species and age composition of vegetation structure can be extremely important. Simple vegetative structure, such as an herbaceous layer without woody over-story or old woody riparian trees without smaller size classes, creates fewer niches for guilds (groups of species with closely related niches in a community). The fewer guilds there are, the fewer species there are. The quality and vigor of the vegetation can affect the productivity of fruits, seeds, shoots, roots, and other vegetative material, which provide food for wildlife. Plant communities are a valuable source of energy for the biological communities. Poorer vigor can result in less food and fewer consumers (wildlife).

The sensitivity of animal communities to vegetative characteristics is well recognized. Numerous animal species are associated with particular plant communities, many require particular developmental stages of those communities (e.g., old growth), and some depend on particular habitat elements within those communities (e.g., snags).

Habitat-Edge and Interior

Habitat is a term used to describe an area where plants or animals (including people) normally live, grow, feed, reproduce, and otherwise exist for any portion of their life cycles. Habitats provide organisms or communities of organisms with the necessary elements of life, such as space, food, water, and shelter.

Two important vegetation characteristics are edges and interior. Edges are critical lines of interaction between different ecosystems. Interior habitats are generally more stable, sheltered environments where the ecosystem may remain relatively the same for prolonged periods. Edge habitat is exposed to highly variable environmental gradients. The result is a different species composition and abundance than observed in interior habitat. Edges are important as filters of disturbance to interior habitat. Edges also can be diverse areas with a large variety of flora and fauna. [An edge could be an ecotone (a relatively narrow overlapping zone between two ecological communities).]

Edges and interiors are scale-independent concepts. Larger mammals, known as interior forest species, may need to be miles from the forest edge to find desired habitat, while an insect or amphibian may be sensitive to the edges and interiors of the microhabitat under a rotted log.

Interior habitat is typified by more stable environmental inputs than those found at the edge of an ecosystem. Sunlight, rainfall, and wind effects are less intense in the interior. Many sensitive or rare species depend upon a less disturbed environment for their survival. They are therefore tolerant of only "interior" habitat conditions. The distance from the perimeter required to create these interior conditions is dependent upon species' requirements.

Interior plants and animals differ considerably from those that prefer or tolerate the edge's variability. With an abundance of edge, stream corridors often have mostly edge species. See figures 23 and 24.

Figure 23—This photograph shows the concept of naturally occurring habitat edges. One is the edge of the stream; the other is the feathered edge or ecotone of the trees and meadow.

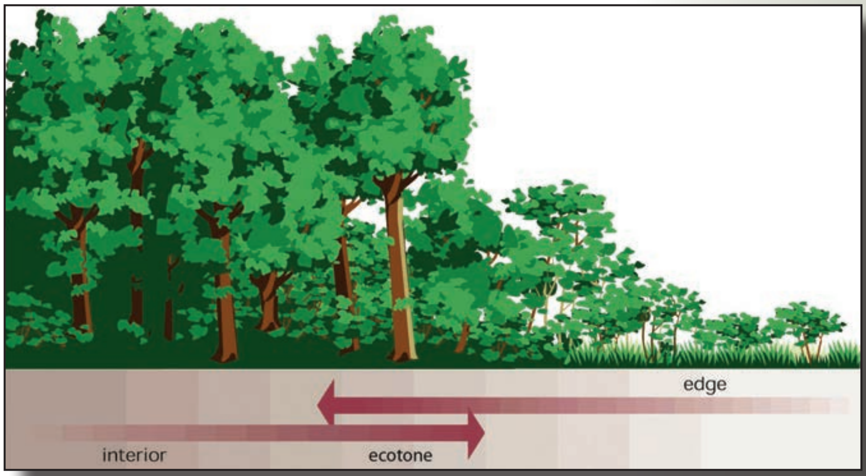


Figure 24—Edge and interior habitat of a woodlot. Interior plants and animals differ considerably from those that prefer or tolerate the edge's variability (FISRWG). An ecotone is a relatively narrow overlapping zone of two ecological communities, in this case represented by interior and edge habitats.

Riparian Ecosystems

Riparian ecosystems are described as land and vegetation associated with lakes, streams, rivers, natural drainages, and wetlands. Riparian ecosystems are important for flood mitigation and control and for water quality. They provide critical habitat and food sources to a diverse population of wildlife, including fish and fowl, and humans; they also are travel corridors for both aquatic and terrestrial species. Of all forest types, riparian ecosystems support the greatest diversity of plant and animal species.

Riparian ecosystem influences are best described topographically from upstream to downstream, from upslope to downslope, and from subsurface up through the vegetated canopy. This concept is best expressed as the longitudinal, lateral, vertical, and temporal influences. See figure 25.

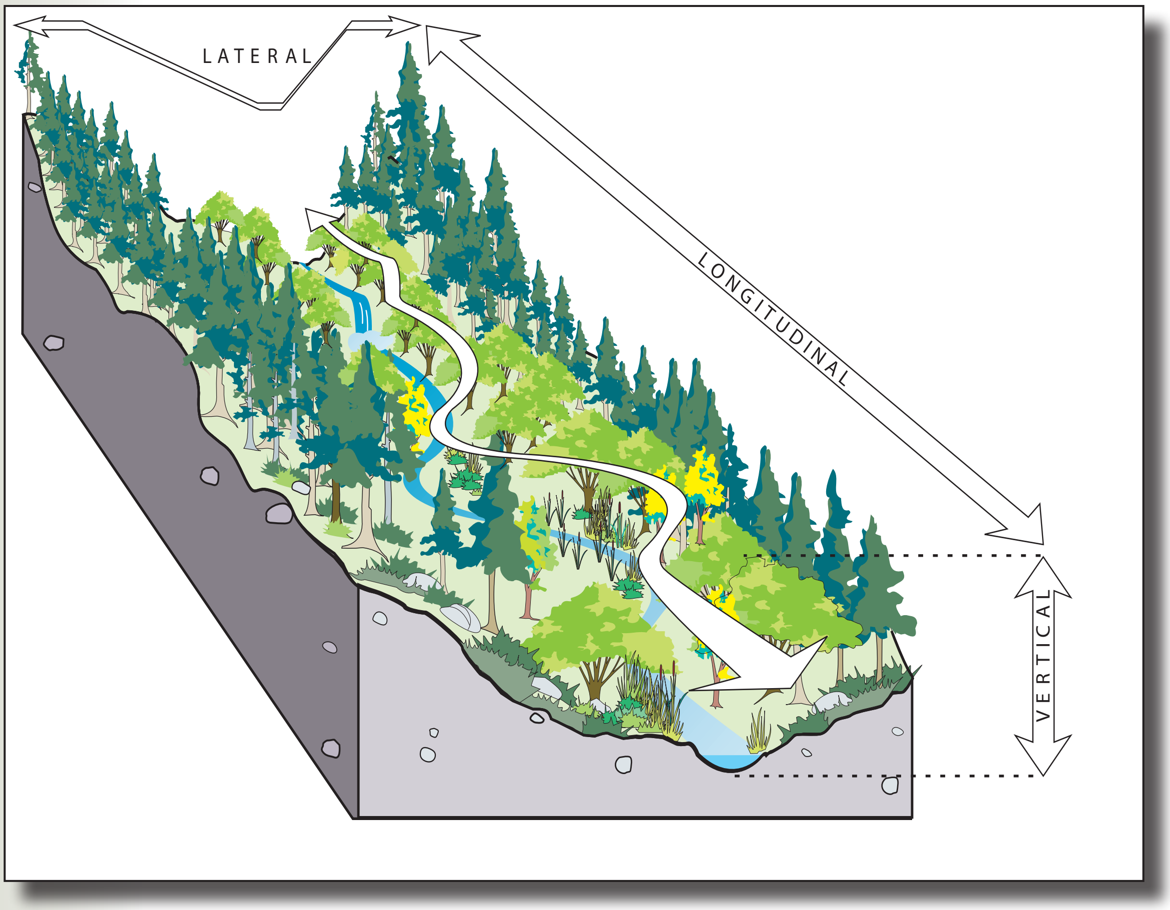


Figure 25—Identifying the riparian ecosystem.

Riparian ecosystems are the link between upland forests and aquatic habitats or ecosystems and have a unique array of functions, such as regulating not only the movement of water between terrestrial and aquatic ecosystems, but also the movement of nutrients, sediments, and particulate organic matter over flood plains. On active flood plains, riparian vegetation traps sediment and particulate organic matter outside the active channel during overbank flows (Swanson et al. 1982; Harmon et al. 1986, as seen in Gregory et al. 1991). See figures 26 and 27.

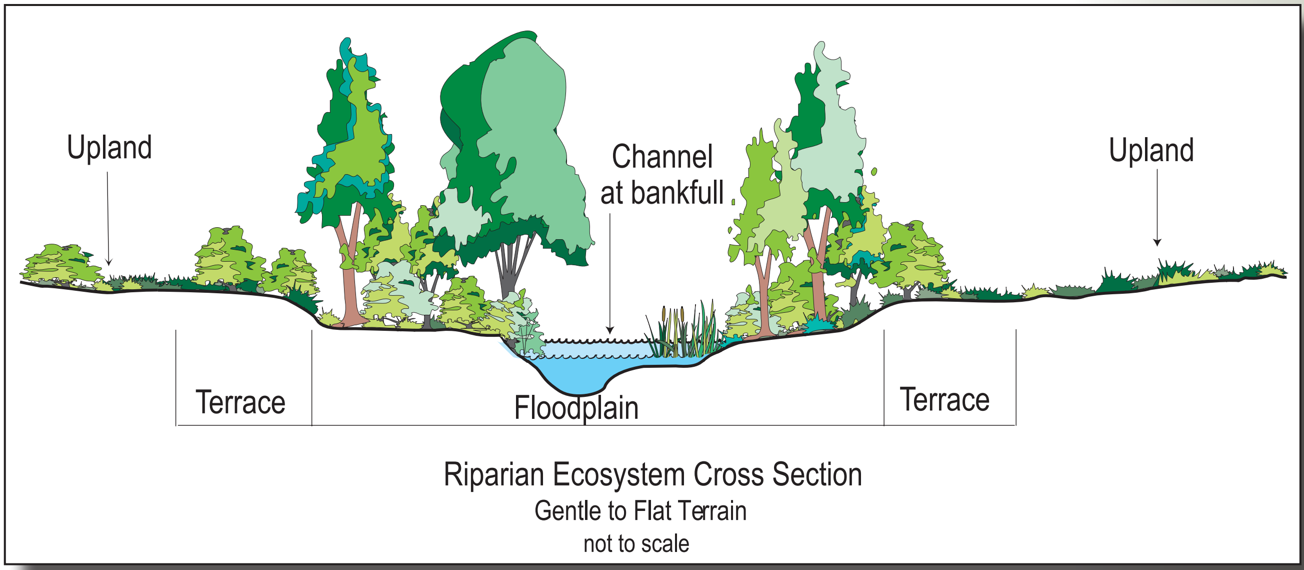


Figure 26—Riparian ecosystem cross section 1.

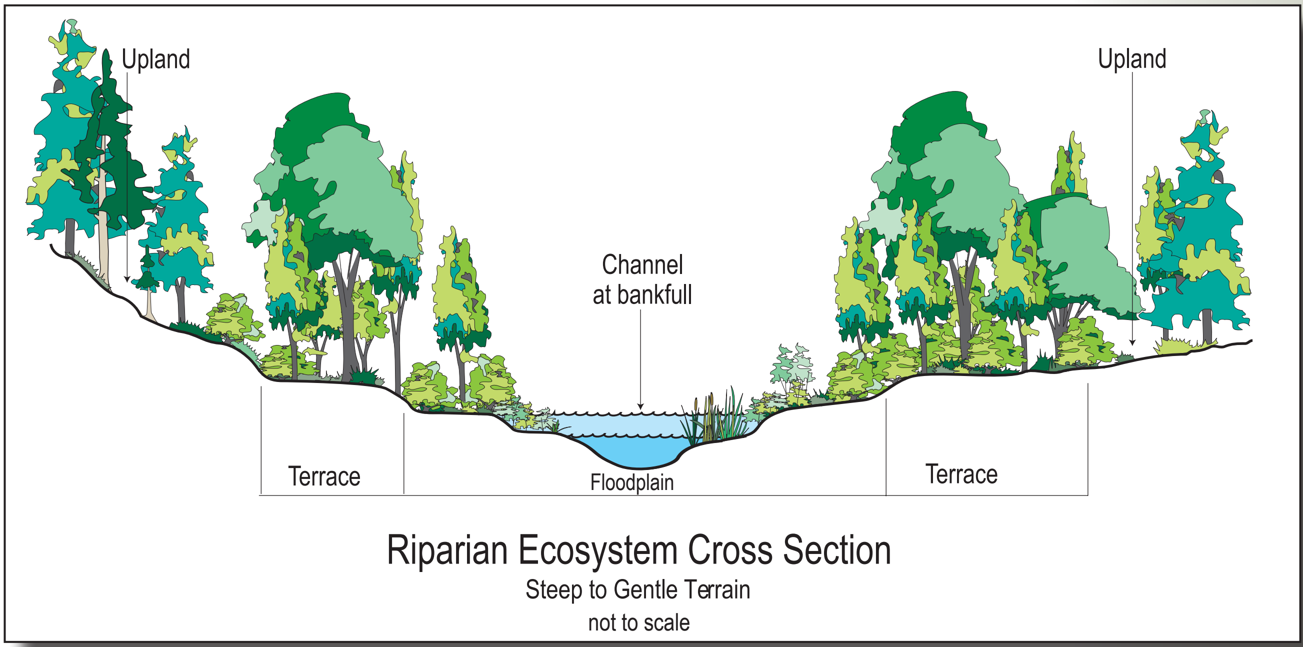


Figure 27—Riparian ecosystem cross section 2.

Cover and shade from vegetation create microclimates that function to cool the riparian area, lower water temperatures, and shelter wet areas. The riparian vegetation plant structure (standing and dead and down), leaf litter, and uneven ground capture sediment and slow and detain runoff and overland flow, as well as provide water storage and water infiltration areas.

Desert Ecosystems

Desert ecosystems are fragile in part because little water sustains plant and animal life. Deserts typically are windy and hot in the daytime and cool or cold at night; temperatures and winds dry the soil. Soils vary from sand to gravel to heavy clay. See figure 28.

Figure 28—Mojave Desert, CA.

Porosity is influenced by soil or ground texture and soil development. Studies suggest that old and less developed soil classifications significantly affect plant roots. There is an adaptation of vegetation to soils. Younger soils are from more recent flood deposits and have unconsolidated soil allowing a plant to send a tap root deep into the earth. For example, the roots of a mesquite tree can be 200 feet deep, and roots of a 1-inch-tall seedling can be 40 inches deep (Bainbridge 2007).

Older, highly structured soils, such as the caliche layer prevalent in Arizona, tend to force roots to grow horizontally and close to the surface (Caldwell 2006; Hammerlynck 2002, as seen in Bainbridge 2007). These older soils form an alkaline soil layer of calcium carbonate 1 to 2 meters below the surface and have properties similar to concrete (Bainbridge 2007). “The root system of creosote bush consists of a shallow taproot and several lateral secondary roots, each about 10 feet (3 m) in length and 8 to 14 inches (20-35 cm) deep. The taproot extends to a depth of about 32 inches (80 cm); further penetration is usually inhibited by caliche” (Marshall 1995).

The flora usually is distinct, with features such as stomata, microscopic pores on plants that close in extreme heat limiting transpiration to preserve water/moisture in the plant. Creosote roots are found to emit a fluid that inhibits root growth of adjacent creosote bushes, but does not inhibit growth of other desert plant species (Ridenour 2001). Some plants are short lived and many are drought tolerant and dormant during dry periods. Annuals grow and produce seed only when there is sufficient warmth and soil moisture. Succulents store water. Plants have extensive root systems adapted to withstand dry periods. Shrubs have extensive roots systems that are either very deep and dependent on monsoons or flooding, or shallow and dependent on frequent soft rains (Brattstorm in Webb 1983).

According to Bainbridge (2007), “Deep soil recharge may occur only during prolonged rains or floods. After a one-day rainfall of 0.6 inches (1.5 cm) in early 1989 a sandy soil ...was wetted to a depth of 7.9 inches (20 cm) in Anza Borrego Desert State Park.

“Long-term soil moisture monitoring in a desert wash near Palm Springs has shown the recharge effect of a flood compared to a gentle rain with no flow in the wash. ...The low intensity 0.8-inch (2 cm) rain wetted the soil to a depth of only 3 feet (1 m), sufficient for the herbaceous species to complete their life cycle. In contrast, the flow from the intense storm, 8.6 inches (22 cm), produced a flood that recharged the soil to a depth greater than 23 feet (7 m) in the wash. More than 8 months after the flood, the water content at 8.2 feet (2.5 m) depth was still higher than it was before the flooding.”

Creatures that dig, such as ants, termites, rabbits, rodents, coyotes, lizards, and tortoises, increase water infiltration. Flash floods move great amounts of sediment, filling the creatures’ holes and tunnels with loose soil and debris, which absorb and hold moisture deep in the ground. Plants also direct water when rain water trickles down branches to the ground (Bainbridge 2007). See figures 29 and 30.

Figure 29—A black-tailed jack rabbit, Lepus californicus, common in the Mojave Desert. Rabbits dig burrows under plants.

Figure 30—A 6-inch-long desert tortoise, Gopherus agassizii lives in burrows. The species is listed as threatened.

In dry regions, biological soil crust (BSC) may cover soil not sheltered by terrestrial plants (Rosentreter 2007). BSC increases soil stability and generally positively influences water infiltration (Cole 1990). Some soils have a BSC that is made of algae, fungi, lichen, and other microorganisms. Lichen and mosses generally are recognizable. Smaller organisms are harder to spot. These can be seen as tiny fibers in the top 1 millimeter of the soil (Belnap 2008).

“Biological soil crusts (BSCs) are an intimate association between soil particles and cyanobacteria, algae, microfungi, lichens, and bryophytes (in different proportions) which live within or on top of the uppermost millimeters of soil. These communities have been known by a variety of names, including cryptobiotic, cryptogamic, and macrobiotics soil crusts. They are found in all dryland regions of the world, including the Polar Regions, and in all vegetation types within these lands. In these landscapes, BSCs often cover all soil spaces not occupied by trees, grasses or shrubs and can comprise over 70% of the living ground cover. [These organisms have their own succession patterns.]

“The presence of these organisms on the soil surface increases soil stability. Because they are photosynthetic they also contribute carbon to the underlying soils. Free-living and lichenized cyanobacteria can also convert atmospheric nitrogen into bio-available nitrogen, and thus are an important source of this often limiting nutrient. All these organisms also secrete compounds that increase the bio-availability of phosphorus. Lichen morphological types with a more discontinuous cover (crustose, squamulose) allow water, gases, and seedlings to pass through to the soil surface, whereas mosses and lichens with a more continuous cover (foliose, fruticose) often block the flow of materials to the soil surface” (Rosentreter 2007).

Poorly Functioning or Nonfunctional Ecosystem Components

Thus far, the focus of this section has been to introduce the functions of a few of the components of an ecosystem: soil, hydrology, vegetation, and habitat. The purpose for the discussion was to create awareness and understanding of the complexity, fragility, and the essential interdependency of these components.

Focusing on ecological functions gives the restoration effort its best chance to recreate a self-sustaining system. This next section discusses the ramifications to a healthy ecosystem when unmanaged OHV use is allowed to go unchecked. Fittingly, this discussion begins with soil.

Compromized Soil

Soil is the supporting function for all terrestrial life. Unmanaged OHV use disturbs this function by compacting soil, creating depressions for puddling, and kicking up dust. Once the soil is compromised, water inception, infiltration, soil moisture, and runoff are all affected negatively. Unmanaged OHV use results in the loss of vegetation, compaction, reduced infiltration, increased surface runoff, and wind and water erosion. Soil pounded by raindrops is displaced. As a result, erosion occurs, overland flow accelerates, and rills and gullies form. See figure 31.

Figure 31—Larger materials, such as gravels (A) and wood chips (B), protect the soil and sown seeds by absorbing the energy of rainfall impact. While unprotected soil and seeds are removed through splash and sheet erosion, protected soil remains in pedestals, sometimes several inches above the surface of the soil. Seeds that do remain on or near the surface have a difficult time germinating through the surface crust created by rainfall impact (C). Plants that do establish will have roots exposed by successive rainfall events (Steinfeld 2007).

Compaction

Compaction can occur in all soil types except sand; very rocky soils also are less able to compact. Compaction disturbs the natural function of the physical, biological, and chemical characteristics of the soil resulting in lower productivity and lower water infiltration rates. This leaves poor soil quality that supports little or no native plant growth (Bainbridge 2007; Iverson 1981; Liddle 1997).

Compaction can be thought of as "squeezing the air" out of the soil. When soils are compacted, soil structure and the very fragile macropores created and maintained by soil organisms and plant roots are the first to collapse. Compaction takes place when the soil does not have enough strength to bear the load. As the soil compacts, soil strength increases until the soil has enough strength to bear the load. During this consolidation process, soil pores collapse and soil porosity decreases, which reduces infiltration rates.See figures 32 through 34.

Figure 32—The drawing shows loss of vegetation, leaf litter cover in the tire track, and the beginning of soil compaction. The soil pores are collapsing.

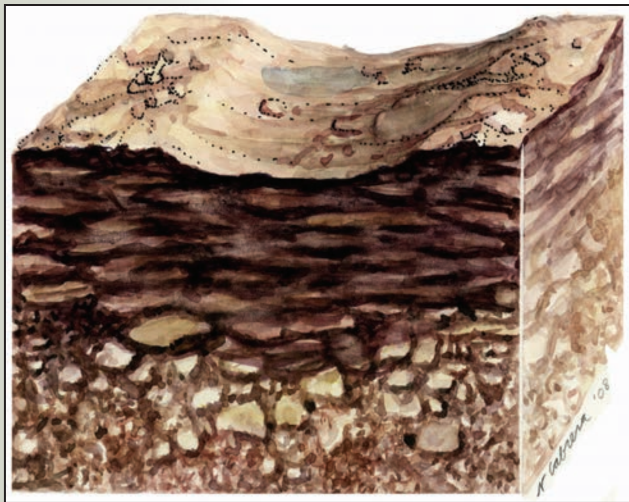


Figure 33—The drawing shows loss of cover outside of the tire track and more compaction within it. Notice that there are no roots.

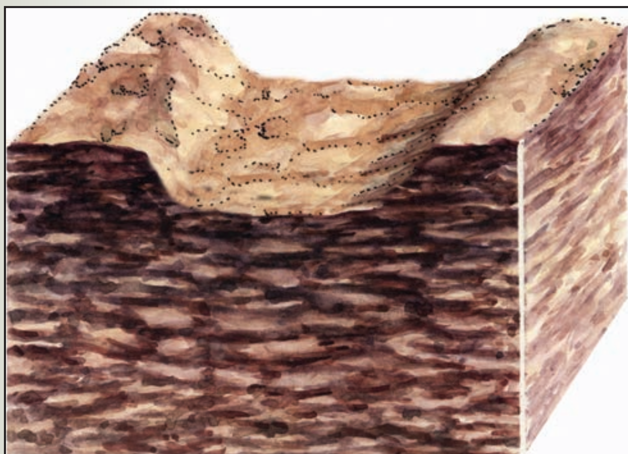


Figure 34—The drawing shoiws that the soil is denuded and compacted leaving a depression incision, which leads to heavy runoff and changes in percolation rates and patterns.

Puddling

Another process that destroys soil structure is puddling, which occurs in areas where soils are saturated from precipitation or have high water tables. When soil is saturated, all soil pores are filled with water. Since there is no air to squeeze out and water is not compressible, traffic on saturated soils displaces the soil. Puddled soils typically have ruts with berms. Puddled soils may increase in density and lose porosity as they dry out, but puddled soils do not have the strength of compacted soils (Poff 2006). Infiltration rates are affected negatively.

Exposed soil is very susceptible to sheet, rill, and wind erosion. At all-terrain vehicle (ATV) test areas on the trails, vegetation was reduced by a minimum of 40 percent and was more often completely eliminated as a result of ATV traffic. During tests, soils were compacted (except sands and gravels), displaced, or loosened making them available for transport (erosion) by water and wind (Meadows 2008). See figure 35.

Figure 35—This photo shows the forest floor with vegetation and leaf litter cover and without the cover where the ATV has gone.

Impaired Hydrological Function

Dewatering and Erosion

The key functions in the hydrologic cycle most affected by unmanaged OHV use are interception, infiltration, soil moisture, and runoff. Hydrologic function is changed not only by loss of vegetation, the depth of litter layers, and soil compaction, it also is changed on cross slopes, ridge tops, and hills as unmanaged OHV use cuts trails, interrupting surface and subsurface flows patterns. Cross-slope disturbances can affect the soil moisture storage and percolation patterns, which affect the natural hydrologic piping functions on the slope. Changes in pore pressure may lead to slides or sloughing (Pierson 1983; Carey 2002). Changes in flow patterns affect soil moisture by causing soil to be wetter or drier than normal, which can affect soil health and plant life, and over the long term can lead to vegetation conversion or a change in vegetation type. Changes can redirect flow causing gullies to form. Through cuts can have the same effects. Sediment generated as a result of through cuts and hill climbs is carried into streams and wetlands and/or deposited at the bottom of slopes, further changing the hydrologic functions in the area. See figure 36.

Figure 36—This hill climb has become a through cut, changing flow patterns and causing massive amounts of erosion.

Unmanaged OHV use changes infiltration rates and depression storage and usually leads to increased overland flow rates, reduced soil moisture storage capacity, and perhaps less percolation to groundwater. Reduced infiltration and increased runoff erode rills and gullies that route water to streams faster, harm water quality and aquatic habitat, and are tough to erase from the landscape. Higher overland flow rates erode topsoil affecting vegetation growth and decreasing recovery potential. Essentially, unmanaged OHV use redistributes surface flow and sediment and subsurface flow. This can lead to changes in percolation patterns in an area and consequently less water in the unsaturated zone available for plants and less groundwater for recharging water bodies during dry seasons.

Vegetation Losses

The short-term effects of destroying and removing vegetation can result in an immediate short-term rise in the local water table due to decreased transpiration. Loss of vegetation can cause changes in soil temperature and structure, resulting in decreased movement of water into and through the soil profile. Loss of vegetation equates to thinner leaf litter layers, which causes a gradual loss of organic matter in the soil and changes the infiltration rates. These losses change the surface flow patterns and greatly contribute to soil erosion.

Unnatural Edges

Unmanaged OHV use forms unnatural edges, which have characteristics similar to natural edges but with many unintended effects on ecosystems. Edges are more open to disturbance by humans and to the influx of out-of-area native and nonnative species, both plant and animal (Falk 2000). This changes the interior habitat conditions. Benninger-Traux (1992) found that species on trail edges tend to be adaptable to disturbed areas, that there are a greater number of exotic species closer to trailheads, and that the amount of trail use affects edge plant composition. Species composition also is changed by trail use because the larger or better armored plant species survive (Cole as quoted in Alexander and Fairgridge 1999). The spread of noxious weed seeds is also another consequence of unmanaged OHV use. See figure 37.

Figure 37—A new edge is cut through a forest, creating easy access for foreign species and the spreading of weed species.

Unmanaged OHV use can lead to increased forest fragmentation. Certain mammals and invertebrates either cannot or will not cross an open area (Marini 1995). Migration and dispersal are effectively stopped for many species that crawl. Some species will not come within several feet of a road or trail, which means these species must survive in less habitat or abandon the area (Ouren 2007).

Riparian Degradation

Unmanaged OHV use destroys vegetation, causes soil compaction, and destabilizes streambanks and shorelines. Riparian ecosystems are disrupted and fragmented when portions of vegetation are removed. Loss of riparian function also damages aquatic ecosystems by adding sediment to streams, which disturbs gravel spawning beds. Added fine sediment of silt and clay causes higher levels of turbidity, which is also harmful to many aquatic species. See figure 38.

Figure 38—Vehicle tires have cut up the riparian vegetation that protects this lake perhaps exposing the high water table. Unmanaged recreation also is apparent in the extinguished campfire dotted with trash.

When Desert Ecosystems Are Damaged

According to Lathrop, "Experiments have shown that one pass of a four-wheel-drive truck on wet soil creates soil compaction sufficient to significantly reduce the cover and density of several annual plants species in the Mojave Desert. ...Surface shearing, which uproots and disrupts root systems, and crushing of fragile, root systems, and seedlings are the direct impacts of ORVs [off-road vehicles] on vegetation ...[causing] changes in patterns and composition of vegetation as reflected in changes in plant density, cover, and species diversity within a site" (Webb 1983).

When soils are displaced, roots are disturbed affecting water infiltration and recharge. Displaced soil leads to less water in the unsaturated zone for roots, which weakens and eventually can kill plants. Because there is less vegetation, there is less habitat and fewer animals. Many desert creatures tunnel and burrow through soils. Without these openings, plants receive less water (Bainbridge 2007).

Cole (1990) found that just walking over the BSC in tennis shoes 15 times was enough to reduce its presence by 50 percent; after 250 passes no BSC was visible.

Depending on climatic conditions, including precipitation rates and soil, it can take from 50 years to several centuries to recover healthy soils, a plant base, and healthy ecosystem functions in a desert (Bainbridge 2007; Vasek 1980). See figure 39.

Figure 39—Desert landscapes are fragile; they take a long time to recover even though damage looks minor. Plants on the edges of these tracks have begun to grow over the tracks, but there is no new plant life in the tracks.

Conclusion

It is critical to understand how change affects components and can jeopardize ecosystem health. It also is important to understand the many interactions among components in order to restore them. Figure 40 illustrates the numerous interactions among components in an ecosystem.

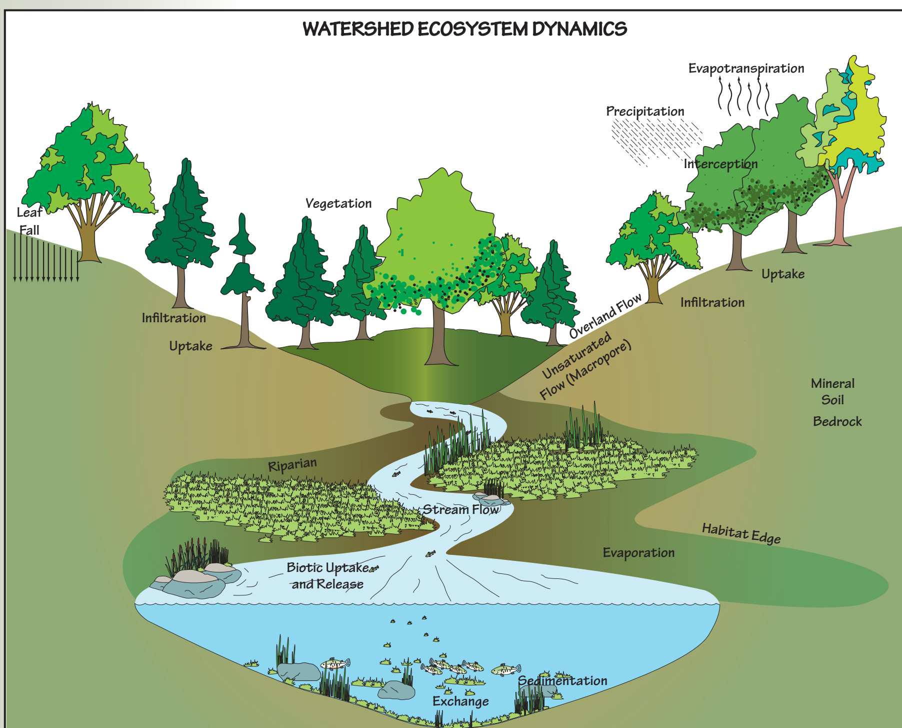


Figure 40—Watershed ecosystem.

Restoration Principles

This section discusses four restoration principles: obliterating sightlines, restoring soil functions, restoring hydrologic function, and restoring vegetation. It is necessary to restore the soil and the hydrologic connection for the best chance of having seeds germinate and plants survive to be part of a functioning ecosystem. These principles are explained and followed by restoration methods. The methods apply to one or more principles. As functions in ecosystems overlap or are interdependent or interrelated, so are restoration methods. See figures 41 and 42.

Figure 41—An unmanaged use area is severely down cut, and a small gully is forming in the bottom of it.

Figure 42—The same area as a restoration site was ripped, soil brought in, and straw mulch applied.

Obliterating Sightlines

Take visual quality (the view shed) very seriously because a visible trail invites use. Become the visitor and map all the vantage points of a particular unmanaged OHV use area, then obliterate it by restoring the landscape. Try to erase the portions of an unmanaged OHV use area that can be seen from any vantage point. This eliminates the challenge or opportunity of using it. See figures 42 and 43.

Figure 42—These unauthorized hill climb trails are visible from miles away. They invite riders to the challenge. Riders will not know until reaching the bases of the trails that they are not system trails, and riders may create unauthorized trails just to get to the unauthorized hill climb trails.

Figure 43—Minimal slash is stacked at the beginning of this unauthorized trail. The remainder of the trail is visible behind the slash. The sightline still exists and may entice use. Add more slash to further obliterate the sightline.

Restoring Soil Functions

Restoration is more difficult when soils are barren, severely eroded exposing mineral soils, and/or compacted. See figures 44 through 46.

Figure 44—Unmanaged OHV use caused soil compaction leading to vegetation eradication and soil erosion.

Figure 45—The restoration site was ripped to loosen the soil to increase water and gas exchange in the soil; it also created an uneven surface to catch rainfall and debris. The site was covered with rice straw mulch in October 2000.

Figure 46—In June 2002, the same restoration site supports grass sprouted from the existing seed bank.

Restoring Topsoil

There are a number of ways to improve soil quality. These include transferring top soil to the restoration area and digging in duff. Duff is the partially decomposed organic layer that sits between topsoil and leaf litter. Topsoil, leaf litter, and duff are rich in nutrients and seeds (commonly referred to as a seed bank) and are porous.

Take topsoil and duff from a reference site. A reference site is a functioning, intact area that is adjacent to the restoration area, a short distance away in the same watershed, or in a different watershed a with similar ecosystem. The reference site needs to have characteristics similar to the project site, such as soil type, aspect, topography, geology, stream patterns and profile, weather patterns on lakes, and climate.

To transfer topsoil (fungi and other soil organisms) to the area, dig up soil. Take shovels full and include some roots from an adjacent reference site. Mix this soil with the area's soil as an inoculant. A little bit of soil goes a long way (Claassen 2006). In many instances, it is beneficial to dig in duff an inch deep. This increases the infiltration rate and retains more moisture for vegetation (Woolson 2005). Be selective about taking the soil so that reference sites are not destabilized and plants killed.

Do not use fill dirt (soil hauled to the area and consisting of the soil horizons below the top soil). It is usually devoid of topsoil.

As a last resort—and only in the very harshest of areas—use commercial compost or fertilizer. Check with a soil scientist and/or botanist before applying fertilizer. Slow release fertilizers mimic natural nutrient breakdown. Too many nutrients at one time encourage plants to grow at unnaturally fast rates, which can shorten their lives, encourage weed growth, and disrupt the soil biology.

Restoring Soil Porosity

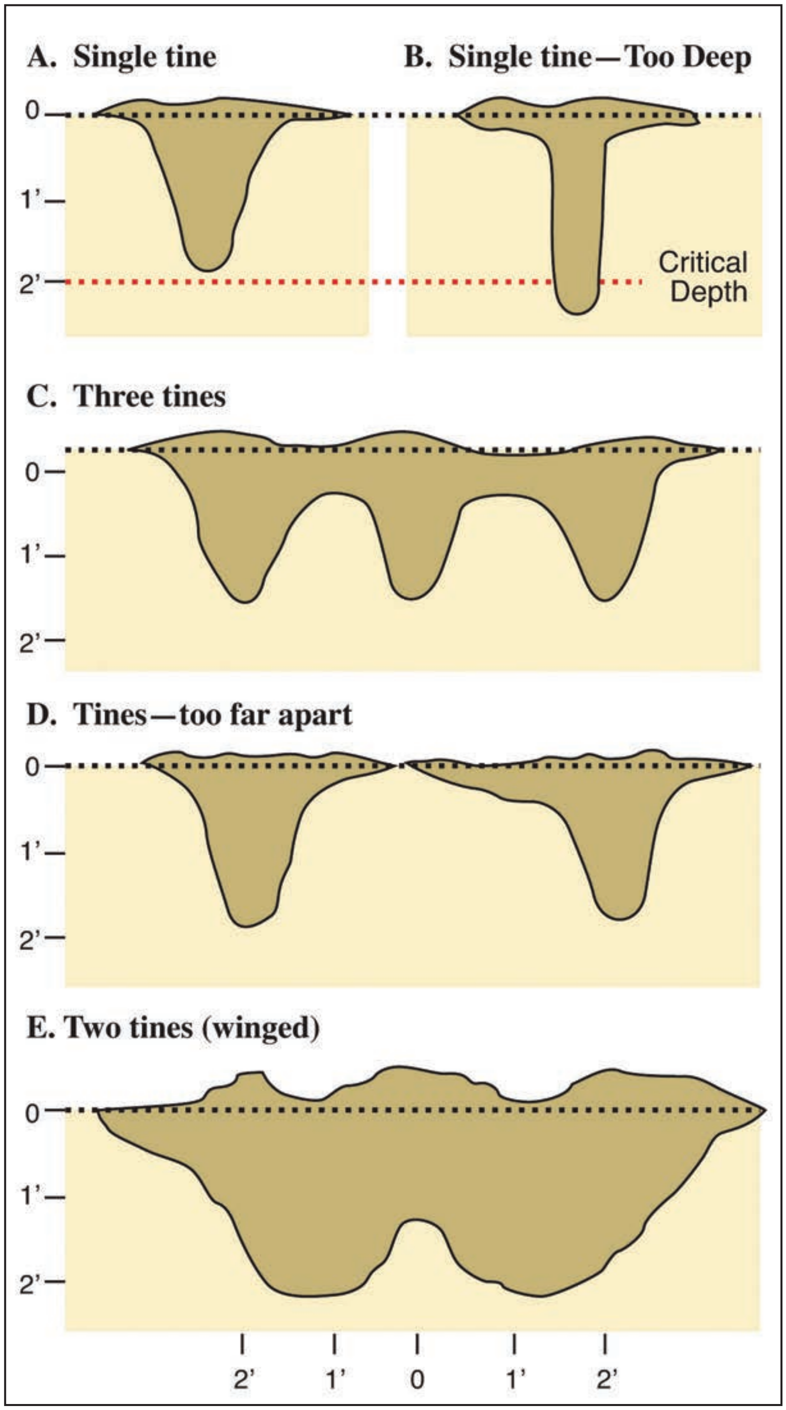
Restoring soil function and structure is the first step in restoring soil porosity. Compacted soil lacks pore space, which slows down biological processes and decreases water infiltration. Compacted soil depth varies depending on use, soil moisture, soil type, and depth to bedrock. Before implementing a mechanical treatment, determine whether there has been enough compaction to justify treatment. If roots, particularly live roots, are present, mechanical treatment is generally not needed. This applies to new, unauthorized trails; it does not apply to old roadbeds of any type. (Vegetation on old roadbeds generally has shallow roots that fan out because the soil is too compacted for roots to penetrate.) Till outside of tree drip lines. If the soil is compacted, establish how deep and how thick compacted layers are, how densely they are compacted, and whether the compaction is in topsoil or subsoil. Appendix A illustrates how to determine the degree of compaction.

There are several implements useful for restoring soil structure. Use a cultivator to stir and pulverize soil; it prepares a seed bed in defined rows. Use a harrow to breakup clods and smooth the soil; the whole surface under the implement is affected. The cultivator and harrow can penetrate the soil to a depth of approximately 8 inches. Use a disc plow to turn over the soil to a depth of 4 to 9 inches. Use a subsoiler (ripper) to break up and loosen soil without mixing soil horizons; it reaches depths of 24 to 30 inches (Kees 2008). See tables 1 and 2.

Table 1—The appropriate tillage equipment for the projects depends on project objectives (Steinfeld 2007)

	TYPE OF TILLAGE		
	Shattering	Mixing	Imprinting
OBJECTIVES	Rippers & subsoilers	Disks, plows, excavator attachments	Dixon imprinter, excavator attachments, trackwalking
Loosen compacted soil	Good	Good	Poor
Incorporate amendments	Poor	Good	Poor
Roughen surface	Good	Good	Good

Table 2—"The effectiveness of the subsoiling or ripping equipment to shatter compacted soil is a function of tine depth, number of tines, distance between tines, and wing configuration. Pulling a single tine (A) above a critical depth does some soil shattering as compared to a single tine ripping deeper than a critical depth (B). Placing 3 or more tines together (C) can be more effective than one tine, but tine spacing should not be too far apart or soils between the tines will not be shattered (D). Attaching wings to the tines is very effective in shattering compaction between the tines (E) (modified after Andrus and Froehlich 1983) (Steinfeld 2007)." Critical depth is a theory that suggests that placing the tine within the compacted soil and not beyond it is most effective (Steinfeld 2011).



Determine the treatment objective; this dictates the appropriate implement to use. For example, if the compacted layer occurs in the topsoil, or the upper part of the subsoil, the objective is restoring soil structure. In this case, till with a winged subsoiler. Do this when the soil has some moisture content. The action of the winged subsoiler lifts the soil—similar to airflow over the wing of an airplane—and breaks the compacted layer into fine soil aggregates, similar to the natural soil structure. This speeds the process of biological recovery.

Fine textured soils with platy soil structure transfer lateral fracture a greater distance than coarse textured soils. As the soil becomes coarser the lateral fracture distance shrinks (Archuleta 2008). Till the extent of the compaction, and make several passes in different directions with the last pass being across the slope.

When compaction is shallow, in the East, and in flat and hilly areas, use a tractor to pull any number of implements, such as a disc plow, disc harrow, and offset harrow (Hardee 2010). Use the offset harrow to direct the soil in one direction when breaking down a berm and moving the soil onto the bare area, or in two directions when moving the soil from the edges of an unmanaged OHV area or unauthorized trail to fill the center. On flat ground and in non-treed areas, use a tractor to tow a rototiller or articulating harrow. The harrow can be adjusted to push soil into the center of the tilling path or to one side, bringing the soil that has been displaced back on to the damaged area.

Where topsoil and subsoil have eroded leaving a compacted layer of very harsh, rocky soil, use a rock ripper to improve water infiltration and create fractures where at least some roots can penetrate. The lateral action of the rock ripper shatters the dense layer. This is best accomplished when the soil is dry. A rock ripper creates large clods and large angular fragments of soil, which improves water infiltration temporarily, but does not create the fine soil aggregates that favor biological activity. See figure 47.

Figure 47—Dozer pulling a ripper used to loosen soil compacted by unmanaged OHV use.

Always use subsoilers and rippers on the contour. When used up and down the slope they create slots that could lead to piping. When tilling or ripping linear features, such as non-entrench roads or trails, add waterbars across the feature to block concentrated flow.

Unmanaged OHV areas that are incised and have lost soil may, when tilled with a subsoiler or rock ripper, exhibit a temporary rise in surface elevation. This can give the appearance that the incised area has been filled. However, the rise of the surface elevation is the result of the large voids created when the soil is shattered into large shards and clods. In time, as the large voids fill in, the soil will settle to its original level or close to it. To restore incised treads to the original contour, import soil either from an adjacent slope or a reference site. See figure 48.

Figure 48—Ripped desert soil that had been compacted by unmanaged OHV use.

Soil Organic Matter

Although it makes up a small part of the soil, organic matter (topsoil) is important because it provides habitat for the soil organisms that maintain soil structure and porosity that encourages plant growth. The porosity, created by good soil structure, promotes infiltration and gas exchange. Soil organisms are aerobic, so gas exchange is important in sustaining the biological processes in soil. When the topsoil has been lost, adding compost or duff can temporarily restore organic matter, but this rapidly breaks down to unstable labile organic matter. Where topsoil has been lost, the real need is to restore the stable recalcitrant soil organic matter component. In all but the most severely damaged soils, seeding and mulching will help get the process started.

Restoring Hydrologic Function

Restore hydraulic function to lessen erosion and to restore soil productivity and plant vigor. See figures 49 and 50.

Figure 49—A breached water-diverting berm at the top of an unauthorized hill climb. Runoff continues down the hillside.

Figure 50—This restoration failed for several reasons. One is that overland flow was not diverted at the top of the hill and at intervals along the trail, so a gully formed. To begin to restore this section, control the water. Till the trail surface and reshape the slope to remove the gully, block the source of concentrated overland flow at the top of the slope, and add waterbars at intervals along the slope so accumulated water does not run too far before being diverted.

Controlling erosion is crucial for restoring hydrologic function. Stop concentrated waterflow down unmanaged OHV areas. Find the source of any concentrated water flowing and divert it back into its normal flow pattern or into vegetated areas where it can naturally infiltrate into the forest floor. Mulch or rock diffusion at drainage points may be necessary to avoid erosion..

Fill

Reestablish natural flow patterns by adding fill and reconnecting slope contours. Sliding and sloughing are the main concerns with adding fill material. Adding fill can create a slip plane; it may lead to piping. When soil is added to a slope, a slip plane is created where the new and existing soils meet. There is a tendency for the fill material to slide or slough on top of this plane. This occurs because there is nothing to join the existing and fill soil together (e.g., no plant roots). See figures 51 and 52.

Figure 51—Angle iron welded onto the bucket of an excavator is an alternative tool for imprinting soil that does not compact soils. The excavator operator presses the face of the bucket into the soil surface to form rough, surface imprints across the slope. Photo credit Steinfeld 2007.

Figure 52—Track-walking creates imprints or grouser marks on the soil surface, but also will compact surface and subsurface soils in place. Photo credit Steinfeld 2007.

There are several strategies for making sure the fill is stable and minimizing the chance of slides and sloughing:

- Build a berm and energy dissipaters to block overland flow at the top of the affected area. Runoff has the potential to saturate the fill, which may cause a mass failure and/or cut gullies.

- Remove-do not bury-any organic debris that accumulates in the incised trail or gully.

- Roughen the bottom of the treated area.
  - Till.
  - Use grouser indentations (the dozer grousers leave indentations in the soil causing fraction indents in the soil).
  - Use the teeth on a bucket to scrap the soil.
  - Form stair steps no more than 12 inches high in the existing slope.

- On deep fills on steep slopes, anchor the fill at several points with rocks, gabions, or other retaining structures. See appendix F. For example, on wet slopes, live cuttings, such as willow stakes and posts, can tie two soil layers together if they penetrate the lower layer deeply enough.

- Compact the fill in lifts, gradually decreasing the soil compaction density toward the surface as described here:

Fill layers are 4 to 6 inches thick. Add the first layer, and run the excavator over the layer to compact it into the existing soil creating a bond to help build structure and a hydraulic connection. (Layers may need to be thinner when using lighter equipment to achieve the desired compaction rates.) More or less match the density (compaction) of the fill material to the adjacent undisturbed soil, and generally match soil texture and rock content. For example, do not fill a gravel gully with clay or a clay gully with sand.

Gradually decrease the density as the fill approaches the surface. Less dense soil near the surface allows moisture to infiltrate and provides a rooting medium for plants. The density does not have to match the adjacent soil perfectly. Use a tile spade or a penetrometer during fill placement to determine whether or not the density is similar to the adjacent soil.

At some point, where the amount of fill and the steepness of the slope become excessive, seek engineering or geotechnical expertise. In this document, excessive is any slope greater than a 5-to-1 ratio (20 percent) or fill greater than 3 feet deep and having a fill volume of more than 50 cubic yards.

Rills and Gullies

Rills and gullies form when water washes over soil carrying bits and pieces of it away. Rills are miniature gullies less than 6 inches deep. They form in unconsolidated soils and where overhead and ground vegetation are missing, which exposes soil to raindrops and to overland flow. See figure 53.

Figure 53—This gully is coming off of and running parallel to an unauthorized OHV trail.

Treatments for Rills and Gullies

Fill rills and shallow gullies with adjacent soil. Smooth the area; seed, plant, and cover with slash. Build a berm and energy dissipaters to block overland flow at the top of the affected area. The berm should redirect water away from the damaged area to a vegetated area. Treat gullies more than 1-foot deep as incised hill climbs; see the section on treating incised hill climbs (see page 203). See figure 54 and appendix F.

Figure 54—This photograph illustrates slope distance and rills. Slope distance is the length of the barren slope. Surface erosion increases with distance downslope. On this slope, sheet erosion turns to rill erosion at point B. Mitigation that shortens slope lengths to less than the distance between A and B will reduce rill erosion (Steinfeld 2007). Two methods to shorten slope length are to install cross-slope waterbars to drain water off the restoration area and to install straw or live fascines across the slope to catch runoff.

Fill the gullies and shape the land to reconnect the contours. On gentle and flat areas, fill and properly reconnect contours using several different types of equipment. A farm tractor with a disk or harrow may be effective in filling shallow gullies. Deeper gullies may require the use of larger equipment, such as an excavator or dozer.

Gully restoration steps:

- Step 1. Build a berm and energy dissipaters to block overland flow at the top of the affected area.
- Step 2. Remove the vegetation and topsoil from the working area and stockpile both separately before starting the restoration. The working area should be at least 20 meters in unconsolidated soils [65.6 feet] wide for smaller gullies in order to have sufficient fill material (Jedrych 2007).
- Step 3. Fill the gully with subsoil. If the subsoil is imported, ensure that it is clean. Fill layers are 4 to 6 inches thick. Add the first layer and run the excavator over the layer to compact it into the existing soil, creating a bond that helps build structure. Good fill compaction is essential and should start with the first layer.
- Step 4. Many gullies are formed in natural swales. When this is the case, leave a swale in the contoured fill. Add the topsoil, till across the slope, and seed. If the area is fairly steep, smooth the soil and apply an erosion control blanket. Make sure the blanket is well secured. Use stripped vegetation as slash.

Disturbed Natural Swales

The most difficult areas to treat are gullies and hill climbs that occur up natural swales. Subsurface water naturally migrates down to its normal position through (soil) pipes at the base of the colluvium filling the swale. When restoring natural swales—and if water cannot be effectively diverted at the top—provide a surface water conveyance, such as an open culvert on top of the fill down the center of the treated area (Poff 2009).

Save Existing Vegetation

Sometimes, there are islands of vegetation in unmanaged OHV areas. Save these islands as an integral part of the restoration plan. Island vegetation is a seed source and adds roughness that helps stop erosion, provides shade for new plant growth, provides habitat, and adds visual diversity. See figure 55.

Figure 55—A vegetation island created between a system trail and an unauthorized shortcut trail. The trail is on the left; see orange trail marker. From an adjacent area not visible from the trail, transplant trees in the late fall to each end of this shortcut and transplant ground cover in the center to reinforce the plant materials on the island.

Bring adjacent vegetation patterns on to the restoration area. For example, if a group of trees is on the edge of the unauthorized trail, extend the grouping of trees into the trail by planting the same types of trees. Transplant trees from the adjacent landscape or contract-grow genetically matching ones.

Restoration Methods

Restoration methods range from blocking access when the unmanaged OHV use is very slight and the landscape can recover on its own to using heavy equipment to rebuilding hillsides. It is common to use one or more methods, such as combining water deflection, area reshaping, and seeding, depending on an area's characteristics and needs. Ensure that landscape restoration is foremost when planning which methods to use and combine, and that the project is not solely an exercise in blocking access to an area. See figures 56 through 58.

Figure 56—A new unauthorized ATV trail detours around a locked gate. It crosses one of the few salmon-spawning streams in the area and creates edges in the riparian ecosystem. Leaf litter is still in place, although the vegetation has been trampled. This can recover on its own. Disguising the tracks would help ensure that.

Figure 57—Use a mini dozer or compact excavator to reshape this area and to dig up and place transplants.

Figure 58—Unmanaged OHV use is causing severe erosion in this sandy bowl. Once the vegetative layer is removed, the sand starts to erode because there is nothing holding it in place. Notice the rills forming along all the use edges and in the center of the trail. There are several steps to take to stop the erosion. First, block the use and block any overland flow coming from the top of the slope. Gather as much displaced soil as possible and move it back on to the hillside. Smooth and cover the fill with erosion control blanket. Because the soil is so sandy, transplant native, low shrubs to this site. In other soil types, seed and transplant.

Waterbars

At the top of a restoration site, use a waterbar or water-diversion berm to divert concentrated flow or runoff from the unauthorized trail or area. Waterbars block concentrated flow down an area and divert it into the established landscape. Waterbars are sometimes referred to as V-ditches, and they are ruined when walked or driven over (Lockwood 2008). For water control on steep slopes, place waterbars at intervals; spacing depends on rainfall amounts and slope steepness. The idea is to get the water off the area before it can pick up speed and soil particles (sediment). See figure 59.

Figure 59—A waterbar stops water from flowing down the exposed soil, and directs it into the landscape. There is another waterbar at the bottom of the slope; they are often used in series.

When installing waterbars:

1. Look for signs that runoff is being funneled toward the unmanaged OHV use area or unauthorized trail. Find the source(s) of this runoff and build the waterbar or berm there.

2. When tilling, dozing, or ripping an unauthorized trail, build the bar by cutting a trench across the trail by angling or tilting the blade (6-way angle dozer) or by lifting the blade to leave a mound. Make sure the egress (drain) is clear and open. If tilling or ripping is not done, dig a 12-inch-deep trench at 45 to 60 degrees across the unauthorized trail. Place the soil on the downhill side of the ditch to form the bar.

3. Drain the waterbar to undisturbed native material.

4. Use a wide and flat drain exit to slow and disperse water to reduce erosion and to prevent head cutting. If necessary, use a water dissipater, such as a rock spillway, a brush bundle, or a coconut fiber or jute fascine. The waterbar and drain will silt in; that is part of the restoration. Seeds will sprout in the trapped sediment.

Figure 60—There is still some low growing vegetation on this hillside, but rills are developing. Install waterbars to drain any overland flow off the surface and into existing vegetation to prevent more rills from forming. Begin this in the shaded portions of the photo. Rake over the tracks and block access to this hill climb. Tie a barrier into existing vegetation on either side of this hill climb. Remember to treat other access points.

Raking

Rake new incursions to erase vehicle tracks. Raking is especially appropriate on sparsely vegetated ground, such as sandy soft soils, washes, landscapes under pines with no understory, and other areas with open ground. Rake fresh tracks with a leaf rake to erase them and, if available, rake adjacent leaf litter over the bare soil being careful not to expose soil in the intact area.

On tilled soil, rake leaf litter from adjacent intact areas over the exposed soil to make it less noticeable and to distribute seeds held in the litter. Do not take so much from an area that it draws attention. See figure 61.

Figure 61—Raking over the tracks will make them much less visible, and therefore less likely to be used again.

Chunking

Chunking works well on areas where topsoil is intact and the seed bed preserved, such as annual grasslands and chaparral. Chunking is a way to till the soil to encourage vegetation regrowth. It breaks the surface up into 1- to 1½-foot mounds (or higher) set at odd intervals. Riders have a difficult time riding over the mounds so they stay off. The mounds do not need maintenance. The vegetation comes back, and the mounds disappear over a 3- to 5-year period. See figures 62a, 62b, and 62c.

Figure 62a—Dozer at the far end of the bald area is beginning to "chunk" the area.

Figure 62b—Dozer operator creating the mounds. The SWECO's blade can be manipulated in eight different directions.

Figure 62c—Bald area just after chunking. Work will continue out to the system trail.

To create the mounds, use a dozer blade to move soil back and forth, pushing and pulling dirt in different directions. Intersperse chunks with berms. According to Dale Deneweth, San Bernardino National Forest, chunking allows water to "slow and pool slightly but continue to flow slowly, depositing silt in the chunked earth." See figure 63 and 64.

Figure 63—Chunking makes it difficult to ride over the same unauthorized area.

Figure 64—Chunking with returning vegetation from the seed bank.

Deneweth (2006) reported that he can "chunk" approximately 1 mile of an 8-foot-wide trail per day. He said, "So far the soil in the chunked sections promotes vegetation growth fast enough that the chance for erosion has been minimized by next [the first] wet season. ...[and] I have documentation of hill climb closures using chunking that shows the soil movement is substantially minimized compared to waterbars and the native vegetation recovery is approximately 90 percent faster and thicker than just using waterbars." See figure 65.

Figure 65—Chunking was used to restore the landscape on these three unauthorized trails.

Erosion Control Methods

Generally, erosion control methods are not restoration methods by themselves and are usually combined with other restoration methods. Erosion control methods discussed here are mulches, hydromulch applications, wood chips, and erosion control blankets. These methods provide soil cover until native vegetation begins to reestablish itself. Restoration is not possible unless above normal runoff rates for an area are stopped. Effective erosion control requires: (1) water control (protection from concentrated flows) and (2) soil cover (protection from raindrop splash and sheet erosion). Soil cover helps prevent erosion. Cover includes mulch, erosion control blankets, and live vegetation. These all break the impact of raindrop splash and discourage the flow of runoff.

Properly applied soil cover provides many benefits from modulating extremes of soil temperature and moisture near the soil surface to creating an environment favorable for soil micro and macroorganisms. These organisms are responsible for maintaining good soil structure near the soil surface, which is important for water infiltration and gas exchange. Soil covers are temporary soil protection measures used until permanent vegetation becomes established. See figure 66.

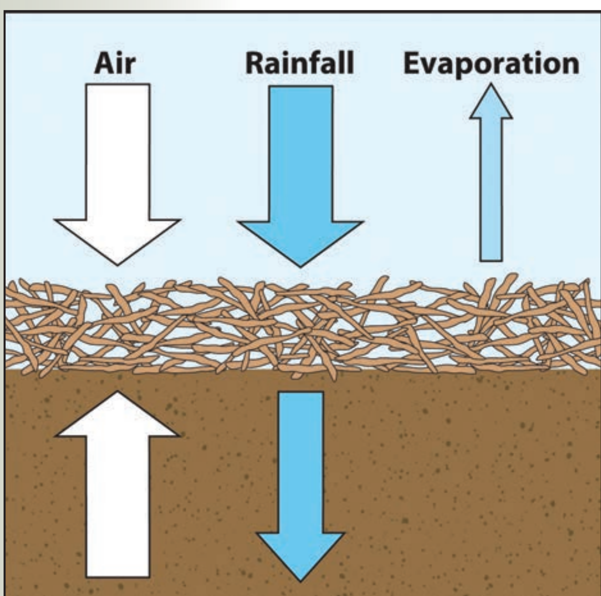


Figure 66—An effective mulch for seed cover is one that is stable and allows good airflow and rain entry, while reducing evaporation from the soil surface (Steinfeld 2007).

Mulch

Mulch includes excelsior, straw, wood shreddings, jute, and coconut (coir) fiber. Mulch protects the soil while allowing for moisture in the air to reach it, moderates the soil temperature—except in alpine environments—and helps keep the roots cooler in summer and warmer in winter (Wyman 1971) (Marinelli 1998). Mulch tends to blend into the landscape. Good mulch has irregularly shaped pieces so it doesn't cake or mat together and it catches debris. On desert test areas, "mulch reduced evaporation from soil, increased infiltration in larger rain events, and increased biological activity in the soil" (Bainbridge (2007). Certain mulches are more acidic or alkaline; match them to the ecosystem. For example, do not import and use pine needle mulch, which is acidic, into an area where pine trees are not native, such as the Mojave Desert.

Wood mulch has a reputation for leaching nitrogen out of the soil as it deteriorates. This also occurs with any high carbon mulch, such as straw, slash, and non-decomposed plant material, used in restoration. Because of the wide carbon to nitrogen ratio, the organisms involved in the decay of the high carbon material immobilize the limited nitrogen available to plants. To counteract this, a nitrogen containing fertilizer can be applied before a high carbon mulch is used (Wyman 1971). Always consult a botanist, soil scientist, or local native plant nursery before applying any fertilizer.

Mulch can be over-applied. Understand the weather pattern specific to the restoration area and apply mulch accordingly. For example, if it's too windy, the mulch blows away. In areas of light rainfall, rainwater may not penetrate the mulch leaving the soil dry (Therrill 2006). At high elevations, especially on north-facing slopes, mulch can prevent the soil from warming up at all. Too much mulch inhibits growth of soil organisms, and favors the growth of non-native plants and woody species over native plants.

Mulch longevity depends on climate. Generally, loose materials, such as blown straw, last approximately 4 months before they noticeably start to deteriorate. Note that even though the product may last 1 year, it does not all disappear at the 1-year mark.

Excelsior, straw, needles, wood fiber, and woodchips are applied as loose mulch. Roughen the soil surface for better mulch adherence. If seeding, do so before applying the mulch. On steep slopes, punch the straw in using track walking (i.e., running tracked machinery over the straw). A shovel also can be used to punch the straw into soil. In high-wind areas, use heavy slash or a staked or stapled erosion control blanket instead. Do not use loose mulch on slopes over 65 percent (Napper 2006).

There are many methods for applying mulch: by hand, plane or helicopter, sky crane, and hydromulch. In large areas, aerial application is less expensive than a contracted on-the-ground application (Napper 2006).

Excelsior

Excelsior is a green wood-fiber product generally made of aspen trees and is applied to bare ground as an erosion control measure. It has a lifespan of approximately 2 years. Excelsior strands have rough edges that interlock with each other holding the strands together. Use untreated, weed-free excelsior.

Mena Showman, San Juan National Forest, reports, “Users actually stay off of it for the most part because they can tell something is actually being done. When we just seeded and put up signs to keep folks off, they pretty much ignored the signs” (Showman 2006). See figure 67.

Figure 67—Excelsior formed into a mat and unrolled at a restoration site. Excelsior is sheltering seeds.

Straw

Use certified weed-free agricultural straw and native hay straw for erosion control. Apply mulch at about 70 percent coverage (Napper 2006). When straw is fed into a blower it is chopped into small lengths. Blown straw shows deterioration at 3 to 4 months (Napper 2006). Rice straw contains silica, which causes it to decompose slower than other agricultural straw. See figures 68 and 69.

Figure 68—Spreading rice straw after the ground has been ripped.

Figure 69—Straw was punched in using track walking.

Pine Needles

Use locally gathered pine needles as mulch. Needles have rough edges that interlock, forming a loose mat that allows water and air to reach the soil. Needles create long-lived mulch, 3 to 4 years (Wyman 1971). In some parts of the country, tree plantation operators sell pine needles. Ask about the tree species and about harvesting techniques to avoid bringing different tree species and weed seeds on to the restoration area. See figure 70.

Figure 70—Pine needles from an adjacent area spread over a graded restoration site.

Wood Strands

Wood strands are a byproduct of veneer manufacturing (WoodStraw™). Wood-strand pieces are engineered to be within certain sizes, 4.7-mm wide by 2.5-mm thick and 160-mm or 64-mm long, causing them to bind together (Foltz 2007b). Wood strands also are dust and weed free and last up to 3 years. On slopes with up to a 50-percent grade use wood strands at 50-percent coverage (Foltz 2008).

Copeland's study (2006) showed wood strands superior to straw for staying in place and for reducing sediment loss in 6.5 meter per second and 18 meter per second winds.

A 2006 study comparing straw, wood strands, and wood shreds at test areas found that wood strands lost only 1 percent of coverage over a 1-year period, which has positive indications for long-term coverage, while straw lost 29 percent, and wood shreds lost 36 percent (Foltz 2007a). While wood strands may last longer, it is heavier, which keeps it in place but also may make it more difficult to transport and apply. See figure 71.

Figure 71—WoodStraw™.

Wood Shreds

Wood shreds are made by feeding cuttings into a grinder. The shreds are all sizes and do not knit together as well as the wood-strands product. Twenty percent of the total weight is in material that is either too large or too small to be of value. The advantage of wood shreds is that it is made onsite; its disadvantage is that it may have had contact with the ground and picked up weed seeds and undesirable soil. In a rain simulation test done at the Rocky Mountain Research Station, wood “shreddings at 30-percent coverage performed as well as published estimates for straw mulch at 70-percent coverage” (Groenier 2005; Foltz 2007). See figure 72.

Figure 72—Wood shreds.

Wood Chips
Wood chips are made from any woody part of a tree or shrub that is run through a wood chipper. Chips are different sizes and shapes and tend to interlock and are long lived.

The State of Texas Department of Transportation (TxDOT) uses a 50/50 mixture of compost and wood chips that supports new plant growth. In tests, this mixture was subjected to strong wind, and it did not blow away. It became TxDOTs standard for erosion control (TxDOT 2004). Always ask the landscape architect, soil scientist, or botanist if this is appropriate for the area's ecosystem.

Hydrocompost and Hydromulch
The main objective of hydrocompost and hydromulch is to prevent soil erosion. In essence, they form a barrier over the soil. They do not prevent seed germination of the existing seed base in the soil, but germination is slower because these products promote runoff (from atop the mulch) so it takes longer for any moisture to actually reach the soil. "Use of hydromulch is a good way to cover expanses of bare ground with a layer of mulch to reduce water droplet [raindrop splash] impact" (Lockwood 2007). Use hydromulch on slopes up to 60 percent. Coordinate hydromulch applications with a resource specialist to determine specific applications. See figures 73a and b.

Figure 73a—Hydromulch fibers form a smooth, dense mat; 73b-A slice of hydromulch.

Hydrocompost With and Without Native Seed
Hydrocompost is a mix of water and clean compost that provides a growing medium. Because it stays on the slope, it has been suggested that this material absorbs more moisture, has lower runoff rates, and allows less soil erosion than standard hydromulch.

Hydromulch With and Without Native Seed
Hydromulch combines water, mulch, and high viscosity tackifier in a slurry that is sprayed on to the ground. Tackifiers in the hydromulch mix cause the mulch to adhere to the ground creating a tight mat for protection from raindrops and overland flow. Several different additives may be mixed to create the desired result. Seeds are often added to the mixture as is fertilizer. The seeds remain dormant until precipitation causes germination.

Experienced crews must apply the hydromulch products because of fluid instability and the handling characteristics of vehicles towing or hauling large volumes of liquid. Follow these successful application approaches:

1. Consult product representatives for compatibility of products and applications.

2. Determine the seed treatment mix by asking a landscape architect, soil scientist, botanist, local native plant nursery, or the local hydromulch supplier. Sterile annual seeds added to the mixture may be more aggressive than native annuals and will produce a quick soil cover that shelters native seedlings.

3. Contact hydromulch companies for assistance in choosing the correct mixture of fertilizer, wet-water products, fire retardants, and application rates. Ensure that the company knows the type and size of equipment planned for applying the mulch.

4. Clearly delineate the boundaries of the treatment area to ensure appropriate application rates.

5. Identify and clearly delineate for the crew and contractor no-treatment areas that may have rocky or shallow soils. See figure 74.

Figure 74—Hydromulch and seeding using a portable tank.

Erosion Control Blanket

Erosion control blanket (ECB), is also known as erosion control fabric, erosion control mat, erosion control product, and rolled erosion control product. An ECB tends to cost more than mulch and has a higher labor cost. An additional cost of installing ECB is the dead-stout stakes or the metal staples used to anchor the ECB to the ground. Metal staples are less labor intensive to install, especially when using a staple gun. See appendix E for stake information.

Generally, ECB is a loosely woven fabric made of coconut fiber (coir), jute, straw, pine needles, or other biodegradable substance. An ECB is priced by the square yard and is sold in rolls. The space between the strands is called the open area, such as 38-percent open area, so the tighter the weave the less the open area and the smaller the openings. Use a tighter weave on sandy soils and on steeper grades. See manufacturers' Web sites for installation instructions and for product specifications, including the open-area size in the product and the appropriate products for high-flow areas.

Note that some ECB is called turf mat. Turf mat is used almost exclusively to hold soil in place and does not allow light to reach the soil. Most brands of turf mat have a synthetic backing that does not biodegrade; do not use these unless absolutely necessary. See figure 75.

Figure 75—Excelsior ECB. Plants are being transplanted through it.

Use ECB where there is a serious threat of erosion; on flat or sloped surfaces where vegetation is harder to grow or will take longer to grow; and on sandy, very dry, or noncohesive soils. Use ECB on deeply incised areas that cannot be filled in and where a sizable, concentrated overland flow is expected.

Do not use ECB with a tight backing or wrapping because birds and reptiles can become trapped (Applegate 2007). If possible, choose a loose weave to ensure reptile movement. Check with local providers or other wildland users to see if other wildlife have been trapped by or have had negative interaction with ECB, such as a bear tearing it up.

ECB longevity is about 1 to 1.5 years (Lipscomb 2006). Longevity is affected by a number of variables, such as blanket material, glue, backing, thread, and climate. Coir ECB lasts about 4 to 6 years.

ECB Installation Tips

Remove any vegetation, protruding rocks, and fill in rills and gullies; smooth the soil surface so the ECB has continuous contact with it. Soil dries out where the ECB bridges over it. Install waterbars to shorten a slope's length dividing it into shorter slopes. Water from the waterbars is dissipated into the existing, healthy vegetation. Apply the ECB. Insert plants between the strands where appropriate or cut ECB with scissors to shape pieces and to install plants. See figure 76.

Figure 76—This excelsior ECB is being installed with great care with stakes and rocks holding it in place. This installation could be greatly enhanced by installing waterbars to stop or reduce the flow of water down the slope and filling in the rills to create a smoother surface.

The "Minnesota Small Urban Area Best Management Practices Manual" provides installation instructions. See <http://www.metrocouncil.org/Environment/Watershed/BMP/CH3_RPPSoilMulch.pdf>.

Barriers

Temporary, visual, and permanent barriers are part of visitor use management. Since every project is local, there is not one barrier that works everywhere. However, there are methods that work in most circumstances. Use barriers to protect ongoing and finished restoration work. Use them in concert with signing and law enforcement. Barriers act as visual cues to encourage visitors to keep riding in a certain direction. Place barriers to discourage visitors from leaving the system trail or approved areas. Barriers reassure visitors that they are on the trail and show that the trail is maintained. However, any barrier can be breached. When a barrier is breached, try to discover why. Was it the barrier type, its placement, lack of trail patrol, and so forth?

Remove a temporary barrier when it is no longer needed or serving a purpose, such as when vegetation has grown in and there is no indication of the former unmanaged OHV use. Some temporary barriers, such as slash, decompose. Leave permanent barriers in place.

Temporary Barriers

Temporary barriers include:

- Felled trees.
- Logs.
- Slash.
- Peeler-core log fence.
- Metal fencing-quick-post bracing system.
- No-dig barriers.

Install temporary barriers just before a restoration project begins. In some instances, these barriers delineate a system trail while blocking access to an unauthorized trail. Once the barrier and optional signing are in place begin work so the public can see that there is a real reason for the barrier. See figures 77 and 78.

Figure 77—The no-dig barriers delineate the edge of a system trail.

Figure 78—This temporary barrier failed primarily because it was easily moved. Another reason may have been that there was no obvious restoration work in progress. A Carsonite® post does not work for the following reasons:
1. It is too narrow to block access.
2. It looks like a trail marker.
3. It is too difficult to read.

While the post is not a barrier, law enforcement personnel use the information on the post as a basis for citing those who violate closure orders.

In certain situations, it is necessary to use two rows of barriers before riders take the barrier seriously. Set the double-row barriers parallel and 10 to 20 feet apart depending on the landscape. Tie or key barriers into dense vegetation, boulders, or other permanent landscape features to prevent visitors from riding around them. See figure 79.

Figure 79—A double row of no-dig barriers is effective here-one at the edge of the restoration effort and one set back into it. The barrier is a strong visual cue.

Felled Trees

Block access at the beginning and along trails with strategically felled trees; this looks natural in wooded areas. Felled trees also create a visual barrier, catch seed-laden debris, and help control erosion. There are at least two ways to place trees across, on, and parallel to unmanaged use areas and unauthorized trails. Personnel on the Ouachita National Forest have had successful closures using the hinging tree method. Jennie Freidhof (2006), Wayne National Forest, explained that hinging means "felling trees across the trail but not separating them completely from the stump. Leaving the tree partially attached to the stump keeps life in the tree much longer, and detracts from the firewood value." See figures 80 through 82.

Figure 80—Felled trees block motorized access.

Figure 81—Felled hardwood and pine trees (see red needles) have successfully deterred further unmanaged OHV use as evidenced by extensive new plant growth.

Figure 82—This felled tree creates a temporary barrier.

Another technique for using felled trees is to place them on the unmanaged OHV area parallel to the flow of traffic. The trunk and branches stop riders. This works where there are large trees and where there is sufficient vegetation or natural barriers to block users from going around the barrier. See figure 83.

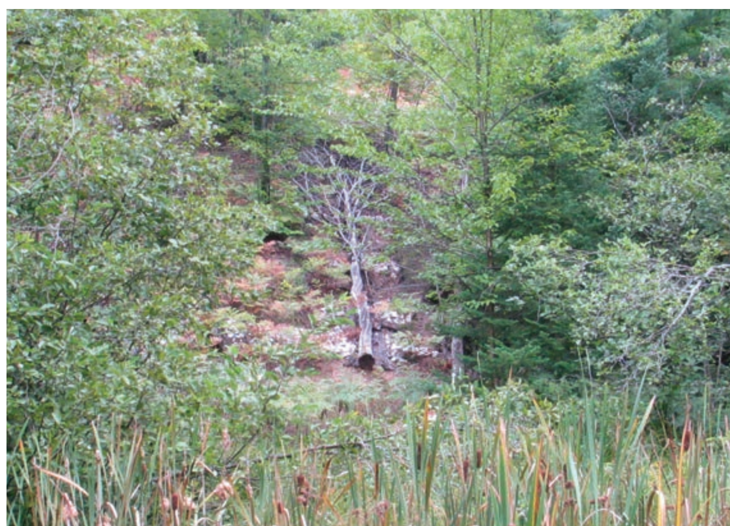


Figure 83—This felled tree was placed on a slope in an unauthorized hill climb trail.

Logs

Place logs horizontally across hill climbs and gentle slopes. Push them into the soil to prevent the soil from moving downhill and to prevent vehicle access. The logs collect seed and debris and provide shelter for seedlings. See figure 84.

Figure 84—On the Rapid River, Manistique Ranger District, Hiawatha National Forest, in northern Michigan, logs help hold soil in place, trap seeds and debris, and provide shade for seedlings. These logs are covered with slash.

Figure 84 shows that the natural slope ends with a 12-inch drop-off. Runoff flows down the slope over this drop and cuts rills into the bank. To speed recovery of proper hydrologic function and vegetation, connect the contours to recreate the natural slope. Eliminate the drop-off by breaking down the edge. Use heavy equipment to slope the edge to create a gradual transition from the ground cover to the exposed soil.

Use an 18-inch-diameter (or greater) log across a banked outside curve, sometimes called an "eyebrow." Place the "bole [log] ... perpendicular to the route with one end buried at the edge of the road [trail] prism and extending up slope above the peak of the eyebrow. This can also be accomplished with boulder placement" (Applegate 2006). Attach a strand of inconspicuous but noticeable heavy wire with numerous fence staples along the length of the log to discourage removal by woodcutters. See figure 85.

Figure 85—Eyebrow protected by log. New vegetation is growing on ravel collected at the base of the slope.

Slash

Slash is the debris left from timber harvesting or thinning. Covering the restoration area with slash gives the ground a chance to rest and rejuvenate. Slash discourages riders because it is difficult to ride over and it can become caught in wheels. The slash also provides camouflage and screening when stacked as a wall along the edge of a system trail. The density of the slash pile often depends on trial and error and knowing the riding clientele. For example, the small slash stacks in figure 86 were enough to keep riders off the restoration area and on the trail. In figure 87 the much larger pile kept most riders off the unauthorized trail, but some found a way through where the slash was not as tall or as thick.

Figure 86—Scattered slash is effective in keeping motorcyclists off the area.

Figure 87—This slash pile was placed to protect the ECB on the unauthorized trail. Unfortunately, it was breached (see the lower left corner). In this situation, the slash needed to be bulky until it reached (or was keyed into) thick, live vegetation.

Scatter slash that is bulky enough to be seen easily; be sure there is good ground coverage. If necessary, add more slash as the first application decays to prevent rider access and/or if vegetation has not had time to grow and fill in. See figures 88 and 89.

Figure 88—Before. Unmanaged OHV area seen from Hog Valley photo point 1, 2007, National Forests in Florida.

Figure 89—After. Unmanaged OHV area seen from Hog Valley photo point 1, 2008, National Forests in Florida. Slash was added to the end of the sightline. The climate is conducive to fast growth. Notice that the partially buried palm trees are thriving and have multiplied; the tree in the foreground is seen as a stump.

Peeler-Core Log Fence

These log fences are quite sturdy. Be sure that each end is keyed into thick brush, a tree, or boulder to help prevent circumvention of the fence. See figure 90.

Figure 90—A double row of barriers provides a strong visual cue.

No-Dig Barriers

There is more than one type of no-dig barrier. This publication discusses a metal fence corner-bracing system and a specific wooden barrier. Neither requires digging.

Metal Fence-No-Dig Quick-Post Bracing System

Build a metal fence using t-posts and 14- to 10.5-gauge welded-wire fencing material. Use the quick-post bracing system to save time and effort. The quick t-post bracing system is similar to the Kiwi wooden brace described in “Fences” (Karsky 1988). See appendix C for construction instructions.

The quick t-post bracing system was developed a number of years ago. The brace rests on the ground, barely touching it. Use the speed brace at corners and gates. When the fence is no longer needed, disassemble it and use the brace at another area. See figures 91 through 93.

Figure 91—Sleeves are mounted over a t-post with side brace t-posts pushed up into side sleeves.

Figure 92—The brace t-post “floats” over the ground and is not anchored.

Figure 93—Metal gate with quick t-post bracing system with barbed-wire fence.

No-Dig Railroad-Tie Barrier

Use no-dig railroad-tie barriers where archaeological areas might be endangered by digging and where the ground is particularly hard. Use reinforcing bars (rebar) to hold the barrier in place. Always check with the forest archaeologist before inserting rebar as this may disturb artifacts. This barrier can be readjusted if pushed out of place. For example, if a barrier is backed over or moved out of place by frost heave, use a digging bar as a lever to right the barrier. Barriers can be removed easily with a jack and, unless the rebar is bent badly, easily reinstalled. See appendix D for construction and installation instructions.

Jeff Applegate (2007), Mendocino National Forest, reports, “We have had very little vandalism or removal of this type barrier.” Visitors do not want to touch creosote, the barriers cannot be used as firewood, and they will not be vandalized or played on. See figures 94 and 95. (On other forests, visitors have been known to steal creosote-soaked wood.)

Figure 94—Installed no-dig barriers. Sections were laid end to end, and the rebar driven into the ground.

Figure 95—A no-dig barrier protecting a hillside.

Visual Barriers

Vertical Mulch

Vertical mulch, also called vertical obliteration, is planted dead shrubs and trees that appear to be part of the natural landscape. Vertical mulch disguises an unauthorized trail or unmanaged OHV area by creating a visual barrier and imitating natural vegetation patterns, thus obliterating the sightline; it also makes riding on the area difficult. Vertical mulch traps seed-laden debris and provides shade and shelter for seeds, seedlings, and animals. It is most visible as a linear feature in desert, grassland, and chaparral landscapes during seasons when surrounding live vegetation is green. See figures 96 and 97.

Figure 96—This photograph was taken in May. By June, the grass and many of the surrounding drought-deciduous shrubs will be brown or leafless and the mulch will blend in.

Figure 97—Yellow flowers have grown at the base of this dead plant used as vertical mulch.

Vertical mulch does not stand out in desert and chaparral landscapes where standing dead and summer deciduous plant material is common. In temperate climates, vertical mulch blends in with deciduous plants in the fall, and by next spring new vegetation has filled in, hiding the vertical mulch. See figures 98 and 99.

Figures 98 and 99—Before and after photographs. Vertical mulch was applied to disguise this unauthorized trail. A thicker treatment is applied at the beginning of the unauthorized trail.

Collect local dead branches and whole plants. Plant them at the beginning of an unmanaged OHV area to the end of the sightline. In general, space mulch to mimic existing vegetation planting distances. Stand where the unmanaged OHV use leaves a system trail; the sightline is as far as one can see evidence of the unmanaged OHV use. Always check to see if the unmanaged OHV use is visible from other vantage points. Thin the spacing at the distal end of the treatment section. In windy areas, anchor the mulch in the hole by adding locally gathered rocks to weigh down the dead wood, and then fill in the hole. See figure 100.

Figure 100—A Student Conservation Association intern is digging a hole for vertical mulch.

There is an art to installing vertical mulch. Ensure that the installation is somewhat diffuse rather than a single-file line of dead plant material following the unauthorized trail. Try to break this line by adding clumps of vegetation, large rocks, or whatever might be indigenous to the area. Vertical mulch may still be noticed, but should not stand out. See figures 101 and 102

Figure 101—Joshua trees grow in clumps or groups, not in lines. As vertical mulch, Joshua trees are not an ideal choice because they create a strong line that stands out. While the landscape under this Joshua tree vertical mulch has healed, it was probably a combination of the trees and the berm at the base of the slope that kept riders off.

Figure 102—This was an early U.S. Department of the Interior, Bureau of Land Management installation of vertical mulch. The brush is too thin and tall, and too widely spaced to look natural, block entry, or catch debris.

In Denali National Park, Alaska, dead trees are planted in groupings to disguise unmanaged OHV areas. Volunteers use posthole diggers to dig 18-inch-deep holes in which they plant 3- to 4-inch-diameter dead trees. These trees could be supplied by thinning operations.

Permanent Barriers

Permanent barriers are built rather than planted or simply laid on the ground and tend to be more substantial than temporary barriers.

Permanent barriers include:

- Welded-wire fence.
- Utility poles.
- Boulders.

See "Vehicle Barriers: Their Use and Planning Considerations" for information on permanent barriers. Be cautious about using what might be considered an urban barrier (i.e., a metal guardrail) in a rural setting. Check the Recreation Opportunity Spectrum for an area's classification.

Welded-Wire Fence

Use a welded-wire fence instead of three single strands of wire. It takes longer to cut through welded wire than through a three-strand fence, so people are less likely to try. Install the fence 6 to 12 inches off the system trail's edge to prevent a vehicle's pedals or a rider's clothing from catching on it.

According to Jeff Applegate, Mendocino National Forest, "The welded wire should be no less than 14 or greater than 10.5 gauge. We usually use the 10.5. It's not as easily bent over or cut. Also, the mesh should be 3 [inches] or less horizontal (wide) and up to 6.0

[inches] vertical. This ensures that feet cannot be inserted in [sic] attempt to scale the fencing. Three to [four feet] is usually plenty of height while still allowing deer/elk to leap over in a single bound" (Applegate 2007). See figure 103.

Figure 103—Welded-wire fence.

Where wildlife passage is a concern, put the bottom of the fence 16 to 18 inches off the ground and the top of the fence no higher than 42 inches (Lis 2007).

Utility Poles

Utility companies often have surplus telephone poles. Use poles to build a barrier across the unmanaged OHV area. Mount poles on sturdy posts approximately 18 inches to 2 feet above the ground.

There are a number of ways to install utility poles, such as hiring a utility company or recruiting utility company volunteers who will bring pole-moving equipment with them. The recreation staff on the Hiawatha National Forest used a feller-buncher to move the poles into place. See figures 104 through 106.

Figure 104—Telephone-pole barrier. The high voltage sign was left on as a deterrent to cutting the pole.

Figure 105—Telephone-pole barrier.

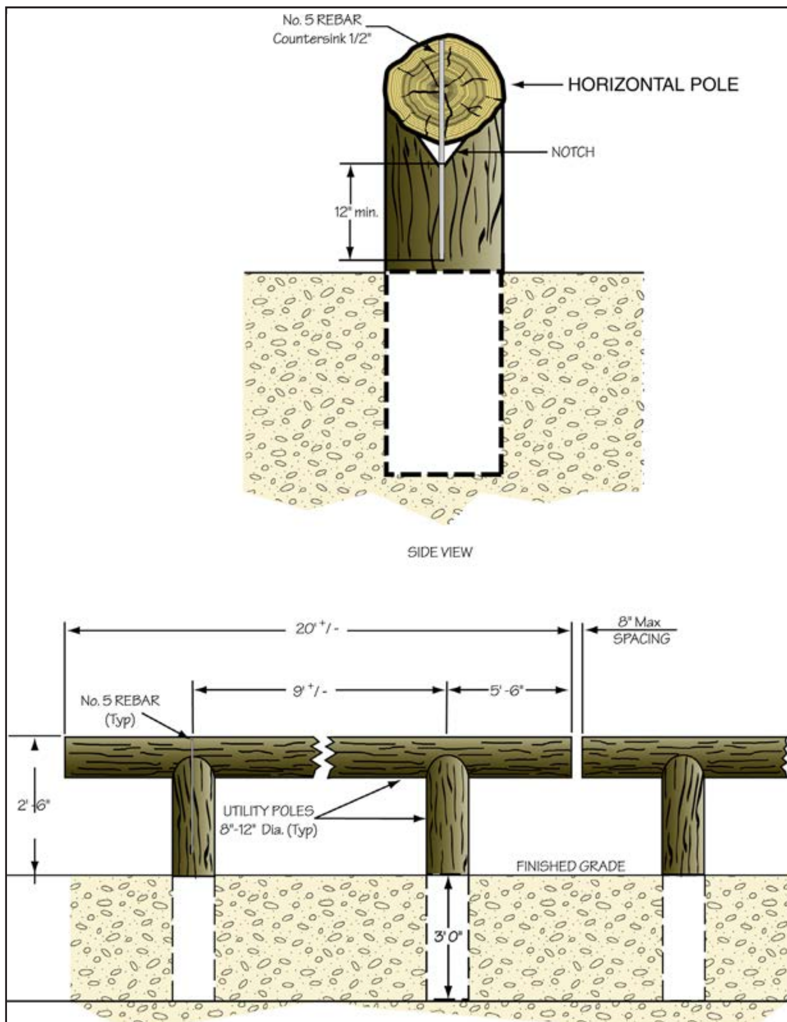


Figure 106—One method of assembling a telephone-pole barrier. Another method is to attach the cross piece to the side of the posts eliminating the need for the notch.

Bollards

Vertical single poles or bollards also can be used as barriers and spaced to allow or block certain sized vehicles. See figure 107.

Figure 107-Bollards delineate this section of a trail. The sign's heading is, "Your dollars at work;" it is sponsored by the Forest Service and Michigan Department of Natural Resources.

Use one or more of these methods to discourage pole cutting:

- Drive 10D pole-barn nails at a 45-degree angle around the pole beginning at ground level and up to the top. Leave the nails partially exposed so they are visible to a would-be sawyer or vandal. (10D equals 3 inches)

- Drill the length of the post and insert a piece of rebar. Leave a tiny length exposed at the end so a person can see it.

- Nail wire mesh to the pole. It takes a while for persons to peel it back, which increases the probability of being caught and represents lost riding time. Some poles on the Hiawatha National Forest have wire mesh attached to the back side to preserve the pole's visual quality.

Boulders

Plant a row of large, 24- to 36-inch boulders as a permanent barrier. Mimic nature by arranging rocks in clusters of one to five and vary space between the rocks and between the clusters. If large rocks are not common to the area, do not use them; they will appear out of place.

Bury one-third of the rock for stability, anchoring, and a more natural look. Tie or key boulders into dense vegetation, or other permanent landscape features to prevent visitors from riding around them. See figures 108 and 109.

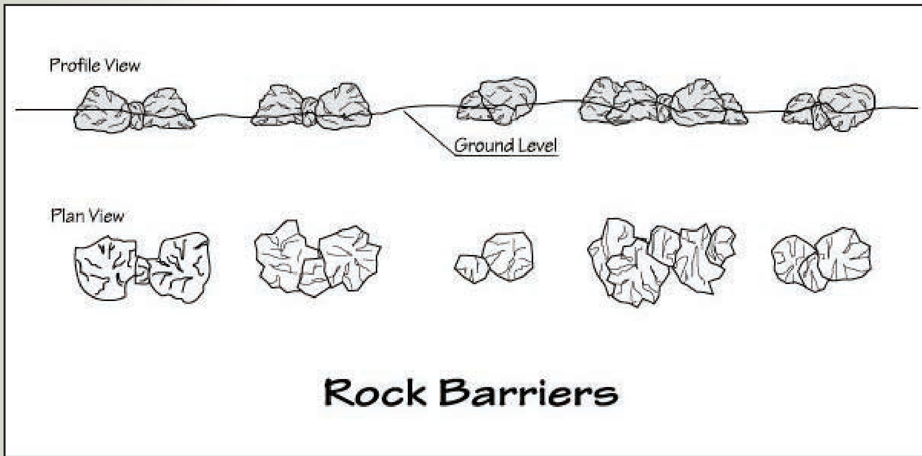


Figure 108—Plant boulders to mimic nature.

Figure 109—Granite boulders define the trail edge and provide shelter for seedlings.

Restoring Vegetation

There are many methods for restoring vegetation to the area. Some of them are listed here, generally from least expensive to most expensive. Use plants and cuttings in small areas. Group plants to block a view to a restored unmanaged OHV area.

When restoring large landscapes, plant vegetation in groups in random patterns to create resource islands of dense vegetation. This process is sometimes referred to as bootstrapping. The resource islands will disperse seed and provide habitat. Take transplants and cuttings from the adjacent landscape (reference site) to reduce the chance of introducing genetically different plants of the same species harvested elsewhere. When treating large disturbed areas, such as concentrated use areas, creating resource islands can be more cost effective than attempting to treat the whole area uniformly with plants.

Seeds

Seeds often lay in the soil, duff, and leaf litter for years without sprouting, creating a seed bank. When conditions are right for a specific species, the seed will sprout. When these layers are missing, the seed bank is gone.

Seeding is most appropriate for treating broad areas and grasslands. Collect seeds from plants surrounding the area. Seed bare ground with native perennial seed mixes and grass seed. When seeds are not covered by erosion control fabric, gently rake a thin layer of soil over the seeds to help keep birds from eating them.

Use caution with seeds to prevent the introduction of genetically different plants. When purchasing seed, make seed selections based on the area's native plants. If there not are enough native-seed sources available, contract for seed collection and/or add sterile nonnative annual seeds to the mix. Do not add sterile nonnative annual seeds in the desert (Bainbridge 2007).

Consult the landscape architect, botanist, soil scientist, or ecologist to suggest a native-seed mix, the seeding rate in pounds per acre, and the season to seed. A local native plant nursery may be able to make informed suggestions, or contact a local chapter of the Native Plant Society; the U.S. Department of Agriculture, Natural Resources Conservation Service; State farm extension; or local college or university botany department for assistance.

Self-Sowing Seed

There are several ways to trap or move local seed to an unmanaged OHV area.

a. Reestablish a seed bank by transferring seeds by taking small amounts of leaf litter, duff, and topsoil from the adjacent landscape and broadcasting the duff and soil over the reshaped area.

b. Use resource islands for their natural ability to spread seeds.

c. Swap a shallow shovel-full of soil from the unmanaged OHV area with a shallow shovel-full of soil from the lee side of a nearby plant. Topsoil harbors seeds.

d. Dig shallow, small indentations called pits to catch debris; debris carries seed. Pits or divots are an excellent restoration method for desert landscapes because the divots collect moisture and protect new seedlings.

e. Use native rock or downed wood arranged to catch seed-laden debris.

f. Rake leaf litter over the unauthorized trail. Duff from the adjacent area carries seed. Do not take all of the duff off one area. Use a light touch.

See figures 110 and 111.

Figure 110—Debris caught in a shallow pit; seedling in pit.

Figure 111—Rock shelter.

Desert Seed

Collection

Seed production varies from year-to-year based on rain, and seed quality varies based on pollination success, and so on. In a good production year, gather as many seeds of the appropriate species as possible and bank them. The maturity of the seed is based on how rain, wind, and temperature affect plants, so some seeds may never sprout. Seed viability after harvesting varies with the species. Most seeds need to be scarified to sprout (Bainbridge 2007).

Fungi and pests may be on the seeds when they are harvested; drying the seeds and storing them at subzero temperatures eliminates most pests. Store seeds in rodent-proof containers. "A Guide for Desert and Dryland Restoration" explains several nontoxic methods for lowering the risk of fungal infection of seeds and of spreading pests (Bainbridge 2007).

In the Mojave Desert, broadcast seed and hydroseed in the fall. In the Sonoran Desert, seed November through March or during the summer rainy season. In the Great Basin and the Chihuahuan Deserts, check with the forest biologist, local native plant nursery, or contact a local chapter of the Native Plant Society to determine when to seed.

Transplants

Vegetative transplants make trails disappear by blending into the landscape for an almost instant restoration. In mixed conifer and hardwood forests, transplant plants in the fall. In spring, the transplanted deciduous vegetation will leaf out with the existing vegetation. The time of year plants are dug up will affect their survival. Transplant from late fall to early spring; do not transplant plants during the hot, dry summer when plants are particularly stressed. If necessary, consult a local nursery for the best times to transplant. In sandy conditions in the Midwest, transplanted shrubs and trees have high success rates, cuttings do not. See figure 112.

Figure 112—Locally transplanted trees with straw mulch.

Use a tree spade to transplant sizable trees. Replant vegetation immediately or place plants in wooden boxes, plastic containers, or burlap, and keep the roots moist. Store the plants in a shaded area for replanting later. Mass transplants at the beginning of an unauthorized trail and thin their spacing at the distal end of the treatment section. Recreate vegetation patterns from adjacent landscapes. See figure 113.

Figure 113—The small conifer trees were transplanted to the edge of a vegetation line on a highway where OHV users had created an unauthorized trail into the woods. The trees blend in with existing vegetation and block the view from a highway into the unauthorized trail.

In climates with sufficient rain or high water tables, transplant forbs, shrubs, and trees from adjacent areas when they are dormant in late fall, winter, and early spring. Cut plugs to transplant forbs and grasses. Transplant sizable shrubs and trees, such as a young sapling 5 feet tall, to block a trail entrance and obscure the trail from view. Most plants need sufficient root balls and soil moisture to survive. On the other hand, some plants, such as yucca, require very little water to survive. See figures 114 and 115.

Figure 114—These five Yucca whipplei were transplanted from a few hundred feet away and are thriving in this hot, dry pinion pine and juniper landscape. This area receives some snow in the winter and occasional summer thunderstorms.

Figure 1.115—Transplants with cages to keep deer browse to a minimum.

In Denali National Park, Alaska, with an annual precipitation of 14 inches and soil temperatures between 22 and 33 degrees Fahrenheit (°F), 6-inch-diameter spruce trees were transplanted on to unmanaged OHV areas with a 75-percent-plus success rate (Tomkiewicz 2006). Trees are shallow rooted, and a tree spade mounted on a miniloader was used to transplant them. See figure 116.

Figure 116—Transplanted trees get support.

In high alpine areas, the tundra is cut like sod and moved to unautorized trails. First, till any compacted soil layers in the tread and then, transplant the "sod." Because of the extreme amount of daylight during summer months in Alaska, plants root quickly. See figures 117 through 119.

Figure 117—Harvested tundra being transported.

Figure 118—Transplanted tundra will soon blend in with existing vegetation and, along with transplanted saplings, will erase this shortcut.

Figure 119—High altitude transplants are growing on this former user-made hill climb. The excelsior ECB that once covered the hill climb has deteriorated.

There are a number of plant material types for transplanting. See table 3 for general information.

Table 3—Comparison of plant material types for revegetation planting (Steinfeld 2007)

Type	Advantages	Disadvantages
Balled-in-burlap The plant is grown in the field, dug up with its roots and surrounding soil, and wrapped in a protective material such as burlap.	• Well-developed root systems increase chances of survival on site • Provide shade and earlier establishment of upper canopy on site	• Expensive • Large and heavy to transport
Bare-root The plant is sold without any soil around its roots.	• Less expensive • Easier to transport to site, lightweight to carry around for planting • Roots have not been restricted by containers	• Require care not to let root systems dry out before planting. • Difficult to establish in dry sites or sites with warm, sunny spring seasons.
Container The plant is sold in a container of potting media or soil with drainage holes. Sizes and shapes of containers range from very small to very large.	• Well-established root systems with intact soil • Provide "instant" plants on site • Available in a variety of sizes, many are available year-round • Can be planted all year long	• Native soil not used in nursery, transplant shock may occur when roots try to move into native soil • Can be expensive • Can be difficult to transport to and around site if large numbers are used • Can be difficult to provide irrigation until established, may actually require more maintenance than plug
Liners/Plugs A small plant, rooted cutting or seedling that is ready for transplanting. They are often used for herbaceous plants and grasses.	• Well-established root systems with intact soil. • Easy to transplant, plant material pops out of containers easily	• Same as above • Smaller plants may take longer to establish, require more initial maintenance
Cuttings A piece of branch, root or leaf that is separated from a host plant and used to create a new plant. These may be placed in a rooting medium or stuck directly into the ground for planting.	• Inexpensive to produce; Cuttings may easily be taken on site or from nearby site • Easy and light to transport Known to work well in rocky areas or areas difficult to access	• No established root systems • Timing of taking cuttings and planting them is important, varies among species limited to dormant periods
Salvage Native plants that are removed from a site (to a nursery, storage area, or directly to another field location) before ground disturbance at that site occurs. (Can also refer to salvaged cuttings or seed sources.)	• Can use plant material that would otherwise be destroyed • Plant material could be local to site • Relatively inexpensive • Small or young salvage plants often adapt more readily to transplant than do mature specimens	• Different native plants respond differently to being dug up, some loss could be expected • Requires fairly intensive measures to protect plants and ensure they have adequate irrigation

Nursery-Grown Stock

The Forest Service has six nurseries that may be able to assist with projects. See the references section for Forest Service nursery contact information. A local chapter of the Native Plant Society can also provide native plant information and assistance. See figure 120 and 121.

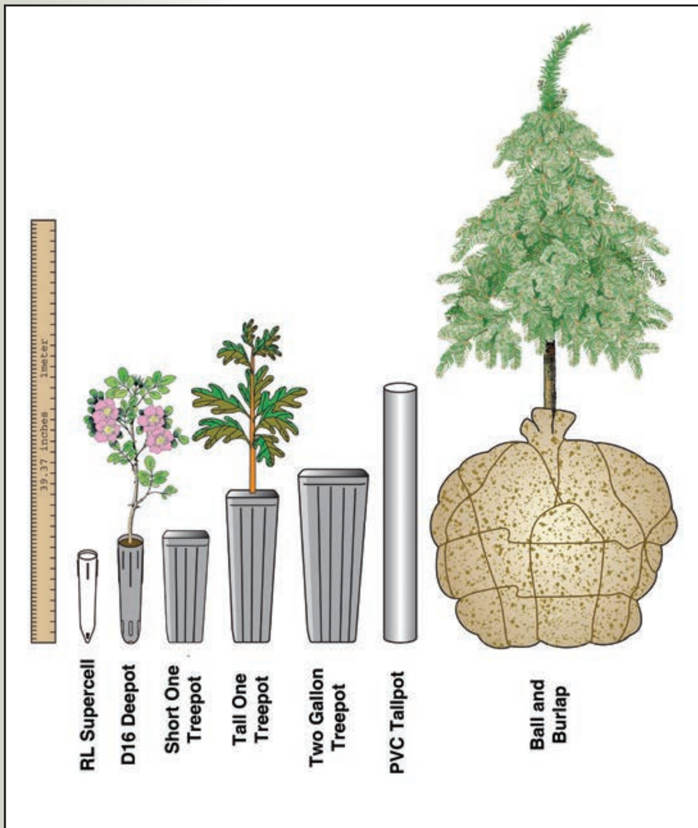


Figure 120—Nursery stock is available in many container sizes and shapes. Consider the advantages and drawbacks of different options before ordering plants (Steinfeld 2007).

Figure 121—These native plants were grown at the San Bernardino National Forest's small native plant nursery and are ready for planting.

Contract with local native plant nurseries to grow seeds that have been harvested in the project area. Do not introduce nonlocal, nonnative plants, or nonlocal native plants into the landscape. The gene pool may be different and could change the area's ecosystem. See figures 122 and 123.

Figure 122—Nursery-grown pines planted in restoration area. Grasses and palms have come up on their own.

Figure 123—The plastic pipe cut into sections is used as tall pots. The smaller square pots are called plant bands. Each is open at both ends. Tall pots allow the plant to grow for several seasons. Once the plant is in the ground and after soil is packed around the pot, the pot is slid up and over the plant causing little root disturbance (Bainbridge 2007). In the Mojave Desert, the holes were hand dug. Where available, use an auger attached to a mechanized piece of machinery to dig holes.

Bare Root

Plant bare-root stock in the fall, early winter, or spring when the leaves are off the trees. Bare-root planting is especially effective in areas that are closed for the winter. Plants leaf out as the rest of the forest comes back to leaf; plants, especially large, bare-root shrubs and trees, look as though they have always been there.

In desert and chaparral landscapes, plant very young stock. The older plants have larger root systems, which may need more water than is available. Plant during the wet season. See figure 124.

Figure 124—The native willows in middle ground were started in a nursery and transplanted along an intermittent stream.

Most, if not all, small nursery stock needs protection from the elements. Provide protection for seedlings from animals and from day long, hot sun. A tight circle of rocks can protect a seedling from extreme temperatures. Plant tubes or shelters give the plant a chance to establish roots and grow. A wire cage is better for plants with a spreading growth habit than are tree shelters. Cages of wire or plastic mesh, some extending into the ground, protect against burrowing and grazing animals, while solid plastic sleeves also provide shade as the seedling grows. See figures 125 through 127.

Figure 125—Create a microclimate around seedlings using corrugated plastic tree shelters to enhance moisture and temperatures for seedling growth. They also protect plants from animal browsing (Steinfeld 2007).

Figure 126—Install rigid netting 3 inches below the surface to protect the seedling from gophers; the foliage and terminal leader are protected from browsing cattle, deer, and elk (Steinfeld 2007).

Figure 127—Transplant with liner, collar, and screen. Do not use these in clay soil or on flood plains. If the tree still needs protection, construct a 6-foot-tall wire cage for the plant that is wide enough to avoid interference with its branch structure (Steinfeld 2007).

See Bainbridge (2007) “A Guide for Desert and Dryland Restoration” and Steinfeld (2007) “Roadside Revegetation” for more information on protecting seedlings <http://www.wfl.fhwa.dot.gov/td/publications/revegetation.htm>. Information on moving nursery stock is available in “Wilderness and Backcountry Restoration Guide” (Therrell 2006).

Desert Seedlings

In deserts, plant seedlings with good root systems to increase the plants' chances of survival (Bainbridge 2007). Contract with a nursery to grow plants from seed. Specify what type of container to use for hardening-off plants. Ask the plant biologist for advice. Plants can be shipped or transported in containers or bare root. Certain plants will not survive bare root handling. See Bainbridge (2007) for explanations on container types, and for planting and watering techniques. See figures 128.

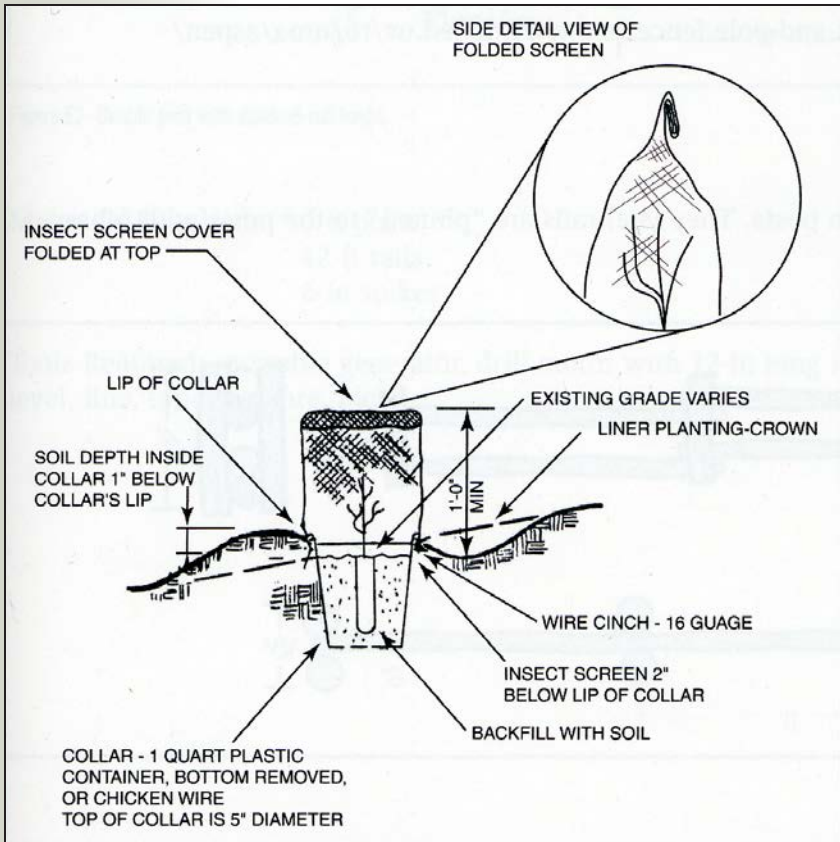


Figure 1.128—A description from Pacific Gas and Electric says, "The planting collar is used to aid establishment of adapted woody plant species in nonirrigated extensive natural and landscaped areas. It is most effective at difficult [to reach] disturbed sites with well-drained soils where plants are to survive and grow under the existing environmental conditions" (Griggs and Stanley 2000). The collar increases the soil temperature to promote root growth and protects roots. It also concentrates moisture at the root zone. The attached screen protects against browsing and insect infestation during the first growing season. The collar is not appropriate in clay soils because of frost heaving or on flood plains (Griggs and Stanley 2000).

Cuttings

Take cuttings from deciduous plants when they are dormant and plant the cuttings in early spring. It is important that there be no leaves on the cuttings. For a list of plants that grow well from cuttings see “Soil Bioengineering for Streambanks and Lakeshores” (Eubanks 2002) or the “Natural Resources Conservation Service Engineering Manual, Chapter 16” (NRCS 1996). See figure 129.

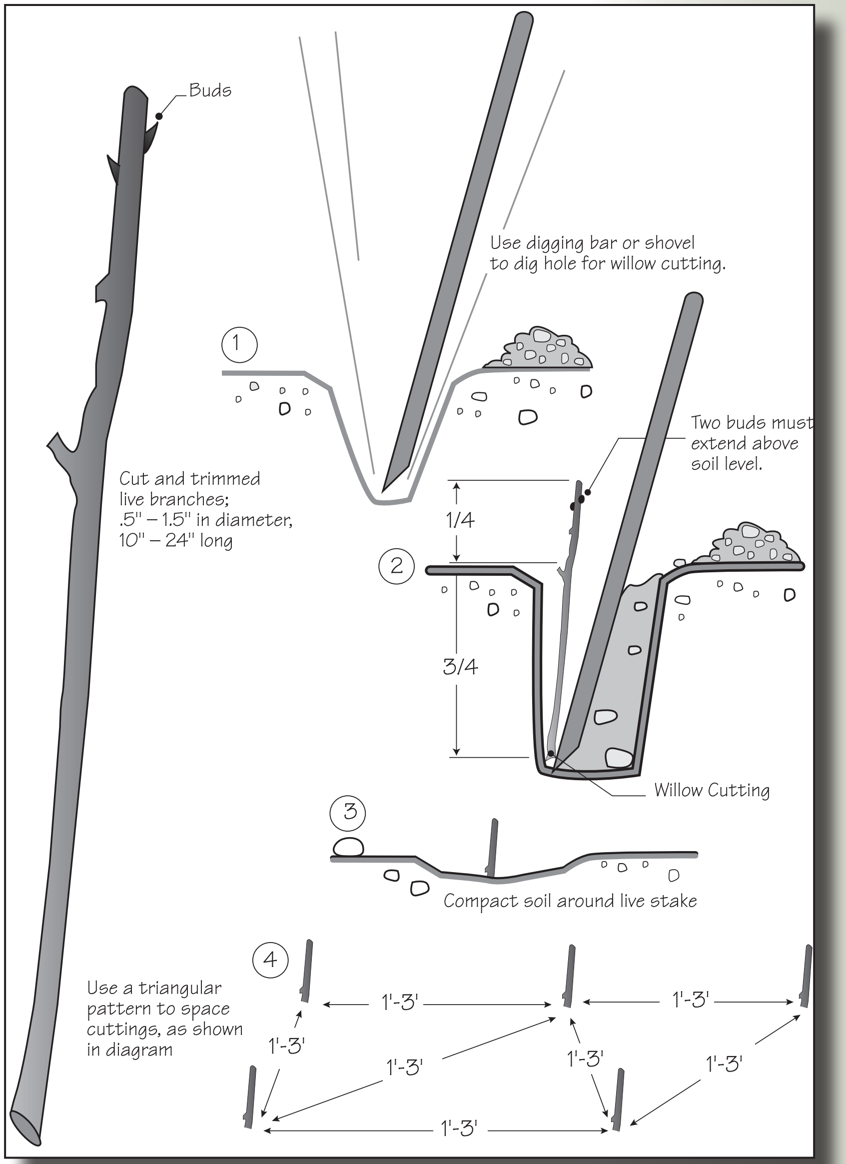


Figure 129—Live cutting.

Harvesting and Storing

Cutting lengths vary with the species and the sources. Cuttings can be used within a day or two or stored through the winter.

- Harvest cuttings from branches that are at least 1-year old, but not older than 12 to 15 years. DO NOT cut branches with old, heavily furrowed bark, diseased or insect-infested growth, dead or broken branches, basal shoots, or suckers (Hoag 1994).
- Consider the esthetics of the plant when selecting cuttings, DO NOT cut off more than one-third of a single plant's branches. Avoid public use areas, such as campgrounds, picnic areas, fishing areas, roadways, and so on (Hoag 1993).
- Shield cut branches from the sun at all times and keep them as cool as possible.
- Store cuttings in a cool place, such as a walk-in refrigerator, at between 34 to 45 ˚F, or in the dark for several months. Wrap cuttings in burlap or peat to keep them damp.
- Before planting, move cuttings outside and soak them for at least 24 hours and up to 14 days. This brings the cuttings out of dormancy, leaves them well hydrated, and causes the root buds to swell. See figure 130.

Figure 130—Live willow cuttings soaking before use.

- Remove (by cutting) the apical bud at the top.
- On 4- to 6-inch-diameter post cuttings, dip the top 1 to 2 inches of each post in a mixture of equal parts latex paint and water or paraffin to seal it. This decreases desiccation and tells you which end is the top (Hoag 1992).

Planting Live Cuttings

- Plant 2 to 3 feet below the surface where soils are moist or where the end of the cutting reaches into the dry season water table.

- Install the basal end, not the top; the buds always angle upward.

- Insert the cutting into the ground without tearing the bark. The bark shields the cambium layer, the vascular system for the plant. The cutting will not survive if the cambium layer is damaged when the bark is torn.

- Use a dead-blow hammer for installation to avoid splintering or mashing the top of a cutting.

- Ensure good soil-to-stem contact or the cutting will dry out and fail to sprout. See figure 131.

Figure 131—A growing live cutting. Second-year growth on a silver cottonwood live post visible in the foreground and background.

Cactus Cuttings

Harvest a cactus using long-handled barbecue tongs or snake grabbers. Place the tongs on the plant at a joint or at the ground level and turn the tongs, the cactus should breakoff cleanly at the joint.

Tammy Pike, Tonto National Forest, reports that the prickly pear cactus (Opuntia) roots easily and spreads quickly in the Sonoran Desert. Harvest cuttings when the cactus is plump and hydrated, and plant them right away. Plant November through March and during the summer rainy season. If transplanting is done during the rains, make sure that the soil drains. Bury one-third to one-half of the cutting; enough so that it stands upright on its own (Pike 2008). Be aware that the cutting may become sunburned because there is no root system. Do not plant cuttings in the dry, hot summer. See figures 132 and 133.

Figure 132—These cactus cuttings were planted in May 2005.

Figure 133—The same cuttings in February 2011. Low shrubby species and grass also are making a comeback.

In the Mojave Desert, the Bureau of Land Management has successfully grown the silver cholla *(Cylindropuntia echinocarpa)* from cuttings. Unlike the method used in Arizona, the Mojave method calls for scarifying the cutting before planting. The cuttings are left outside for 7 days to prevent mold and mildew from forming (the cut area becomes callous), and then are "lightly pushed in to the soil ... This mimics one of the natural propagation methods for this species" (part of the plant dropping to the ground) (Gartland 2008).

Note: *Cylindropuntia echinocarpa* is a protected species. Before taking a cactus cutting, find out if the plant is listed as a threatened or endangered species and if any permits are needed. See figures 134 and 135.

Figure 134—Silver cholla (Cylindropuntia echinocarpa).

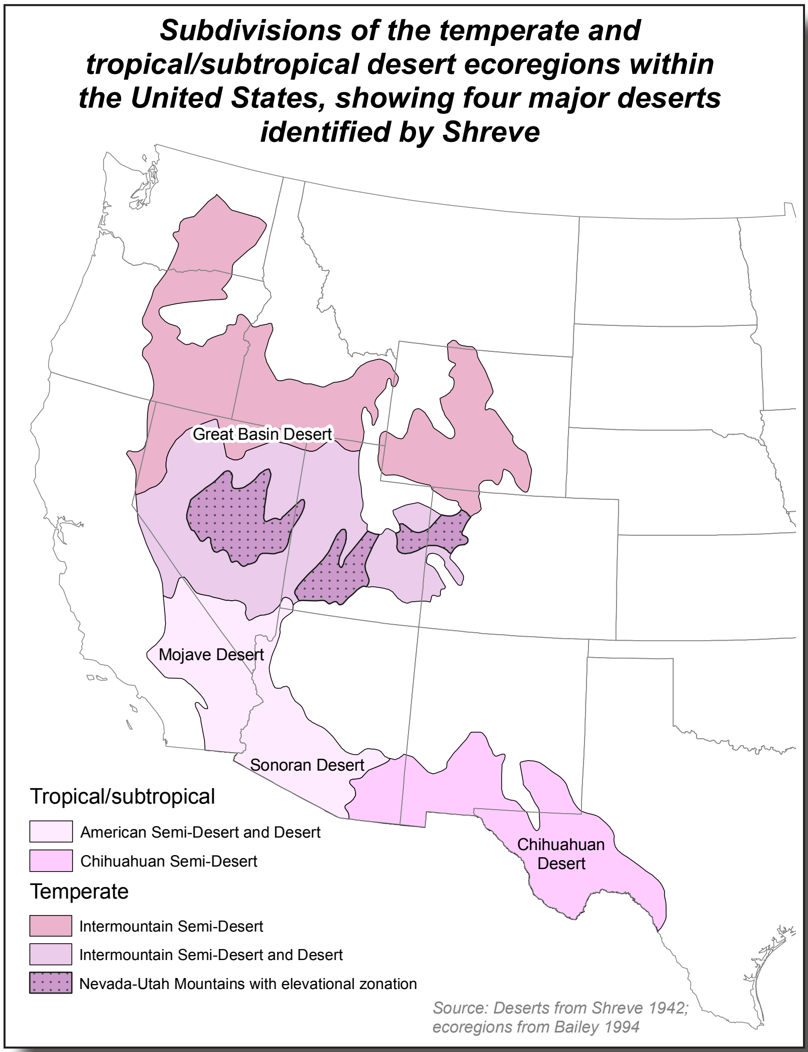


Figure 135—Map of deserts of the United States. Courtesy of South Central Service Co-op, Arkansas, Outwest Group/Richard Lachowsky, photographer.

Hill Climbs, Through Cuts, and Gullies

Hill climbs follow the fall line of the slope, that is, they go straight up and down. Over time, vehicles accelerating throughout the climb, precipitation, channeled runoff, and wind erode these unmanaged OHV areas leaving deep and wide incisions; expose roots, rocks, and mineral soils; and deposit sediment at the bottom of the slope. These incisions change the surface and subsurface flow and dewater adjacent slopes, leading to plant mortality and weakness of vegetation adjacent to the hill climb. Ridge-top trails also change surface and subsurface flow patterns by diverting surface water away from its natural pattern and by compacting soil, thus changing the percolation rate and pattern. Hill climbs can turn into through cuts, and gullies often form in hill climbs, which can erode entire hillsides. See figures 136 and 137.

Figure 136—This unauthorized hill climb trail shows downcutting of the soil, exposing tree roots and the beginnings of a gully in the center.

Figure 1.137—Hill climbing resulted in destroyed vegetation, exposed roots, and eroded soil (deep downcutting).

Repairing Hill Climbs, Through Cuts, and Deep Gullies

In every situation, build a berm and energy dissipaters to block overland flow at the top of the affected area at the source of the concentrated flow. On long wide slopes, install cross slope drainage swales, and cover the slope with mulch to help prevent further erosion. Build in lateral “natural” swales to drain the surface runoff to stable, vegetated areas. On ridge-top unauthorized trails install V-bars with apexes pointing up the center of the trail. The goal is to divert concentrated flow to redistribute it evenly to both sides of the ridge.

Use a large excavator on a very steep slope because it is more stable than a small excavator or other mechanized equipment and has a long reach. It also has the power necessary to negotiate steep slopes.

This publication discusses three approaches for repairing hill climbs, through cuts, and deep gullies. Depending on the severity of the damage and situational circumstances use one or a combination of these three approaches: on-hand material, imported fill, or reshaping the hillside. Size the equipment, dozer, excavator, appropriately to the task and the size of the project.

On-Hand Material

Using on-hand material, pull soil into the incision from built-up berms and adjacent slopes and from the bottom of the slope, and grade the area. On gullies and hill climbs, which are 2 or 3 feet deep with occasional spots 4 to 5 feet deep, remove existing vegetation and stack it for use later as slash. In open areas, clear the area some distance on each side of the hill climb to allow movement of the machinery. Use a large excavator to pull in soil and debris. Pull as much sediment from the bottom of the slope as possible. Roll the excavator over the fill to compact it. Use the excavator to scatter any woody debris and slash across the restored area after soil is in place.
See figures 138.

Figure 138—Soil has been downcut, leaving islands of trees and changing the subsurface and overland flow patterns. Concentrated flow accelerates in the downcut area. Displaced soil collects at the bottom of the hill, covering any vegetation that may have grown there.

Figure 136 shows one approach for restoring the landscape at the site of a severely downcut unauthorized trail. Remove the perimeter trees and stockpile them, then rip the surface of the unauthorized trail. Bring in fill from the bottom of the slope to reconnect the contours. Fill layers are 4 to 6-inches thick. (See page 43 through 45 for more information on fill and layers.) Compact each layer to the soil density found in the reference area soil (adjacent intact slope). Cover the final layer, top soil, with duff from adjacent to the area. Place felled trees and other extracted plant materials over the area. The trees will block access, and they and other plant materials will slow overland flow, catch debris, and drop seeds on the area.

Imported Fill

Importing fill soil requires an existing access route wide enough for a truck. Truck in fill material to fill gullies and hill climbs incised deeper than 3 or 4 feet, with occasional spots 7 to 8 feet deep, and when there is no onsite soil or not enough. Add soil in 4- to 6-inch layers. Compact each layer. Reshape the area to reconnect contours to the existing landscape. On slopes greater than a 2-to-1 ratio, add a structural component, such as a rock or retaining wall keyway or geogrid. See figures 139 though 142.

Figure 139—Continued downcutting displaces soil and ravels to the bottom of the hill.

In figure 140, there is no accumulated soil at the bottom of this hill climb to use for restoration. To restore this hillside, haul in fill and add it in layers to connect the contours. See page 43 through 45. Using a berm, block concentrated flow at the top of the gully. Install waterbars at intervals to shorten the slope, and dissipate the water into intact vegetation on either side of the gully. Mulch the slope. There is an access road at the bottom of the slope.

Figure 140—A 5-foot-deep hill climb through cut created by unmanaged OHV use. The depth and steepness of this hill climb require using retaining walls or boulders placed at intervals to hold the fill in place. There is vehicular access for delivering fill at the bottom of the climb. (see appendix F).

Figure 141—The slope between the trees is a 60 percent slope. A gully approximately 40-feet wide and 15 feet deep was caused by OHV use and acerbated by weather conditions. Numerous rows of retaining walls are buried in the fill. Fill was brought in from catch basins on the area. There is an access road at the top of this hill.

Figure 142—This segmented timber-lagging retaining wall is a structural component holding the fill in place.

Repairing Through Cuts by Reshaping

A through cut is a worndown hill climb that creates a saddle usually leaving a channel through a section of a hill; this can occur on any slope grade. The channel could be 12 inches to greater than 8 feet deep and wide; it could be a short or long section of a hillside, and it could be eroded all the way to the base of the hill. In the worst situations, for example a hillside with two or more large or profound through cuts, reshaping the hillside may be the only option for a full restoration. Do not treat each cut individually. Reshape and rebuild the hillside to blend the restoration in with the nearest hill and ridge. It is similar to forming a landfill to resemble a natural looking hill or slope. See figure 143.

Figure 143—A truck can be driven through these through cuts in the Sonoran Desert.

Remove existing vegetation; stack it for later use as slash. Remove any topsoil to a secure area; cover it to keep it intact. Break down ridges and divisions between the cuts. If there is not enough soil available, use a borrow site in a reference site to avoid introducing weeds and unrelated plants.

Add fill in 4- to 6-inch lifts; contour the fill to match the surrounding land. Compact each layer. Gradually decrease the compaction density as the fill approaches the surface. Less densely compacted soil near the surface allows moisture infiltration and provides a medium for rooting plants. See page 43 for determining proper soil compaction. Create drainage swales to move water laterally off the restoration site.

On slopes greater than 2 to 1, add a structural component, such as a rock or retaining wall keyway or geogrid. See appendix F for detailed construction instructions. In wet climates, use vegetated geogrids. See appendix G. See figure 144.

Figure 144—Treat these through cuts as one project by obliterating the affected part of the slope and rebuilding and shaping it to blend with the natural topography.

Soil Bioengineering Techniques

Where there is enough soil moisture to support sprouting and rooting, use soil bioengineering to stabilize hillsides and streambanks and to augment other methods. Vegetated geogrids, branch layering, and live posts add structural components to fill. Use live posts for vertical reinforcement to help prevent slides. See appendix G for specific techniques.

Note that live plant material will only survive and grow on wet slopes, in water, and in riparian areas where the dry season water table is 2 to 3 feet below the surface. Plant cuttings and transplants in these wetter soils.

Repairing Streambanks

Where unmanaged OHV use has occurred through streams and other wet areas, and where system trail crossings are ill placed, banks often are disturbed and need repair. These soil bioengineering methods may be applicable: tree revetment, live cribwall, root wad, live siltation, trench pack, brush mattress, dead and live fascines or wattles, vegetated geogrid, coconut log, jute-mat log, and native rock. When using these methods in a stream, trench down to a depth below the anticipated scour, build from there to protect the toe of the bank from wash out. Plant materials take root and grow, thereby stabilizing and shielding the bank or shoreline. See figures 145 and 146. For extensive information, see <http://www.fs.fed.us/publications/soil-bio-guide/> and <http://www.nrcs.usda.gov/Internet/FSE_PLANTMATERIALS/publications/idpmcpu116.pdf>.

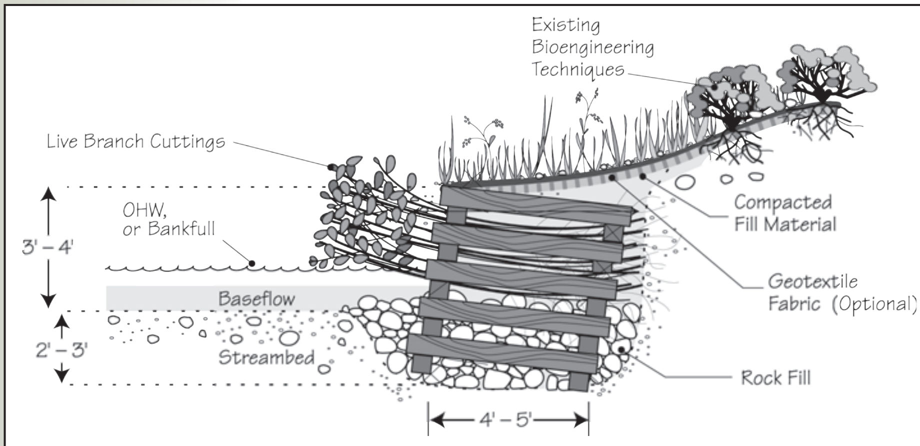


Figure 145—Live cribwall. A live cribwall is a boxlike interlocking arrangement of untreated logs or timbers used to rebuild the bank in a nearly vertical setting. The structure is filled with rock at the bottom and soil beginning at the ordinary high water mark or bankfull level. Layers of live branch cuttings root inside the crib structure and extend into the slope. As the live cuttings root and become established, the vegetation takes over the structural functions of the wooden members.

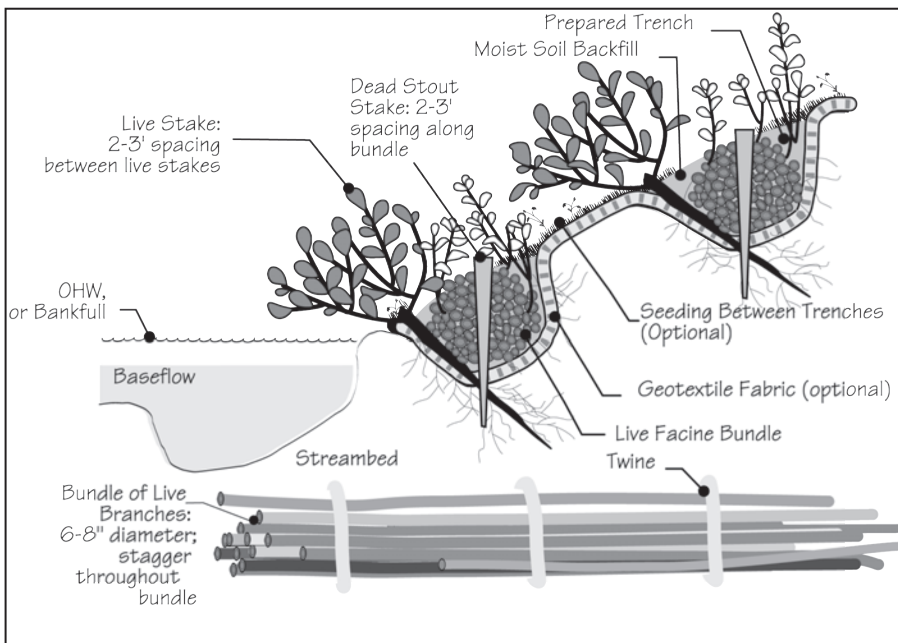


Figure 146—Live fascine. A live fascine is a bundle of live cuttings placed in a shallow trench to reduce erosion and shallow sliding. Roots from the sprouted fascine help stabilize the bank, while branches and leaves shield the bank.

CHAPTER 3 - RESTORING OHV DAMAGED WETLANDS

This chapter was written by Thomas R. Biebighauser, wildlife biologist, Forest Service, Region 8, Daniel Boone National Forest. All photographs in this chapter were taken by Biebighauser unless noted.

Wetlands are fascinating, critical, and dynamic features of forests and grasslands. Restoring wetlands damaged by off-highway-vehicle (OHV) use can be important for the survival of individual plant and animal species, as well as the maintenance of healthy ecosystems. This chapter is divided into four sections. The first defines and describes wetlands and how they work as ecosystems. The second discusses how OHVs damage wetlands and how to identify the damage. The third offers step-by-step directions for restoring surface-water and groundwater wetlands, and the fourth presents two case studies. See figure 147. Damage is defined as "…setting standards that clearly specify the maximum amount of a particular impact to be tolerated. Impacts that exceed the standard become "damage" (Washburne 1982). See figure 148.

Figure 147—Healthy, thriving, restored wetland.

Figure 148—Damaged bog.

Wetlands

Wetlands are areas that contain shallow water on or near the surface during all or part of the year, sustain plants that are adapted to life in water or on wet ground, and have soils that are saturated or poorly drained for part of the year. Included in this definition are areas containing water seasonally known as ephemeral wetlands and vernal pools. As much as possible, the wetlands described in this chapter are named using the "Classification of Wetlands and Deepwater Habitats of the United States" by the U.S. Department of the Interior, Fish and Wildlife Service (Cowardin 1979).

Wetlands are wet, muddy places full of life; they look and smell different than dry land. These environments support cattails and bulrushes, wood ducks, shorebirds, dragonflies, frogs, beavers, and more. Wetlands can be found most anywhere—near rivers and streams, on hillsides, and even on mountain tops.

The following, from the U.S. Environmental Protection Agency's What are Wetlands? Web site, is presented to further describe wetlands.

> … Water saturation (hydrology) largely determines how the soil develops and the types of plant and animal communities living in and on the soil. Wetlands may support both aquatic and terrestrial species. The prolonged presence of water creates conditions that favor the growth of specially adapted plants (hydrophytes) and promotes the development of characteristic wetland (hydric) soils.
>
> Wetlands vary widely because of regional and local differences in soils, topography, climate, hydrology, water chemistry, vegetation, and other factors, including human disturbance. **Indeed, wetlands are found from the tundra to the tropics and on every continent except Antarctica**. Two general categories of wetlands are recognized: coastal or tidal wetlands and inland or nontidal wetlands. See figure 149.

Figure 149—Wetland alongside a stream in Turnagain Arm, Alaska. (Photo by Scott Groenier.)

Tidal wetlands in the United States, as their name suggests, are found along the Atlantic, Pacific, Alaskan, and Gulf coasts. They are closely linked to our nation's estuaries, where seawater mixes with freshwater to form an environment of varying salinities. The saltwater and the fluctuating water levels (due to tidal action) combine to create a rather difficult environment for most plants. Consequently, many shallow coastal areas are unvegetated mudflats or sandflats. Some plants, however, have successfully adapted to this environment. Certain grasses and grass-like plants that adapt to the saline conditions form the tidal salt marshes that are found along the Atlantic, Gulf, and Pacific coasts. Mangrove swamps, with salt-loving shrubs or trees, are common in tropical climates, such as in southern Florida and Puerto Rico. Some tidal freshwater wetlands form beyond the upper edges of tidal salt marshes where the influence of saltwater ends. See figure 150.

Figure 150—Pacific coast tidal wetland.

Non-Tidal wetlands are most common on flood plains along rivers and streams (riparian wetlands), in isolated depressions surrounded by dry land (i.e., playas, basins, and 'potholes'), along the margins of lakes and ponds, and in other low-lying areas where the ground water intercepts the soil surface or where precipitation sufficiently saturates the soil (vernal pools and bogs). Inland wetlands include marshes and wet meadows dominated by herbaceous plants, swamps dominated by shrubs, and wooded swamps dominated by trees. See figures 151 through 153.

Figure 151—Restored inland seasonal wetland in mixed hardwood forest. Daniel Boone National Forest.

Figure 152—Wet-meadow wetland. Roosevelt National Forest, Colorado.

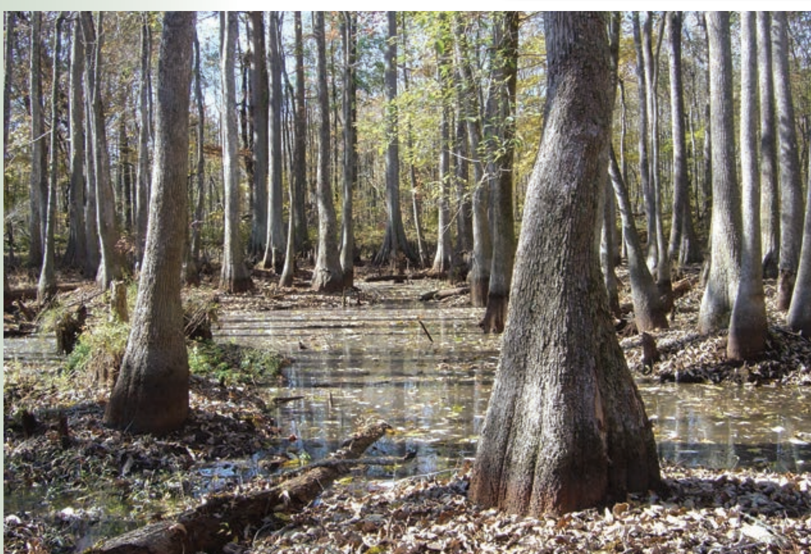


Figure 153—Cypress swamp, a forested wetland. National Forests in Alabama.

Certain types of inland wetlands are common to particular regions of the country: See figures 154 and 155.

- Bogs and fens of the Northeastern and North-central States and Alaska.
- Wet meadows or wet prairies in the Midwest.
- Inland saline and alkaline marshes and riparian wetlands of the arid and semiarid West.
- Prairie potholes of Iowa, Minnesota, and the Dakotas.
- Alpine meadows of the West.
- Playa lakes of the Southwest and Great Plains.
- Bottomland hardwood swamps of the South.
- Pocosins and Carolina Bays of the Southeast Coastal States.
- [Vernal pools in the Mediterranean climate conditions of the West Coast and can also apply to other small ephemeral wetlands found countrywide.]
- Tundra wetlands of Alaska.

Figure 154—High mountain valley wetland. Bob Marshall Wilderness. (Photo by Scott Groenier.)

Figure 155—The low-elevation Great Meadow, Isle au Haut, Maine, Acadia National Park. The deep red colors in the foreground are seasonal orchids. (Photo by Charlie Jacobi.)

Many of these wetlands are seasonal (they are dry one or more seasons every year), and, particularly in the arid and semiarid West, may be wet only periodically. The quantity of water present and the timing of its presence in part determine the functions of a wetland and its role in the environment. **Even wetlands that appear dry at times for significant parts of the year, such as vernal pools, often provide critical habitat for wildlife adapted to breeding exclusively in these areas** [such as woods frogs and fairy shrimp]…

Wetlands are among the most productive ecosystems in the world, comparable to rain forests and coral reefs. An immense variety of species of microbes, plants, insects, amphibians, reptiles, birds, fish, and mammals can be part of a wetland ecosystem. Physical and chemical features, such as climate, landscape shape (topology), geology, and the movement and abundance of water, help to determine the plants and animals that inhabit each wetland. The complex, dynamic relationships among the organisms inhabiting the wetland environment are referred to as food webs (see illustration). This is why wetlands in Texas, North Carolina, and Alaska differ from one another. See figure 156.

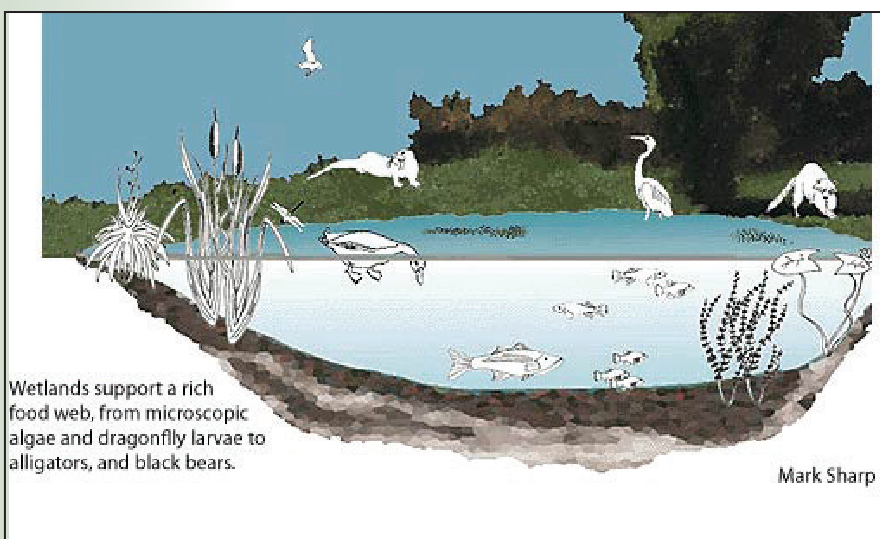


Figure 156—Wetlands support a rich food web, from microscopic algae and dragonfly larvae to alligator and black bears.

> Wetlands can be thought of as 'biological supermarkets.' They provide great volumes of food that attract many animal species. These animals use wetlands for part of or all of their life cycle. Dead plant leaves and stems break down in the water to form small particles of organic material called 'detritus.' This enriched material feeds many small aquatic insects, shellfish, and small fish that are food for larger predatory fish, reptiles, amphibians, birds, and mammals.
>
> The functions of a wetland and the values of these functions to human society depend on a complex set of relationships between the wetland and the other ecosystems in the watershed. A watershed is a geographic area in which water, sediments, and dissolved materials drain from higher elevations to a common low-lying outlet or basin, a point on a wetland, larger stream, lake, underlying aquifer, or estuary.
>
> **Wetlands play an integral role in the ecology of the watershed.** The combination of shallow water, high levels of nutrients, and primary productivity is ideal for the development of organisms that form the base of the food web and feed many species of fish, amphibians, shellfish, and insects. Many species of birds and mammals rely on wetlands for food, water, and shelter, especially during migration and breeding.
>
> Wetlands' microbes, plants, and wildlife are part of global cycles for water, nitrogen, and sulfur. Furthermore, **scientists are beginning to realize that atmospheric maintenance may be an additional wetlands function.** Wetlands store carbon within their plant communities and soil instead of releasing it to the atmosphere as carbon dioxide. Thus, wetlands help to moderate global climate conditions."

http://water.epa.gov/type/wetlands/what.ctm

Wetlands are important for maintaining North American fish populations. They provide valuable nursery areas for both commercial and sport fishery species, such as salmon, largemouth bass, muskellunge, and northern pike. Wetlands help maintain clean water, which aquatic species require, by filtering natural runoff.

Many rare species of plants and animals depend on wetlands for their survival. Of the 256 species listed as threatened or endangered by the U.S. Fish and Wildlife Service in 1991, 43 percent are wetland dependent (Flynn 2006). The bog turtle, bald eagle, whooping crane, Indiana bat, and barrens top minnow are a few examples of endangered wildlife that require wetlands.

Wetlands can be great assets to communities for tourism and wildlife viewing. These special places often attract scores of migrating waterfowl and shorebirds that people are willing to travel thousands of miles to enjoy. See figure 157.

Figure 157—A small forested wetland located on a mountain surrounded by sandstone cliffs in Kentucky's Menifee County. Daniel Boone National Forest.

Wetland Loss

Unfortunately, today's landscape contains far fewer wetlands than it used to. For generations, people have drained and filled wetlands for agriculture and urban development, and they continue to do so today. Experts report that less than one-half of the original wetlands in the lower 48 States remain (Dahl 1990). In many parts of North America, only the deepest historic wetlands remain near rivers and streams. These wetlands may have been too difficult and costly to drain for agriculture, while the majority of smaller (less than 1 acre) and shallower (less than 3 feet deep) wetlands have been drained successfully since the 1700s. Over 80 percent of these wetland ecosystems have been destroyed in California, Indiana, Illinois, Iowa, Kentucky, Missouri, and Ohio (Dahl 1990). Government estimates reveal that approximately 495,100 acres of freshwater-emergent, shrub, and forested wetlands were eliminated in the United States from 1998 to 2004 (Dahl 2006). Conversion of wetlands to other land uses continues across the Nation under a permitting system administered by the U.S. Army Corps of Engineers.

The construction of roads has damaged wetlands for hundreds of years. Road construction through a wetland generally involves ditching, filling, installing buried drainlines, and diverting waters into culverts. Road construction can set the stage for draining surrounding wetlands, first by creating a deep outlet necessary for the installation of subsurface drainage systems, and second by providing a path for moving waters across adjoining lands without causing flooding to neighboring property (Biebighauser 2007). The presence of old roads can continue to affect wetland plants and animals years after construction. Small wetlands (1 acre or less) generally are buried by road construction, while larger ones (larger than 1 acre) often are altered by ditches. Unmanaged off-highway-vehicle (OHV) use and unauthorized trails have the same effects.

OHV Wetland Damage

Damage to wetlands results from two types of OHV users in unmanaged areas, those who ride within wetlands, and those who pass through wetlands in route to adjacent areas. Use in the wetlands can turn a small wetland full of aquatic plants and animals into a mud hole within a matter of minutes, while cross-country riders can create what appears to others to be an acceptable trail or roadway through a wetland after only a couple of passes.

> It is worth taking steps to form partnerships with OHV users to help prevent wetland damage because the few wetlands that remain can be critical to the survival of plant and animal species. Unmanaged OHV activity can push these species closer to extinction.

How OHVs Disturb Wetlands

OHVs disturb wetlands when they modify the quantity or quality of water in a wetland, change conditions needed for aquatic plants and animals to survive, and modify the ability of a wetland to function. Disturbance can be obvious, such as crushed plants and animals, or subtle, such as changes to groundwater flow that feeds a wetland. For example, natural surface-water wetlands generally have a low place or spillway along their perimeter where water exits under flood conditions. OHVs can disturb these spillways by changing them into channels that erode and eventually drain wetlands.

Unmanaged OHV use disturbs wetland hydrology, plants, and animals by:

- Directly harming breeding frogs, toads, and salamanders. Amphibian eggs, larvae, and adults can be crushed and splashed out on dry land by unmanaged OHV use through wetlands. See figure 158.

Figure 158—Wood frog egg mass laid in a water-filled rut on a road closed to OHV traffic in Kentucky's Rowan County. The eggs can be crushed by further unmanaged OHV use. Daniel Boone National Forest.

- Directly harming snakes and turtles. The northern water snake, threatened copperbelly water snake, garter snake, snapping turtle, and many other species commonly hunt wetlands and can be run over by OHVs. The eastern box turtle is often found burrowed into the mud of a wetland and is unable to escape the tires of an approaching OHV.

- Crushing aquatic plants. Several passes of an OHV can kill colonies of aquatic plants and the invertebrates that use these plants. See figure 159.

Figure 159—Ephemeral wetland damaged by unmanaged OHV use in Kentucky's Powell County. Only scattered clumps of aquatic vegetation remain. Daniel Boone National Forest.

- Compacting soils and, thereby, decreasing plant and animal diversity. Soils found in partially dried wetlands are easily compacted by rubber tires. Compacted soils generally are unsuitable for plant growth and for animal burrowing.

- Compacting snow. Compaction of insulating snows caused by unmanaged OHV use (including snowmobiles) traveling over bogs and forested wetlands in the winter may cause a deeper and longer freeze, changing areas previously occupied by shrubs and trees into paths of sedges and grasses. See figure 160.

Figure 160—Wet-meadow wetland damaged by unmanaged OHV use. Roosevelt National Forest.

- Spreading nonnative plants. The deep treads found on most tires hold mud and consequently seeds from previously traveled routes. If vehicles are not washed before transporting, invasive plants can be spread over each subsequently traveled landscape.

- Changing the natural pattern of water moving across the surface into a wetland. Unmanaged OHV use can concentrate the thin sheet flow of water moving over a wetland into deep narrow channels that act like ditches to dry the wetland. OHV tracks upstream from a wetland can divert water flows that supply the wetland, changing entire plant and animal communities that use the wetland. This problem is affecting the Sacramento Mountain Thistle, a federally threatened species on the Lincoln National Forest.

- Changing how groundwater moves in a wetland. Groundwater moving through bogs, forested, and shrub-scrub wetlands can be blocked by the compacted soils in unauthorized OHV trails. Trails act like dams to raise the water table upslope, making conditions too wet for trees, such as black spruce, tamarack, Douglas-fir, white oak, black/Douglas hawthorn, chokeberry, and white cedar. Conversely, downstream areas become drier and grow unnaturally dense thickets of trees and shrubs when waters are blocked.

- Creating deep ruts of compacted soils that form unnatural zones of permanent water. In southern areas, these narrow strips of permanent waters serve as refuges for predatory fish, which in turn decimate populations of pond-breeding salamanders, frogs, and toads (Cromer 2002). Nonnative carp also can survive in these ruts, which can reduce plant abundance and diversity in the entire wetland. See figure 161.

Figure 161—Unmanaged OHV use caused erosion and deep depressions in wetlands that unnaturally contain water year round in Kentucky's Powell County. Daniel Boone National Forest.

- Causing erosion that adds soil to waters, affecting fish and wildlife use and survival. The soil that washes into wetlands and streams from unauthorized OHV trails on adjacent upland sites has the potential of clogging riffles in streams, covering gravels used for spawning, burying aquatic plants, and disturbing mussels.

Identifying possible OHV impacts to wetlands and streams in forested areas can be done efficiently by using an OHV to follow the same routes visitors use for their recreation. User-developed OHV trails can be narrow, traverse steep and muddy terrain, and may not be possible to follow with street-legal vehicles. Because these routes can go for miles, it may be too time consuming and too expensive to record impacts on foot. Using aerial photographs to help identify problems is not always possible due to the tree canopy, which often masks the narrow unauthorized OHV trails and routes.

Knowing what problems to look for when visiting a wetland can provide the basis for developing a program to restore the wetland. Evidence of unmanaged OHV-use disturbances to wetlands includes:

- Water flowing down ruts. A single pass made by an all-terrain vehicle (ATV) can be critical when that pass leaves a shallow ditch that drains a wetland.

- Water standing in ruts and deep troughs.

- Patches of mud.

- Amphibian eggs displaced. In the spring these can be found on dry ground when they are splashed out of the water. See figure 162.

Figure 162—A spotted salamander egg mass displaced by unmanaged ATV traffic. Daniel Boone National Forest.

- Aquatic plants crushed.
- Clumps of scattered aquatic plants surviving in rutted, wet areas near trees too large to run over.
- Amphibian and invertebrate larvae suffocating in muddy water and mud-splashed trees.
- Areas of exposed, dark-colored soils and compacted soils.
- Invasive species growing in disturbed soils.
- Absence of plant and animal species one would normally expect to find in a wetland, such as sedges, bulrushes, dragonfly larvae, and tadpoles. See figure 163.

Figure 163—Unmanaged OHV use, in this case ATVs, damaged an ephemeral wetland in Kentucky's Menifee County. Daniel Boone National Forest.

Assessing OHV Damage to Wetlands

Before conducting an inventory of OHV damages become familiar with wetland identification and receive training in how damaged wetlands appear. For example, sometimes a patch of sedges surrounded by a muddy water puddle is all that remains of a once natural, productive wetland. Water moving in OHV tracks indicates where stream or spring flow has been diverted. Streams and springs naturally form wetlands, and their flow will continue after wetlands have been damaged by OHVs. Water pooled in OHV tracks also indicates where wetlands supplied with ground or surface water have been damaged. See figure 163.

Figure 163—Unmanaged OHV use damaged this high elevation wet-meadow wetland by creating ruts that are acting like ditches to drain the wetland. Lincoln National Forest.

Walk around each wetland and determine how runoff is flowing into and out from the wetland. Look for erosion at these points as evidenced by deep channels and head cuts. A head cut is a small waterfall that moves further uphill with each rain event. Much erosion takes place as the head cut moves uphill.

Determine the extent of damage to wetlands on a site-by-site basis or over an entire landscape. Make an inventory of wetlands in an area, accompanied by notes describing the location and extent of unmanaged OHV-use damages to help the decisionmaker set priorities for spending restoration dollars. Include the following information to create an inventory:

- Map wetland locations and wetland types; use a global positioning system (GPS) when possible. Show the locations of rare species and archeological sites. Put all information in the forest database as a geographic information system (GIS) layer.

- Photograph damage(s) being caused to wetlands, and label each photo with latitude and longitude.

- Locate routes and areas being used legally and illegally by OHV users. Record these routes using GPS. Using aerial photographs to help identify problems is not always possible due to the tree canopy, which often masks the narrow OHV routes.

- Locate main access points and parking lots serving as staging areas by OHV users.

- Recommend priority actions.

Ask organized OHV groups to provide volunteer assistance for completing an inventory. This is an excellent way to build partnerships and support for future management actions that can affect OHV use in an area.

Restoring OHV Damaged Wetlands

The path towards restoration of wetland ecosystems requires an understanding of how wetlands function and appear. Reversing damage caused by unmanaged OHV use involves a number of steps, both physical and social. Permits may be needed from the U.S. Army Corps of Engineers and State water management offices before using heavy equipment to restore a wetland. Check with agency personnel and the Forest Service hydrologist to see if Section 401, Section 404, and flood-plain permits are required before ground-disturbing activities take place.

The following actions apply to minimally and severely damaged wetlands; the most important are listed first:

- Stop additional unmanaged OHV use-caused damage to wetlands and their watershed within and near wetland areas. Adopt new regulations, enforce existing regulations, inform users, reroute trails, and close trails when necessary.

- Return the natural flow of water into the wetland. Many small wetlands are naturally supplied from runoff that flows overland in a sheet-like pattern. There may be damage if waters enter the wetland in a narrow ditch.

- Identify where waters are leaving the wetland. Look for evidence of water flowing in ditches. Examine any ditches for head cuts and erosion. Remove vegetation and topsoil from ditches and block with layers of compacted clay soils.

- Restore contours within the wetland. Fill deep holes and level the narrow ridges between the ruts to return a more natural shape to the wetland. Use heavy equipment to till compacted soils within the wetland basin.

- Return woody debris to the wetland. In forested areas, large and small woody debris is found naturally in wetlands. Use heavy equipment, such as a dozer or excavator, to pull large dead trees back into wetlands, and hand labor to return smaller branches. These benefit salamanders, snakes, turtles, birds, invertebrates, and plants.

- Replant native plants. Unmanaged OHV use disturbs the ground and eliminates plants and exposes more soils than what would be normally found exposed in a wetland. Moist soils provide a seedbed that native or nonnative plants can colonize. Plant native species on these exposed soils to reduce the chance of nonnative invasive species taking root. Transplant small plugs of native plants from adjacent undisturbed wetlands into disturbed portions of a project area. Begin restoring native plants to a damaged wetland after problems associated with water flow and compaction are resolved. Expect most wetland planting to be done by hand.

- Grade steep sides of deep ruts into gradual slopes to make them appear more like natural wetlands and to increase plant diversity by providing varying water depths.

- Restore disturbed stream channels and fill ruts taken over by diverted streams.

As managers, use the following techniques to reduce OHV impacts to wetlands:

- Close routes that pass through wetlands.

- Change routes so they avoid wetlands.

- Use large logs as guardrails to define trail edges to help keep OHV users out of wetlands.

- Block unauthorized OHV trails with gates and posts. Set gate bar low enough to prevent OHVs from going under, and posts close enough together to prevent passage.

- Build OHV bridges over wetlands and streams.

- Where OHV routes must pass through wetlands, add culverts, buried drain lines, and rock so surface and subsurface water flow is not altered.

- Place interpretive signs at trail entrances to remind riders to stay out of wetlands and on designated trails.

- Block access to wetlands with fallen trees, stumps, and rocks.

- Fence off wetlands depending on the recreational opportunity spectrum setting.

- Enact regulations that restrict OHV travel in wetlands and that prohibit using OHVs that are specially modified with air-intake snorkels, tracks, and suspension lift kits in wetlands. These regulations provide law enforcement personnel with the basis for preventing OHV damage to wetlands before it occurs. See figure 164.

- Close parking areas that are being used for access to unauthorized trails and for unmanaged OHV use.

Figure 164—Signs placed on fiberglass posts provide the basis for law enforcement personnel to ticket those who violate closure orders.

There are advantages to completing wetland restoration prior to closing unauthorized OHV routes. The unwanted trails can provide needed access for transporting heavy equipment, tools, personnel, seed, and straw.

Equipment and Contractor Considerations

Use heavy equipment mounted on tracks, not tires, to restore damaged wetlands. Tire-mounted equipment can cause unwanted compaction and ruts and become stuck in saturated soils. Use a dozer for scraping, moving, packing, and spreading soils and an excavator for digging, sorting soil textures, and placing large woody debris. The dozer should be 105 horsepower or more and weigh at least 20,000 pounds. The excavator should be at least 80 horsepower, weigh 22,500 pounds or more and have a bucket at least 42 inches wide.

Work with a skilled contractor who cares about the goals of the wetland project; this practically guarantees restoration success. The ideal situation is to have a group of contractors who are trained in wetland construction available for work in a geographical area. This is best accomplished over time by having wetland construction jobs available each year and awarding these jobs to local businesses.

Require that the contractor wash equipment before showing up to work to reduce the possible introduction of nonnative invasive plants into the restored wetland. Dozers and excavators are often delivered to the jobsite with soil wedged between the tracks. There is no way of knowing if the soil contains seeds of nonnative invasive plants such as bitterleaf naiad, Brazilian waterweed, caulerpa, Mediterranean clone, common reed, crown vetch, eurasian waterfoil, giant reed, giant salvina, hydrilla, Japanese grass, Japanese siltweed, Johnson grass, melaleuca, purple loosestrife, reed canary grass, water chestnut, water hyacinth, or water spinach.

Use a service contract to pay a contractor by the hour for each piece of equipment that is operating on the worksite. This method often results in the lowest price because the contractor knows that payment will be received for whatever work is required on the site. The contractor does not have to inflate the bid to cover possible unknowns, such as buried gravel layers and wet soils, which might increase the amount of time needed to complete the job. Paying by the hour allows both the contractor and wetland builder the flexibility to modify the design of a wetland, as needed, and to respond to changes in soil texture and moisture without having to negotiate and pay for contract modifications.

When planning to restore a number of wetlands or several large wetlands, prepare a written contract. The contract contains specifications for the job that are indisputable in comparison to verbal instructions. The contract makes it possible to hold fair competitive bidding to obtain a lower price for the wetland project.

Wetland Restoration and Construction Techniques

Restore wetlands to be similar in appearance and function to natural wetland ecosystems. Many historic wetlands have been changed so drastically by previous drainage activities and vehicle damage that few, if any, signs remain to show what type of wetland it might have been.

Was This a Surface- or Groundwater Wetland?

Different construction techniques are used to build surface-water and groundwater wetlands. When planning a restoration, first determine if the wetland was a surface-water or groundwater wetland. A surface-water wetland holds rainfall like a cereal bowl; within a depression made of packed soils that are high in clay and with a natural dam that serves as a rim to keep waters from flowing downhill. A groundwater wetland is like an old fashioned hand-dug well; it is a depression that exposes a high water table, which is often surrounded by saturated soils high in sand or gravel. See figure 165.

Figure 165—Restored surface-water, ephemeral wetland in fall. Kentucky.

Many natural wetlands are supplied by both surface water and groundwater, but don't plan a restoration that uses both. Unfortunately, attempting to blend these two strategies often fails. Generally, there are too many unknowns affecting the location that confuse any attempt to calculate a water budget for the wetland. These unknowns include the presence of buried drainage structures, open ditches, variable soil textures, and burrowing crayfish. Plan to build a surface or a groundwater wetland. If the surface-water wetland also is supplemented by groundwater it is a good thing and vice versa.

To determine the type of wetland once present, use a post-hole digger, soil auger, or shovel to dig a hole at least 3 feet deep near the center of the proposed restoration site. A 1½-inch-diameter soil auger attached to a 4-foot-long handle works well for testing restoration sites. Watch to see if water seeps into the hole from the bottom and sides. If the hole fills partially or completely with water, or the slurp of water is heard as the auger is removed, a high water table is present, and a wetland can be restored that will fill with groundwater. See figure 166.

Figure 166—Restored groundwater wetland near the Trinity River in California.

A seasonally high water table can be more difficult to detect in dry weather, but there are signs that indicate its presence. Look for gray-colored soil and mottling. Another way is to allow more time for water to enter the test hole. Place a board over the top of the hole to prevent rain from entering then check the hole for water the next day. Test the site again when conditions are wetter to see if water is nearer the surface. Test holes showing a weak flow of groundwater, or where water is found to be far below the surface indicate that an excavation on the site will contain little water, and possibly then for only short periods during the year. Such an excavation may not contain water long enough to support the aquatic plants and animals normally found in a wetland. Do not build a groundwater wetland on such a site.

Simply returning contours to a damaged wetland is seldom enough to produce a successful restoration. Unfortunately, when working on top of a historic wetland, it is entirely possible for a restoration attempt to fail because not enough attention was given to determining whether the soils had enough silt and clay to be shaped and compacted to hold water. Many restored wetlands also have failed because of improper construction techniques. These improper construction techniques are described in detail in “Wetland Drainage, Restoration, and Repair” (Biebighauser 2007) and "Wetland Restoration and Construction - A Technical Guide" (Biebighauser 2011).

Where considering the possibility of restoring a surface-water or ephemeral wetland, first determine the texture of mineral soil on the site. Mineral soil is located below the topsoil layer, which is dark colored and contains fine roots and organic material. Generally, mineral soils suitable for holding surface water are high in clay and silt. Soils with just enough clay feel smooth and sticky, those with high silt content feel like flour when rubbed, and those with too much sand to hold surface water feel gritty. See figures 167 and 168.

Figure 167—Restored ephemeral, surface-water wetland in spring. Daniel Boone National Forest.

Figure 168—The same restored ephemeral wetland in fall. Daniel Boone National Forest.

Table 4 shows a simple test to determine if the clay content is high enough to form a surface-water wetland. Soils that contain adequate amounts of clay are firm and take some strength to reshape. Soils that cannot be shaped in these ways are not candidates for surface-water wetlands. See table 4 and figure 168.

Figure 168—A long ribbon shows that enough clay is present in the soil to restore a surface-water wetland (Photo by Sarma Liepins).

Table 4—Soil texture by feel method. Adapted from Colorado State University Extension Publication “GardenNotes #214” at <http://www.ext.colostate.edu/mg/fi les/gardennotes/214 EstTexture.html>.

Soil Texture by Feel

Start: Place soil in palm of hand. Add water drop-wise and knead the soil into a smooth and plastic consistency, like moist putty.
Does the soil remain in a ball when squeezed?

Yes

No

Add more water

Add drv soil

Yes

Yes

Is the soil too drv?

No

Is the soil too wet?

No

Sand

Place ball of soil in the hand, gently pushing the soil out between the thumb and forefinger, squeezing it upward into a ribbon. Form a ribbon of uniform thickness and width. Allow ribbon to emerge and extend over the forefinger, breaking from its own weight.
Does the soil form a ribbon?

Yes

No

Loamy Sand

What kind of ribbon does it form?

Moisten a pinch of soil in palm and rub with forefinger		Forms a weak ribbon less than 1” before breaking **LOAM**	Forms a ribbon 1-2” before breaking **CLAY LOAM**	Forms a ribbon 2” or longer before breaking **CLAY**
Does it feel very gritty?	Yes	**Sandy Loam**	**Sandy Clay Loam**	**Sandy Clay**
Does it feel equally gritty and smooth?	Yes	**Loam**	**Clay Loam**	**Clay**
Does it feel very smooth?	Yes	**Silt Loam**	**Silty Clay Loam**	**Silty Clay**

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Watershed Size Considerations

One does not have to calculate a water budget for a successful wetland restoration. Calculating the amount of runoff that could enter a wetland has captured much attention in the literature and the calculations used to determine the optimum watershed size have become so involved that one may question if it is worth doing the work needed to complete the equations. The most important factor to consider is how floodwaters will leave a restored wetland without causing damage to the site.

Wetlands maintained by a perennial stream can be challenging to restore. Take precautions to reduce erosion and prevent damage to the stream during and after restoration. If not done well, there can be high costs associated with creating a hardened spillway strong enough to withstand the flow of water leaving the wetland under flood conditions; expect to complete frequent inspections and maintenance of water control structures, emergency spillways, and dams on those wetlands.

Historically, where agricultural or mining activities occurred, a majority of intermittent streams were changed into straight channels or ditches. These streams often were moved to the bases of hills and mountains to create large and level areas of land. In this situation there are two restoration approaches: (1) A conservative and less expensive approach is to restore wetlands between ditches so that the streams do not enter wetlands; and (2) A landscape-level and more expensive approach involves restoring affected wetlands and streams simultaneously.

In areas where rainfall exceeds evaporation, which is basically east of the Mississippi River and the Pacific Northwest, small surface-water wetlands are restored successfully, even those that do not have watersheds. This means that emergent, ephemeral, forested, shrub, and wet-meadow wetlands are restored successfully in areas that receive little if any runoff, including those on mountain ridges.

Wetlands often have been filled by surrounding erosion. These represent opportunities for restoration. At times, questions arise about the original depth and shape of a historic wetland that are not easy to answer. In some areas, the surface of the original wetland lays buried. This may occur in small basins surrounded by eroding unauthorized OHV trails, or along rivers where significant quantities of soil have been deposited since European settlement. To determine if a wetland was buried, dig holes deep enough to see if a historic layer of topsoil is present at the site. Sometimes a soil probe will work, but often an excavator is needed to make this determination. If a buried topsoil layer is found, decide if the project will involve removing the deposits to expose the original elevation of the wetland. Remember, historic deposits do not have to be removed to build a successful wetland. The costs associated with moving large quantities of soil can be prohibitive. In some cases, management objectives may be better met by building, at a lower cost, a larger number of natural-appearing wetlands over a filled wetland compared to excavating large quantities of soil to restore a wetland at its historic elevation.

Designing the Shape of the Wetland

When designing a wetland, seek out and examine reference or natural wetlands in the same area to provide information on the size, shape, and depth of historic wetlands. Wetlands in various parts of the country have signature shapes that are wise to copy. Prairie potholes in the Midwest, playas in the South, and pocosins along the South Atlantic typically are round. Oxbow wetlands near rivers and streams are long, narrow, and crescent shaped. Beaver ponds may look like triangles from above, while wet meadows can curve like a ribbon down a hillside. Unfortunately, in many regions it is not possible to find reference wetlands because drainage actions were extensive. See figure 169.

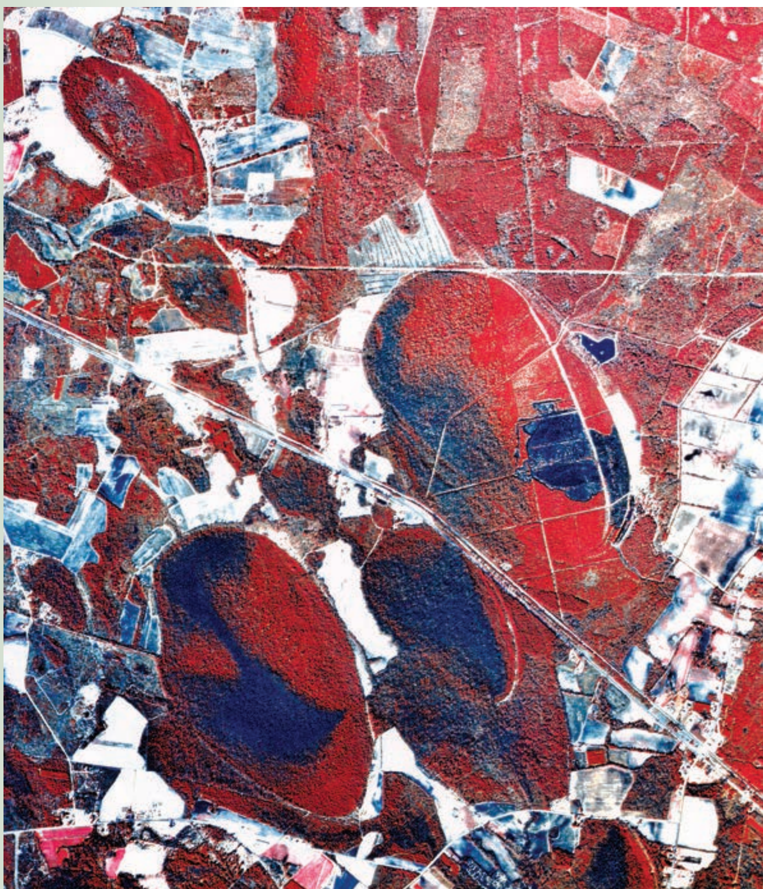


Figure 169—Color infrared aerial photograph showing natural, oval shapes of Carolina Bay wetlands in Clarendon County, South Carolina (South Carolina DNR photo).

The most important factor to consider when building a natural-appearing wetland is no straight lines. A rectangle or square wetland will stand out for hundreds of years, while those restored to match natural features will look as though they have been there forever.

Marking the Restoration Site

There are a number of reasons to mark a wetland in advance of any construction work. The markings help the project leader find the site later, even if it has been recorded on a map or in a GPS receiver; they help other people find the location independent of the project leader. Botanists, archaeologists, utility workers, and prospective bidders and equipment operators may need to survey the site before work begins. Use bright pink or orange colored plastic ribbon to mark the location of a wetland restoration worksite. See figure 170.

Figure 170—Mark clearing limits and the location of the dam. Use brightly colored plastic ribbons to mark the boundary of the work area.

Marking the perimeter is especially important where heavy equipment will be used to remove vegetation. Ribbons create a protective boundary around streams, vegetation, wetlands, and archeological sites. Hang brightly colored plastic ribbons from trees and shrubs to mark wetland construction sites in forested areas; use tall wire flags in grasslands. Do not use wooden stakes to mark worksites as they are hard to find at a later date, they don't last long, and generally are destroyed when clearing vegetation with heavy equipment.

When restoring a small wetland on sloped ground, clear an area at least twice as large as the planned water surface (approximately 60 feet in diameter) to provide room for piling debris, vegetation, and topsoil. Remember that it takes space to pile vegetation, to store topsoil temporarily, and create gradual slopes on the dam.

When restoring deeper wetlands, a larger area is needed that allows room for gradual slopes. In forested areas, it is often necessary to remove trees. When choosing a path for equipment access and to save clearing costs, look for small openings in the forest and areas where trees are less than 12 inches in diameter. Save the removed trees for later use.

Marking too small an area will not allow enough room for reconstruction of a naturally appearing wetland, and may result in a wetland that has steep slopes and a narrow dam. However, clearing an area too large may result in unnecessary costs and damage to trees and shrubs. Basically, when examining a small area marked for wetland restoration, one can predict that the water surface area in the finished wetland will cover less than one-half of the area to be cleared.

Restoring a Surface Water Wetland

A surface water wetland is generally restored by moving soil to shape a shallow basin that's made of pact soils high in clay.

Designing the Dam

The majority of natural wetlands are maintained by naturally occurring dams. These natural dams are often wide with gradual slopes. Most wetland restorations require constructing a dam (or berm) that prevents water from flowing downhill to a stream or river. A dam is not needed to form a wetland on level ground; however, there are few areas flat enough where a wetland can be built without a dam. For a natural-looking wetland, place slopes of 20:1 (or more gradual) on both the front and back of the dam, and shape the top of the dam so that it is at least 12 feet wide. Generally, wetlands with low dams and shallow water depths contain a greater diversity of plants and animals than deep wetlands with high dams. In the long run, low dams also are much less expensive to build and maintain than high dams. To keep wetlands shallow, construct a dam for every 3-foot change in elevation or less over the work area. Another way to picture this is to think of a topographic map where a dam is placed on every 3-foot-contour interval. See figure 171.

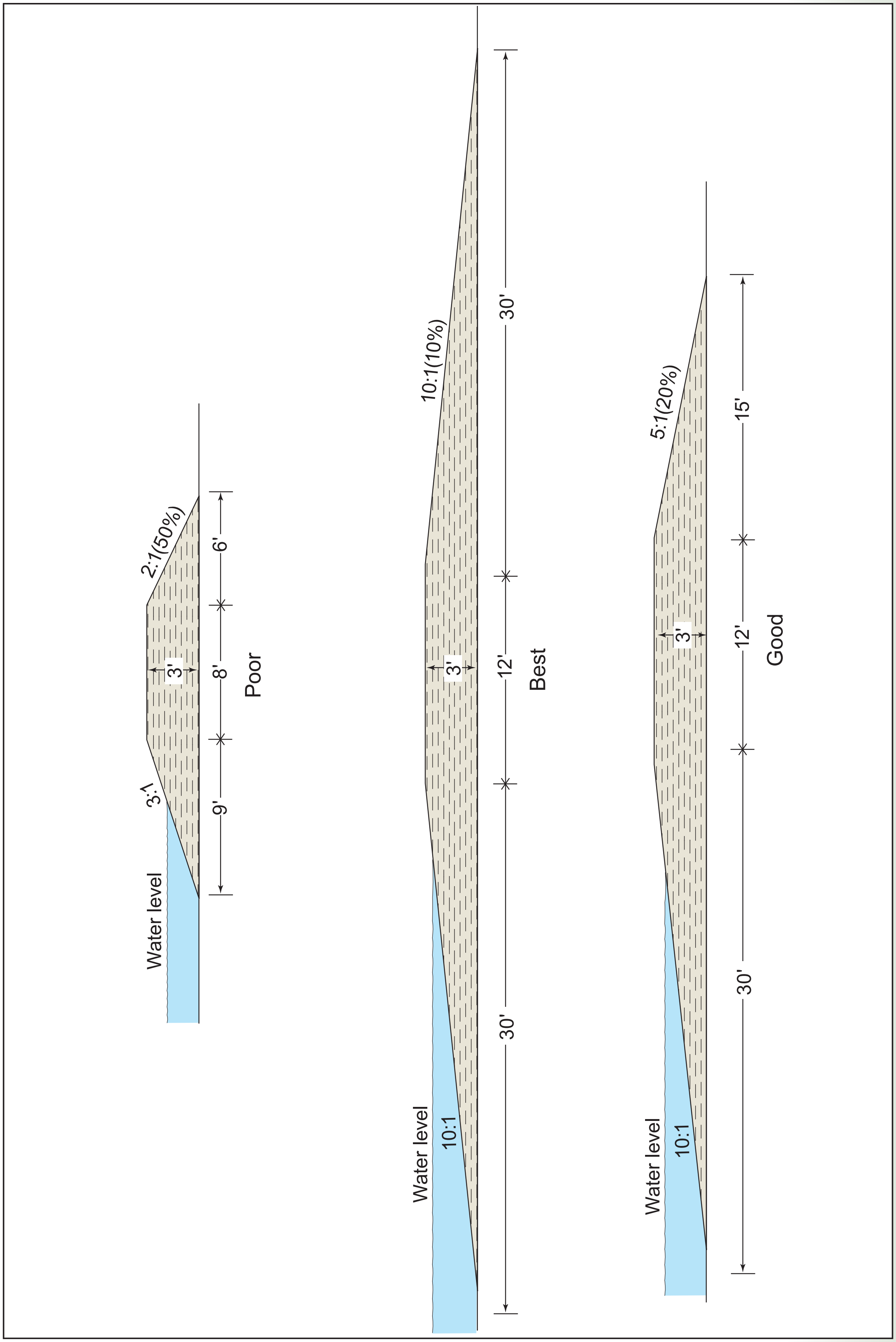


Figure 171—These three drawings show typical cross sections of slopes for wetland dams. The section in the center is most desirable with gradual slopes on both sides of the dam.

The shape of the dam has a great impact on how natural the wetland will appear. Generally, the more gradual the slopes and the wider the top of the dam, the better it will blend with its surroundings. Plant and allow trees to grow on dams with slopes of 5 percent or less. Other advantages of shallow-sloped, wide dams include reduced maintenance costs associated with muskrats and beaver tunneling, less potential for flood damage, fewer leaks from tree roots, and greater plant diversity. Unmanaged OHV use also is less likely to damage a wide dam with gradual slopes. Unfortunately, many wetlands are built with high dams and steep slopes in the hopes of reducing construction costs and to create deep water for watering livestock. Do not do this; a reservoir for watering stock is not the same as a wetland.

When designing a restoration project in an open field, the tendency is to try to inundate the entire opening by constructing one high dam. Unfortunately, this wetland can become very deep and costly. Building one high dam is generally more expensive than building several low dams. There are other advantages to building a series of low dams instead of one high dam, such as creating more natural-appearing wetlands and having the ability to manage a series of wetlands at various water depths.

Determining the Height of the Dam

Determine the height of a dam by measuring the area's slope. The height of the dam is basically equal to the difference in elevation between the upper edge, where water should reach, and the lower edge of the work area.

It may help to think of a bowl of milk when contemplating where to build the dam. When the bowl is set on a flat surface, the space between the milk and the top edge of the bowl is even all around, and there is no need for a dam. However, when the bowl is tipped, water will spill out of the lower side unless that side of the rim is higher. The dam is that rim on the bowl that keeps water in the wetland.

Use a simple construction level on a tripod and a survey rod to measure slope over the proposed restoration site. This is a two-person job. Set up the level on higher ground overlooking the upper edge of where the water should reach. Ask the person with the survey rod to stand along the lower edge of the proposed work area, and take a reading with the level. Then ask him or her to move to the upper edge, where water should reach, for a second reading. The height of the dam is usually equal to the difference between these two readings. However, since a spillway is necessary for handling overflow waters, add 12 inches to the difference between the upper and lower elevation for the maximum dam height. The spillway is usually made 12 inches below the top of the dam. See figure 172.

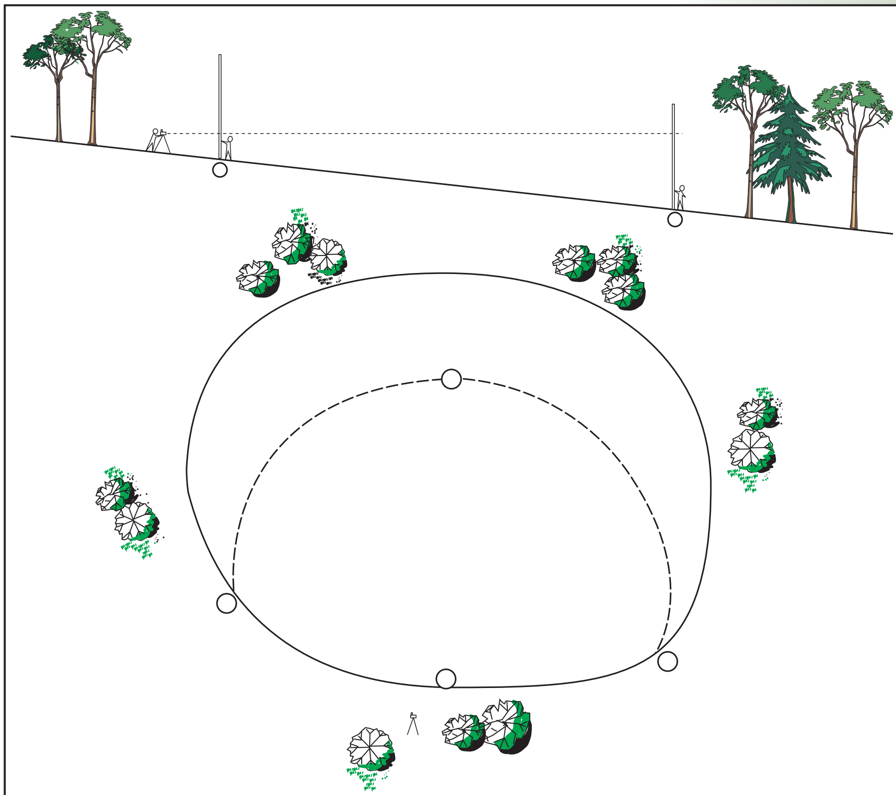


Figure 172—Use a level and survey rod to help determine the elevation of a dam for the wetland.

A wetland restoration site typically has less than a 3-foot change in elevation from the upper edge, where water should reach (the original location of the tripod), to the lower edge and is bordered by features not to be disturbed, such as large trees, steep ground, streams, rivers, trails, or archeological resource sites. Use two sets of different colored ribbons to mark the perimeter of this area. Generally, tie the ribbons in a circle or an oval to represent the approximate shape of the wetland and the land surrounding the wetland where disturbance is allowed during construction.

To locate the dam, stand with the survey rod on a location along the upper edge, where water should reach. A number typically read on the rod at this location is 5.0. Tie a ribbon (wire flags) at this location. Now, walk downhill with the rod until the number read on the rod is 7.0, or 2 feet lower than the first reading. Tie a ribbon at this location. This second ribbon marks where the highest section of the dam will be built.

Now, mark where the dam will begin and end. This is where each end of the dam will tie into higher ground. Walk over to the left side of the worksite and place a ribbon where the reading on the rod is the same as the one taken along the upper edge, or 5.0 in this situation. Walk over to the right side of the area and tie a ribbon where the reading also is 5.0. Tie an arc of ribbons using wire flags between these points to represent where the dam will be built. The arc or dam begins on high ground on one side of the work area where the reading is 5.0, goes downhill to the lower ribbon that was hung at 7.0, and then uphill to the other side where the dam ties into higher ground, and the reading also is 5.0. When finished, the lower half of the circle will have been marked to show where the center of the dam will be built.

Shift ribbons marking the center of the dam uphill if there is not enough room between them and the lower edge of the work area for piling vegetation, topsoil, and for forming the back slope of the dam. The path of the ribbons also can be adjusted to give the wetland a more natural shape. Where needed to mark the lower edge of the work area (clearing limits) in wooded areas, hang another set of ribbons of a different color below the dam for the contractor to use as a guide during construction. It takes practice to learn where to locate the dam.

Before moving the construction level, establish a reference mark that will be the same elevation as the top of the dam. Remember to place the mark 1 foot higher than the difference between the upper and lower edges to allow for the spillway. Outside of the work area along the lower edge, drive a stake into the ground so that the top is equal to the elevation of the top of the dam. Tie a ribbon to the stake for easy visibility. This reference mark will be used to check the height of the dam during construction. On the day of construction, set up the level in an out-of-the-way place with good visibility, place the survey rod at the stake, and take a reading with the level. The number read on the rod will be the same elevation as the top of the new dam.

These examples show how to determine the height of the dam on areas with different slopes:

1. Steep hillside location:

    Lower reading = 8.0.

    Upper edge rod reading = 5.0.

    Difference = 3.0.

    Add for spillway = 1.0.

    Maximum height of dam = 4.0 feet.

    Rod reading equal to the top of the dam at time of set up = 4.0.

    Rod reading equal to water level and spillway elevation at time of set up = 5.0.

2. Ridge top location:

Lower edge rod reading = 8.0.

Upper edge rod reading = 6.0.
Difference = 2.0.

Add for spillway = 1.0.

Maximum height of dam = 3.0 feet.

Rod reading equal to the top of the dam = 5.0.

Rod reading equal to water level and spillway elevation at time of set up = 6.0.

3. Flat location collecting little surface runoff.

Lower edge rod reading = 6.0.

Upper edge rod reading = 5.0.

Difference = 1.0.

Add for spillway = 0.5.

Maximum height of dam = 1.5 feet.
Rod reading equal to the top of the dam = 4.5.

Rod reading equal to water level and spillway elevation at time of set up = 5.0.

If there is more than a 3-foot change in elevation between the upper and lower edge of the work area, move the lower edge of the dam uphill so that a dam no higher than 4 feet is needed (remember an extra foot is added to gain spillway height). Another option on steep slopes is to divide the site into separate wetlands, each with a dam less than 3 feet high.

Leave the following distances between the lower edge of the work area (or clearing limit) and the ribbons at the center of the dam for various dam heights:

3-foot-high dam = 40 feet.

2-foot-high dam = 30 feet.

1-foot-high dam = 20 feet.

Preparing the Site for Construction

To begin, remove vegetation and topsoil from between the upper edge, where water should reach, and the lower edge of the work area; this includes the dam location and the area in front of the dam where soil will be removed to build the dam. Save all the vegetation and topsoil for use later. Place these in separate piles along the edge of the work area. Topsoil and vegetation are generally removed from the entire area marked for clearing on wetland projects less than 1 acre. For larger wetlands, remove a strip of vegetation and topsoil approximately 250 feet wide along the entire length of the dam.

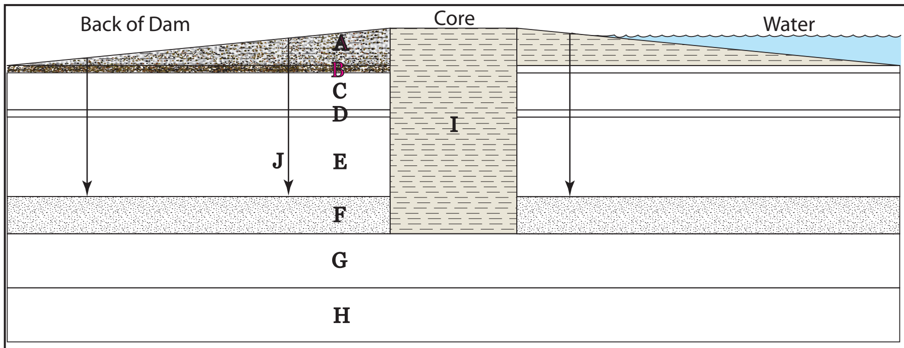
Topsoil generally is darker than mineral soil and contains roots and leaves that will cause leaks if left under the dam. In forested areas, it is uncommon to find topsoil layers thicker than 4 inches, however, in agricultural areas do not be surprised if the topsoil is more than 12 inches thick. A thick topsoil layer generally indicates where a wetland has been filled. See figure 173.

Figure 173—Remove trees and shrubs from the wetland restoration site.

One-half of the topsoil is stripped downhill and piled along the lower edge of the cleared area. The other half of the topsoil is stripped uphill and piled along the upper edge of the cleared area. The topsoil piled on the upper edge will be spread in the bottom of the new wetland, and the topsoil placed along the lower edge will be shaped into the backside of the dam. See figure 174.

Figure 174—Strip topsoil and store it next to the clearing. Note that the tree with the pink ribbon is saved.

Most dams and cores are small and are built in a day. On larger sites and to avoid being stopped by heavy rains associated with thunderstorms, use staged construction when building larger wetlands that have long dams. Strip vegetation and topsoil only from sections where soils can be removed to construct a length of dam the same day. (Figure out what portion of the dam and core can be built in one day, and then remove only the vegetation and topsoil for 1 day's work.) A heavy rain can saturate soils that have been stripped of vegetation and topsoil, making the soil unworkable. These wet areas may take a week to dry out and cause considerable delay to the project. Generally, areas that are left undisturbed can be cleared the day following a rain, and the soils beneath will be dry enough to use the same day to build a section of dam. See figure 175.



A = Dam (silt-clay loam)
B = Topsoil
C = Silt-clay loam
D = Buiried drain pipe
E = Silt-clay loam
F = Gravel
G = Clay
H = Bedrock
I = Core
J = Burrowing cray fish hole

Note:
Dam is 3-feet high.
Topsoil is 6-inches thick.
Drainline diameter = 5-inches slopes downhill.
Crayfish burrows are only 2-inches in diameter.
Gravel layer is saturated with water.

Figure 175—How the dam and core form a wetland (profile view).

Groundwater Dam

When restoring a surface-water wetland, it is essential to prepare a groundwater dam by digging a core beneath the location of the dam and filling it with high-clay content compacted soil. Coring creates a zone of packed soil beneath the dam, which prevents water from moving under the dam. This is the number one cause of wetland failure. Natural soils are loose and porous, and, if loose soils are not compacted under the dam, they form a conduit for water to leave the wetland. The dam and groundwater dam forming the lower half of the wetland's edge are inseparable and should be built as one unit. A core is needed wherever the dam is built, even if a dam is only 1-inch high. See figures 176 and 177.]

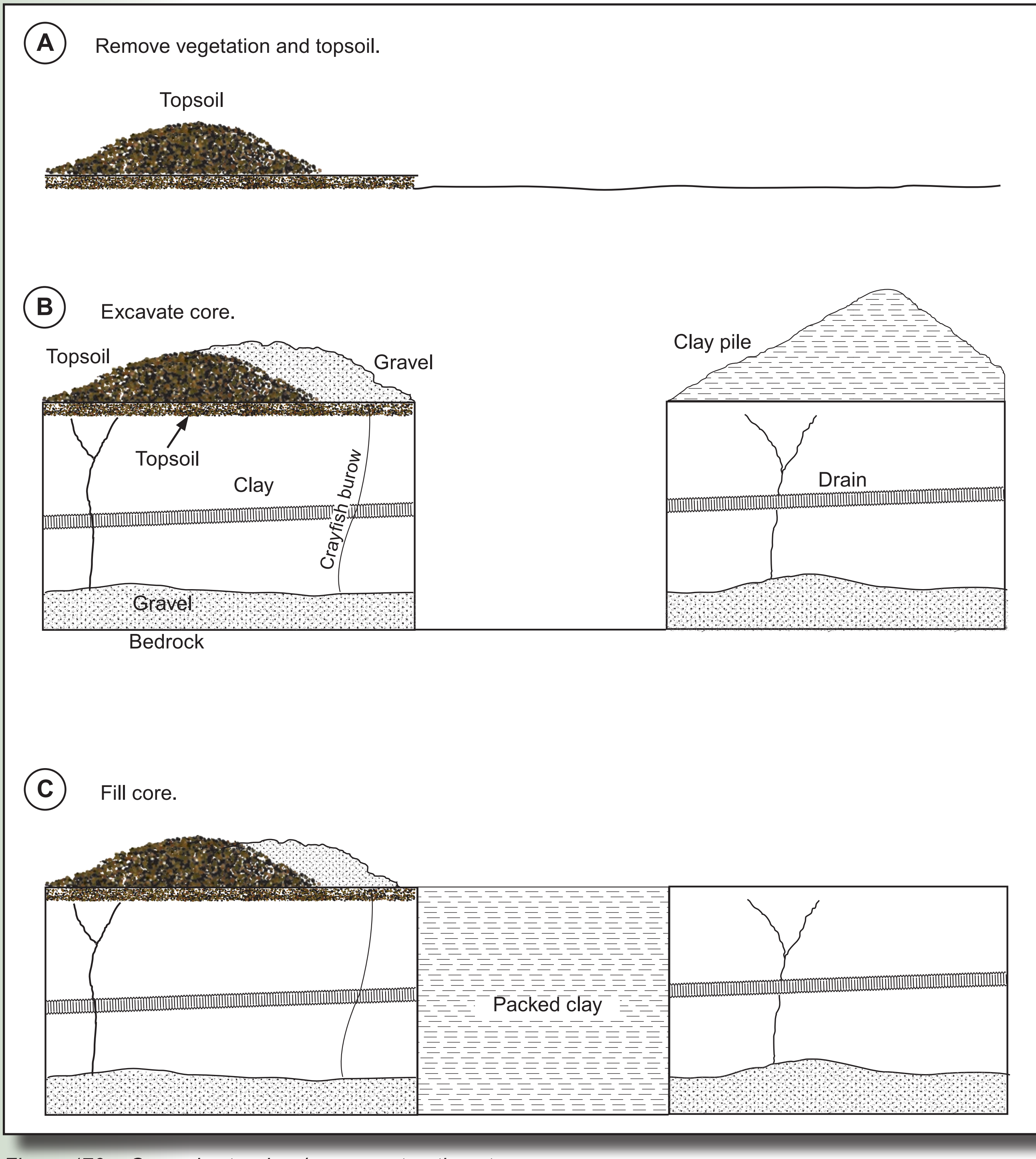


Figure 176—Groundwater dam/core construction steps.

Figure 177—Begin digging the core by pushing the top layer of soil found over the location for the dam towards the edge of the clearing.

To build a groundwater dam, remove soil from beneath the designated dam area and return it in compacted layers. Make the core deep enough to cut through roots, animal burrows, drainage structures, and layers of gravel and sand. In wooded areas where tree roots and animal burrows are the main concern, a core only 4 feet deep may be needed. However, in areas where burrowing crayfish are present, the core must extend down to the bottom of their burrows, which can be 15 feet deep or more. See figure 178.

Figure 178—Watch the area between the blade and tracks to make sure the core trench is dug beneath any holes, pipes, and gravel present in the core.

Base the bottom of the core trench on an impermeable layer of soil or rock. Dig down to the bottom of crayfish burrows if they are present, and if these burrows terminate in a layer of clay or on top of bedrock, use that layer to form the base of the core. However, if the burrows enter into a gravel layer, which may be carrying water, dig deeper until clay or bedrock is found. A suitable base layer is reached when water is seen pooling on its surface. These impermeable base layers are generally gray. See figure 179.

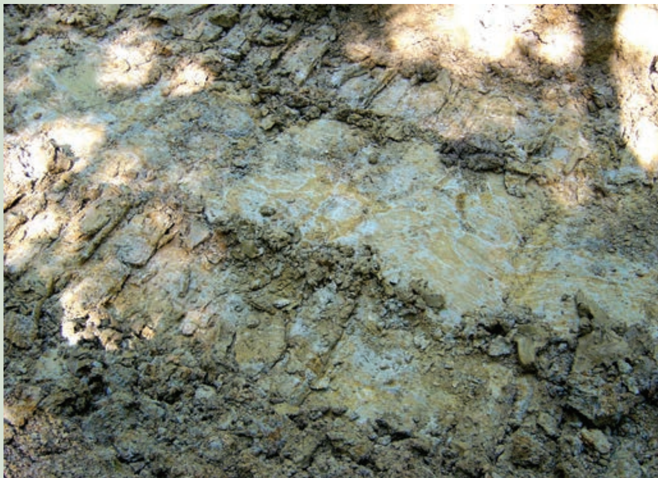


Figure 179—Use clay without holes as a good foundation for the groundwater dam.

Dig the core trench with vertical sides about 1-foot wider than the width of the blade on the dozer being used. Now the heavy equipment can travel over and compact each layer as the soil is placed back in the core trench. Expect building the core to take longer than building the dam. Constructing the core is important; do not to take shortcuts. See figures 180 and 181.

Figure 180—Use a dozer to dig a shallow core and an excavator for a deep core.

Figure 181—Dig a deep core trench 1-foot wider than the dozer blade.

Use an excavator and a dozer combination to most effectively create the groundwater dam. Use the excavator to dig the trench and the dozer to fill and compact the core. When working near streams and rivers, it may be necessary to dig 8 to18 feet deep to reach the bottom of crayfish holes and to remove layers of sand and gravel. While it is possible to dig a deep core using a dozer alone, it is inefficient and costly. Use the excavator to remove permeable layers easily and place them outside the dam location, and to save soils that are suitable to place back into the core by placing them inside the wetland.

Use the dozer to fill the core trench with suitable soils as it is being dug, otherwise portions of the trench may cave in and deposit gravels across the width of the core. Take every precaution to prevent the sides from caving in; removing the collapsed material takes time and a great deal of additional soil. Therefore, digging through thick layers of gravel requires close coordination between the excavator and dozer operator. The dozer operator often needs to be down in the core trench pushing in suitable soil as the excavator removes the last buckets of gravel from the bottom of each section of the core trench.

Use the same mineral soil for the groundwater dam and dam. The soil must have enough clay to form a ribbon between thumb and forefinger at least 2 inches long before breaking. See page 123 and 124. In many cases, the soil removed from the core is placed back in the core. This soil can be supplemented with soil excavated from inside the future pool area of the wetland. Due to the cost, soil is seldom hauled in to fill the core.

Zones of gravel can be difficult to see within the core trench. Fortunately, these permeable soils most often are a different color and texture than the finer textured impermeable soils; they generally are red, gray, or black compared to the lighter brown of silt-loam soils.

Gravel may occur in layers that rise and fall like waves along the length of the core trench or in veins of various shapes and sizes, just like buried stream channels. These permeable layers may be moist and can carry streams of water. The excavator operator also can tell where the gravel is by feel; it is much easier to remove gravel than the denser, finer-textured soils. See figure 182.

A dozer is often adequate for digging a core on a ridge top. These sites generally are above the flood plain where buried deposits of gravel would be found.

Figure 182—An excavator is necessary for digging a deep core. Here the machine is removing a buried plastic drainline.

Place the soil back into the core trench in layers 6 inches thick or less. Compact each layer by running the dozer over it a number of times while leveling it with the blade. After the core is filled to surface level, begin building the dam on top of the completed groundwater dam. See figure 183.

Figure 183—Fill the core with soils high in clay and pack each layer.

Farming in the area near the wetland construction site is a strong warning that a deep core is needed below the dam. Signs of past agricultural activities may include old fields, shallow ditches, broken fences, and foundations. The deep core is necessary to interrupt buried drainage structures, ditches, partially filled ditches, and buried debris. Remember that farmers toiled for generations to remove water from the area where the wetland is being restored.

Many who restore wetlands simply use a deep plow or backhoe to break the path of buried agricultural drainlines along the lower edge of a field to restore the wetland. Unfortunately, this is not enough. Water pressure can be so great that water will continue to flow through the soil surrounding the broken drainline. Drainline outlets often are covered by 6 feet of soil and continue to flow uninterrupted even when broken. Drainlines flow even when crushed, as the water pressure generally creates a new channel that rejoins an intact drainline further downstream. Exposing the drainline where it passes beneath the dam and packing it to create a wide core is the only reliable way to inactivate these systems.

Building the Dam

Build the dam out of mineral soil that has enough silt and clay to form a ribbon between thumb and forefinger at least 2 inches long before breaking. See page 123 and 124. Construct the dam in layers 6 inches thick on top of the groundwater dam. Compact each layer by running over it a number of times with the dozer. Keep roots, branches, topsoil, sand, and gravel out of the dam.

Take soil for the dam from within the wetland's pool area. To avoid creating a deep trench near the dam, back the dozer up to the uphill edge of the cleared area to begin scraping soil for the dam. Remove soil over an irregularly shaped area to give the edge of the completed wetland a natural appearance and to provide conditions for a diversity of plants. Create a dam with gradual slopes to reduce the possibility of muskrat tunnels. See figure 184.

Figure 184—Use a dozer to shape a shallow basin to form the wetland and to move soil from within the pool area to the dam area.

Spillway Construction

When a wetland fills, a spillway allows the extra water to leave the wetland in a way that will not damage the dam. To prevent damage and erosion under flood conditions, build a spillway to direct how water exits the wetland. Build the spillway at a gentle slope, generally 3 percent or less, and a minimum of 12 feet wide. See figures 185 through 187.

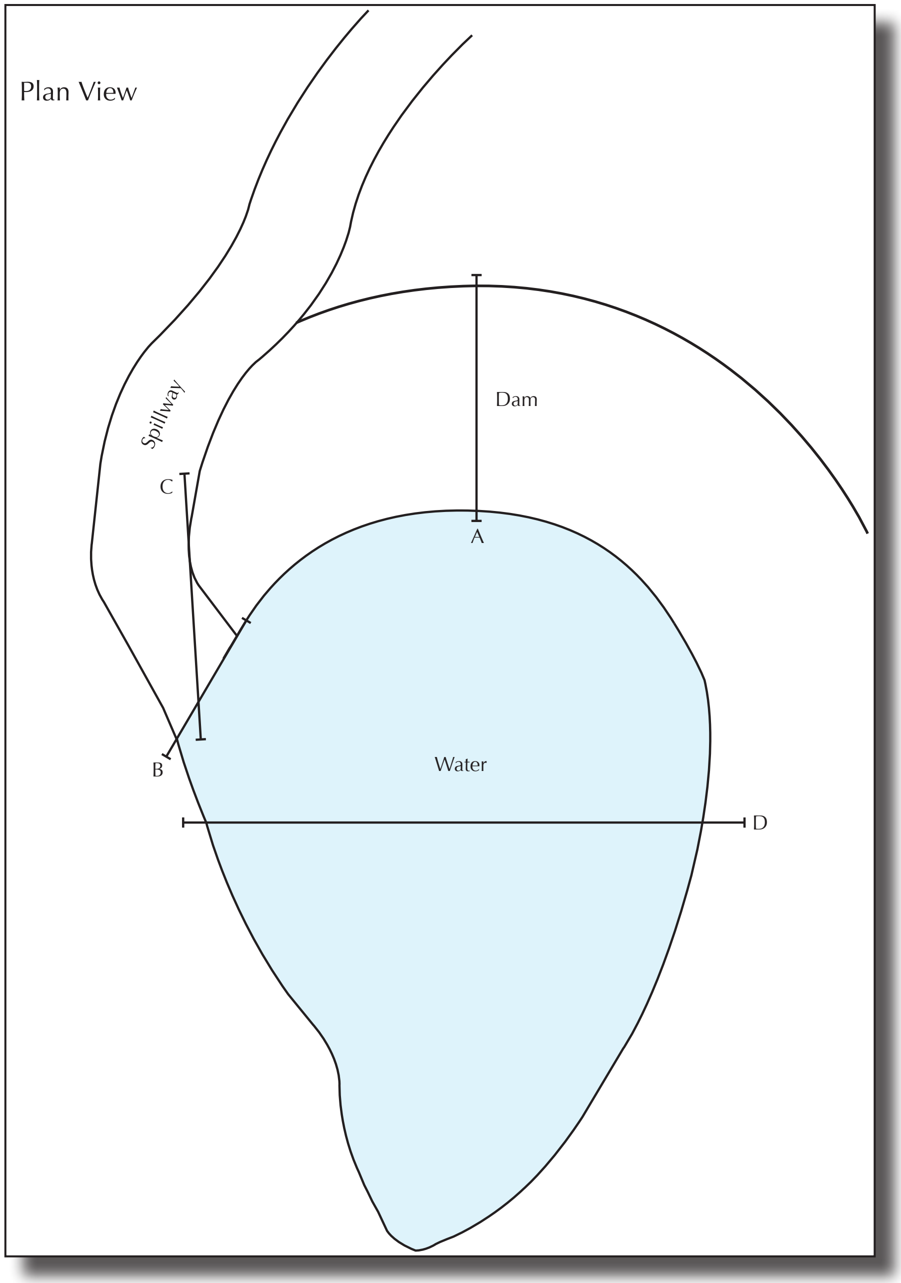


Figure 185—Wetland components and spillway construction in plan view. The spillway is to one the side of the dam.

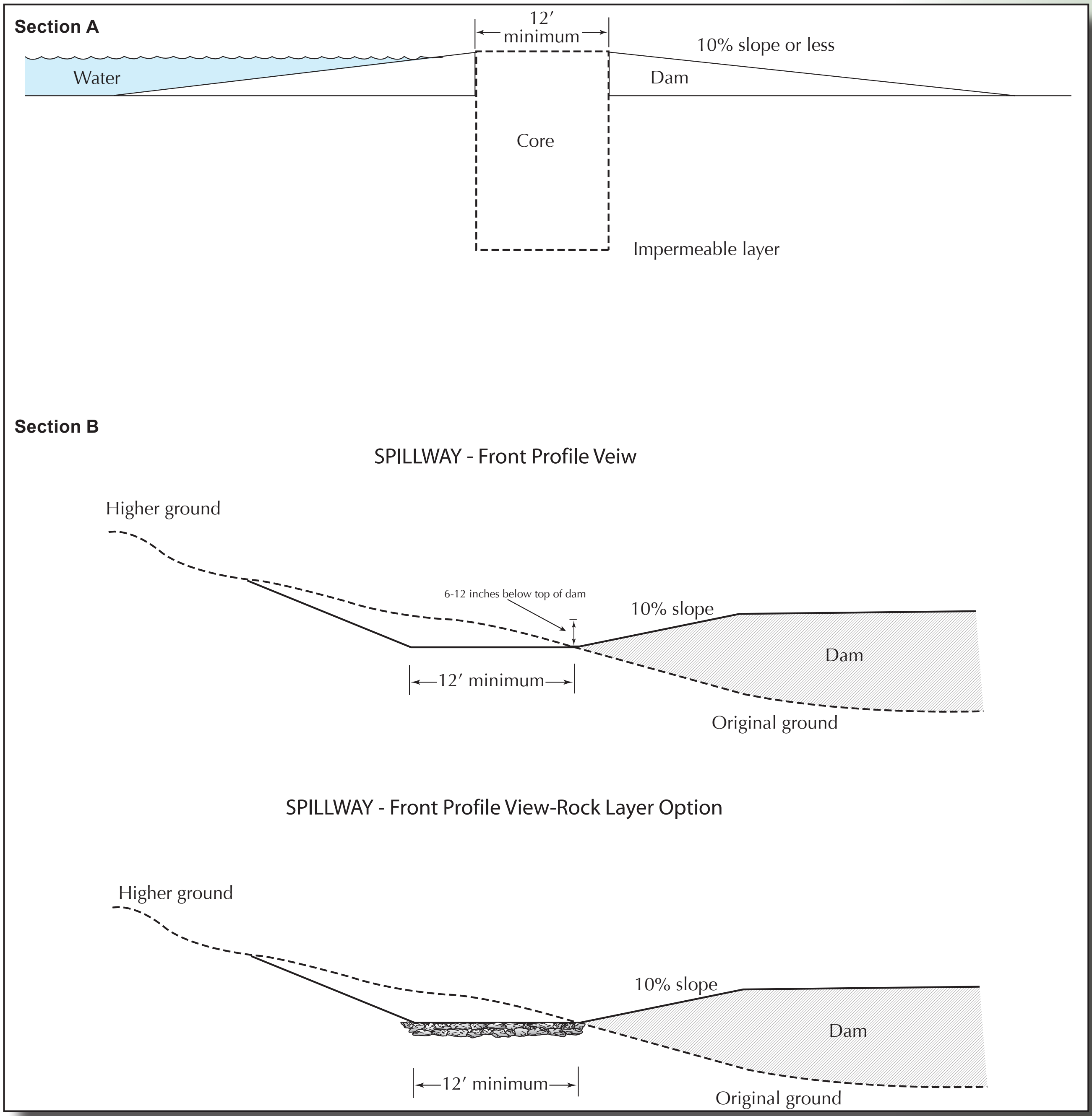


Figure 186—Dam and spillway construction, profile view.

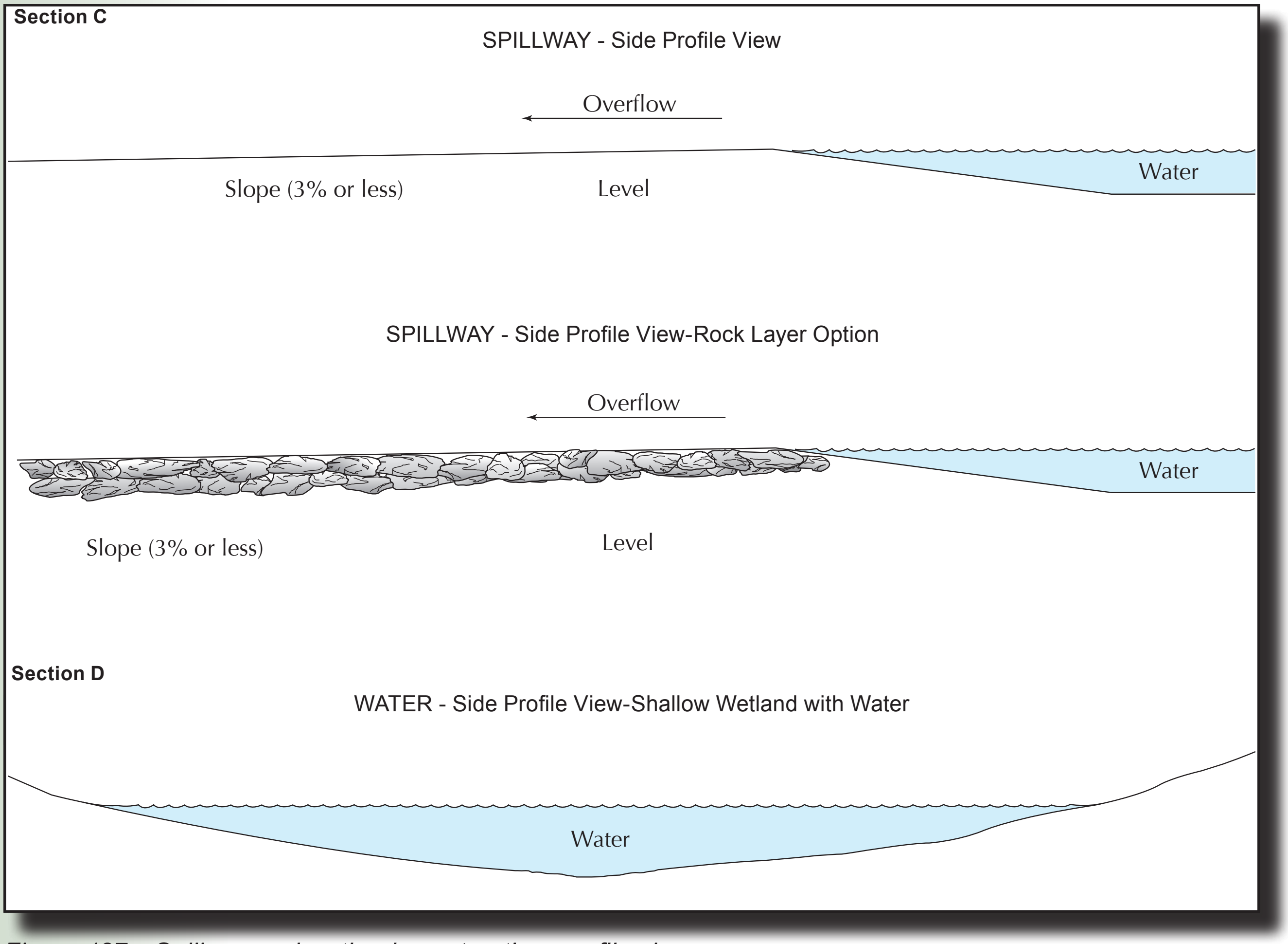


Figure 187—Spillway and wetland construction, profile view.

In areas with beavers and on wetlands with a larger watershed, construct a spillway up to 20 feet across to reduce the depth and velocity of water flowing along its path. A wider spillway diffuses the flow of water into a thin sheet, which beaver may not block. In a watershed with a wetland less than 0.25 acres, build a narrower spillway.

Locate the spillway at one end of the dam where it ties in to higher ground. Mark the elevation for the spillway to be lower than the top of the dam; set the entrance of the spillway 6 to 12 inches below the top of the dam. Because the spillway is often wet and muddy, place it opposite where most visitors will access the dam. See figure 188.

Figure 188—Create a spillway at one end of the dam. See arrow

Use a construction level and rod to layout the path that water takes leaving the wetland down the spillway to ensure that the flow will not damage neighboring property or improvements. To avoid causing problems, create a long path for water to take so that it can empty into a stream or ditch.

Setting the spillway entrance elevation is critical to protecting the dam. If the spillway is set too low too much of the dam is above the water and muskrats can tunnel into it causing damage. Setting it too high also causes problems. The dam will become saturated to the point that heavy equipment, foot traffic, or animals may cause damage by allowing water to breach the dam and cause erosion and drain the wetland.

Since few earthen dams are perfectly level, use a survey rod and construction level to check elevations along the top of the dam before creating the spillway. Place the tripod and level in the original position at the upper edge where water should reach. Walk along the top of the dam stopping every 20 feet or less to record the elevation of the rod. Check any place along the top of the dam that appears to be low. Keep track of the lowest elevation found on top of the dam. For example, the following elevations are recorded while walking along the top of the new dam: 6.0, 6.1, 6.0, 6.1, 5.9, 6.1, 6.1, and 6.0. The entrance of the spillway should be set at 7.1 (6.1 + 1.0), because the lowest place found on the top of the dam was 6.1, and the water should leave the wetland when it is 12 inches below this elevation.

Be onsite during construction to ensure that the spillway is in the best location, has the correct elevation, and a gradual slope. Building the spillway takes time; do not rush. Set a wire flag in the ground on top of the dam to mark the entrance of the spillway. Ask the equipment operator to scrape a path beginning at the entrance to the spillway, removing the soil in layers. Begin with a level spillway path and continue downhill on a gradual slope. The soil removed for the spillway can be spread on the backside of the dam. Ask the operator to begin by only removing a little soil at first, and then stop him or her frequently so you can check the elevation at the entrance of the spillway and along the path that water will follow to see if it will go downhill. Gradually lower the soil level rather than gouge it out in one pass. Removing a little soil each time helps keep the entrance of the spillway from becoming too low and from sloping too steeply. Backfilling a spillway takes even more time and results in poor performance as the soil placed back in the spillway is soft and more likely to erode. See figure 189 and 190.

Figure 189—This spillway was built incorrectly. It is eroded and has formed a head cut because water was directed over too steep a slope. If not repaired, the erosion will eventually drain the wetland.

Figure 190—View of a spillway designed to carry overflow waters over a gradual slope. The restored wetland is in the background, with waters flowing down the spillway towards the reader. See arrow.

Sometimes it is necessary to armor the spillway with rock to prevent erosion. If necessary, add rock where water flows onto steeper ground or across soil not protected by vegetation. Rock also is recommended when the spillway is expected to carry water on a regular basis over several months. Dig the spillway deep enough to make room for the rock. The final elevation at the entrance of the spillway lined with rock will be the planned 12 inches below the top of the dam. Excavate the entrance of the spillway 18 inches below the top of the dam, which allows 6 inches for a rock layer on the spillway. Next, use an excavator or dozer to place and pack the 6-inch thick rock layer in the channel. Pack the rock by either running over it with the dozer or pressing it down with the excavator's bucket. On the spillway, use fist-size to grapefruit-size rock. In the spillway, mix some soil in with the rock so that plants will grow. Plants slow the waterflow and mask the artificial appearance of the rocked spillway.

When Compaction Is a Good Thing

Natural soils found in areas not disturbed by heavy equipment contain air spaces between the soil particles, which allow rainfall to soak into the ground. These soils are considered well structured and can transmit water considerable distances until it reaches the water table and enters a stream or lake. Even fine textured soils that contain high amounts of clay are permeable and can transport large quantities of water (Reed 1995). Compaction causes a reorientation of soil particles that reduces the volume of air in the soil, which slows water movement into the ground (Nolte 2006). Compacted soils can form a barrier to water movement and are said to be impermeable.

Once compacted, soils can remain impervious to water for hundreds, if not thousands, of years. Compaction is why all the soil removed to dig a hole for a large fence post can be tamped back in the hole around the post. Compaction explains why road ruts created by unmanaged OHV use can hold water like mini-wetlands. An example of undisturbed soil's water-holding capacity is how hand-dug holes rarely contain water for more than a couple of days after a heavy rain; the soils lining the bottom of these holes are not compacted.

Be sure that soils are compacted during construction of surface-water wetlands. If soils are not compacted, the wetlands can fail to hold water. There are several simple ways to determine if soils are being compacted during construction. They are:

- Look for wind-blown dust. Dust provides a clear sign that soils are too dry for compaction.

- By hand, and without adding water, shape the soil into a long ribbon between your thumb and forefinger.

- Check that equipment tracks or tires stay on top of the soil and do not sink in after repeated passes.

- Try to dig a hole with a shovel or post-hole digger. It should be extremely difficult to do.

- Examine soil cut with a dozer blade; compacted soils have a smooth, hard surface. They do not tear or appear grainy.

For most wetland projects one can obtain suitable compaction by simply running a dozer or excavator over each 6-inch-thick layer of soil 3 to 4 times as it is placed in the core and dam. Equipment with rubber tires provides greater compaction than do tracked machines. Where soils are somewhat dry or low in clay, a backhoe on rubber tires can be used to travel over each layer for greater compaction.

Civil engineers often use a special gauge called a penetrometer to measure compaction when building roads and parking lots. They generally strive for 90 to 95 percent compaction, which also works well for wetland construction. However, when building a wetland with moist soils it often is neither possible nor necessary to obtain this degree of compaction. When working in wet soils, one is fortunate to shape the basin and dam with a dozer and excavator, and then spread soils to form the slopes of the dam. Even though dams built from wet soils can be expected to settle over time, they also can be expected to hold water as planned. When building a wetland from wet soils, it may be necessary for personnel to return to the site with equipment after the dam has dried to fill and level sections where settling has occurred.

It is difficult to obtain suitable compaction for wetland restoration from soils that are dry. Cores and dams built from dry soils often fail from water soaking through them. Dams constructed of dry soils also may settle and crack causing washouts. There are a number of ways to tell when soils are too dry for building wetlands. The first is when the soil removed from a test hole cannot be shaped by hand into a ribbon or tube. See page 123 and 124 for a full explanation of this process. The second is when dust is seen blowing across the area as equipment disturbs the ground. The third is when the clumps of soil dug out of the ground crumble instead of stick together when crushed by heavy equipment.

It may be possible to wet soils with water pumped from a nearby stream or pond, or even with water from a nearby fire hydrant, to create conditions suitable for compaction during construction. However, when working in remote areas, it often is best to wait for a rain. Then, return to the site to mix the wetter top layers with the drier mineral soil to increase its moisture content.

Handling All That Topsoil

Understand the wetland ecosystem specific to the restoration site before spreading topsoil over the completed project. Wetland restoration projects can generate huge piles of topsoil. Deciding what to do with the topsoil can have quite an influence on the cost of a project. Generally, save one-half or more of the topsoil to spread over the completed project. Use the other half of the topsoil to form the back slope on the dam. Topsoil spread over the finished wetland provides conditions for more rapid plant growth compared to exposed mineral soils. The mineral soils on the bottom of the wetland may have become compacted during construction, and a loose layer of topsoil will provide a better seedbed for plants. Topsoil also may contain the seeds of wetland plants that have been dormant for years; now, with moisture, these seeds may germinate. See figure 191.

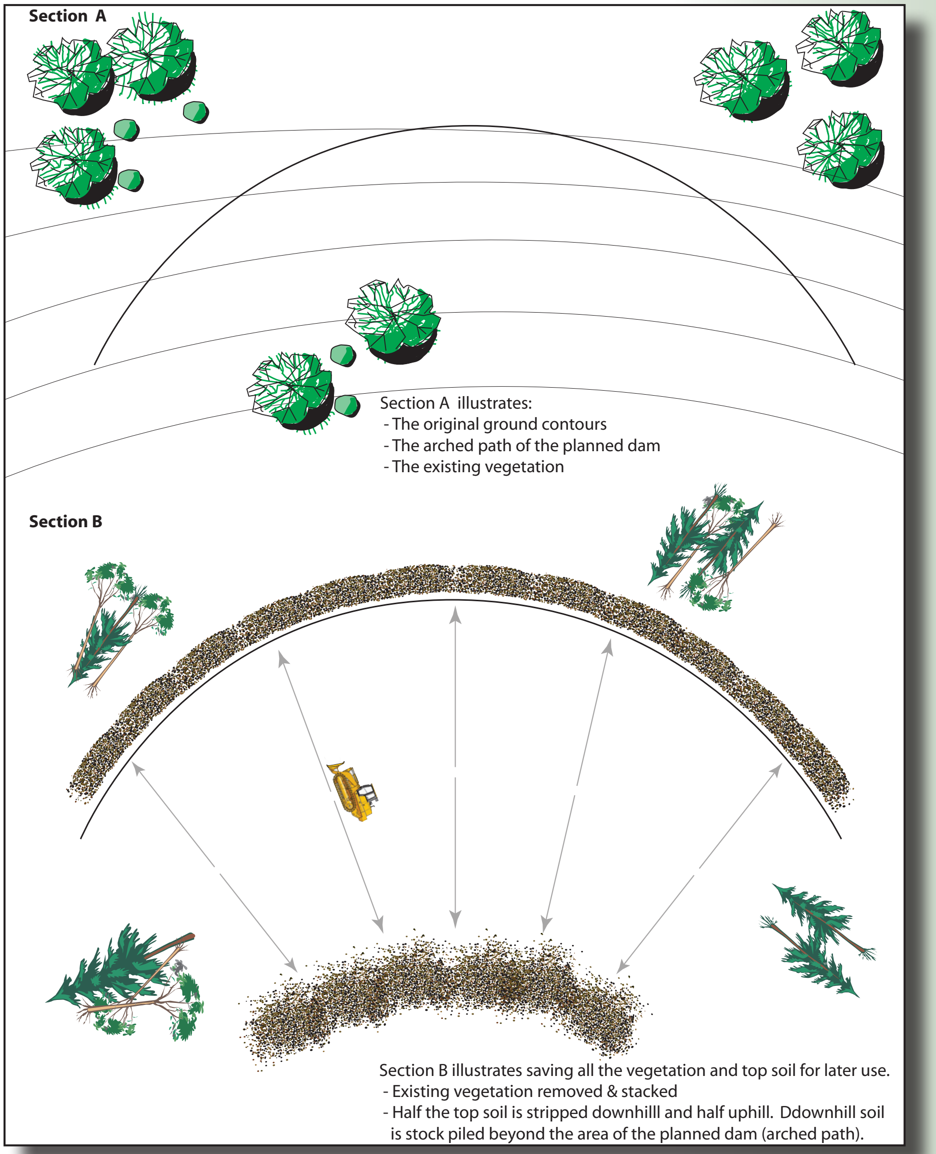


Figure 191—Spread the topsoil that was saved from the pool area before construction over the pool area.

Spread topsoil over surfaces above and below the water level in the new wetland. Seeds planted in the topsoil will grow better than those sown on mineral soil. However, there can be disadvantages to spreading this topsoil should it contain invasive plants, such as Johnson grass or Japanese knotweed. Invasive plants present before construction will have left their seeds and roots in the soil.

Improve turtle habitat by placing thick layers of topsoil in the bottom of each restored spring-fed wetland. Mud provides wintering habitat that will not freeze and protection from predators, such as otters.

Topsoil is not a requirement to restore a wetland successfully. By their nature, wetlands serve as a collection basin for soils, leaves, and other organic material from surrounding lands. Deep ponds created 30 years ago in eastern Kentucky where topsoil was not reused have been found to contain 12 inches or more of organic material in their bottom. Wetlands built in gravel pits or road borrow areas, which were devoid of topsoil, will eventually accumulate a layer of topsoil after restoration, and can show an impressive variety of aquatic plants.

The reasons not to spread topsoil following restoration are the following:

1. In certain cases, the exposed mineral soil wetland bottom is ideal for ecosystem regeneration. For example, the nutrients found in topsoil may slow the development of mosses, which are required for four-toed salamander breeding habitat.

2. Mineral soil can maintain mudflats for shorebird feeding, exposed soils likely will remain open longer when topsoil is not spread after the restoration.

3. When restoring bogs on clay soils, topsoil can raise the pH and make conditions unsuitable for acid-dependent species, such as sphagnum moss.

Returning Wood and Trees to the Wetland

Place logs in wetlands to provide sites for turtles and snakes to bask, perches for birds to hunt from and to rest on, and moist protective covers where the marbled salamander can lay its eggs in the fall when the wetland is dry. There are a number of ways to return large woody debris into a restored wetland: (1) use a dozer with a chain to drag logs into the wetland; (2) use an excavator's bucket to pick up and place logs in any location desired; and (3) fell several trees from the surrounding area into the wetland. Where vertical snags are desired, consider using an excavator to transplant trees upright in a wetland. Leave the large root mass attached to the tree, and to ensure stability bury it about twice as deep as originally found. Digging within the pool area will not cause a wetland to leak; the water is kept in the wetland by the constructed groundwater dam. See figure 192 and 193.

Figure 192—Use a dozer to move trees (large woody debris) into the wetland.

Figure 193—A restored ephemeral wetland near Clearfork Creek. Daniel Boone National Forest.

Restore a forested wetland by creating small islands for planting. Make the islands different shapes and sizes and 1-foot or more above the water level. Planted trees will not survive in saturated ground. Do not compact the soils in the islands. On a large flood plain, create gradual slopes on the islands so they do not wash away in floods and to prevent burrowing muskrats from turning them into Swiss cheese. For generations, foresters have used raised beds to grow trees in areas with standing water and wet ground. See figures 194 through 196.

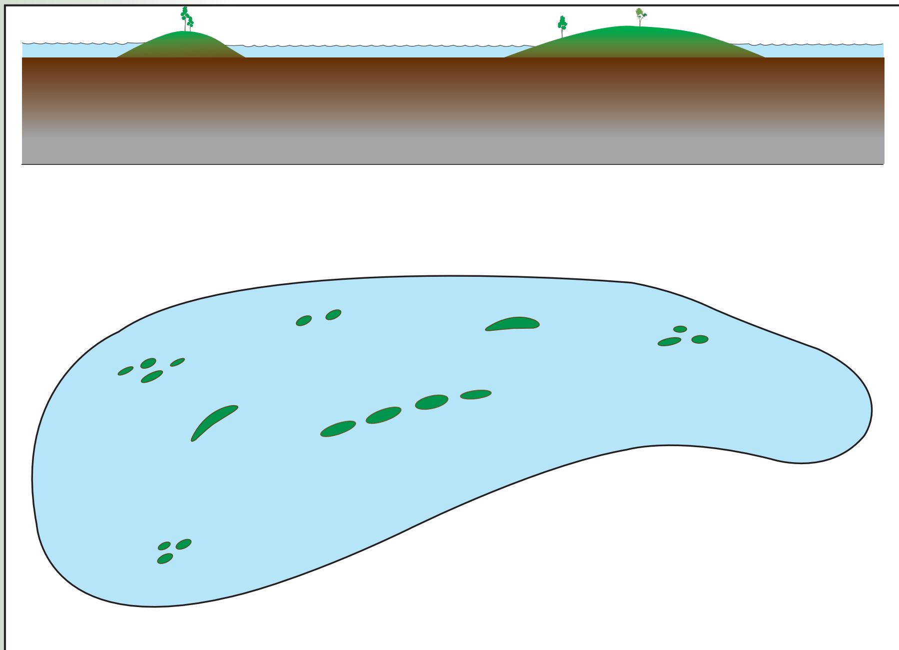


Figure 194—Placement of small islands in wetlands.

Figure 195—A restored forested wetland in Kentucky's Menifee County. Daniel Boone National Forest.

Figure 196—A restoration with an island.

Restoring a Groundwater Wetland

A groundwater wetland generally is restored by removing raised ridges and mounds of saturated soils to create a depression that exposes the water table; the water surface is now the same elevation as the water table. The soil textures in groundwater wetlands can be quite course, consisting largely of sand and gravels. Water levels in these wetlands can be expected to change as much as 3 feet over the course of a year as the water table rises in the spring and drops in the fall. Groundwater wetlands may dry up when there is a long-term drop in the water table caused by drought or from pumping the aquifer.

Establishing the Original Depth of a Groundwater Wetland

Dig a test hole in the damaged wetland to identify how deep the basin should be. In the center of the historic wetland, use a post-hole digger to dig a 3-foot-deep hole. See page 121. After 1 hour, see how deep the water is in the hole. If the water is 1-foot below the surface, and a wetland with a maximum depth of 2 feet is desired, excavate a depression approximately 3 feet deep. Keep in mind the time of year the test hole is dug; the water table will be highest in the winter and spring and lowest in the summer and fall. When restoring a groundwater wetland, determine the elevation of the water table during the driest time of year.

When providing breeding habitat for amphibians, test groundwater elevation in early spring and again towards the end of summer when targeted amphibian larvae are developing. The maximum depth of the excavated depression should equal the elevation of the dry wetland water table. For example, wetlands designed for the red-legged frog should contain water late into fall season, but not year round. Measure the groundwater elevation in early spring and again in late fall. Dig the wetland so that the bottom of the depression is the same as the elevation of the water table when it is lowest. This provides water long enough for red-legged frog larvae to develop, but not long enough for competing bullfrogs to establish. For instance, if the elevation of water in the soil is 12 inches below the surface in March and 36 inches below the surface in November, the wetland should be 36 inches deep.

Building a Groundwater Wetland

Use an excavator to create a natural appearing wetland; the wide pads on an excavator allow it to travel in places where a dozer may get stuck. In less than one-half a day, a medium-sized excavator can restore a wetland 2 to 3 feet deep in the center and up to 60 feet in diameter.

Restoring a naturally appearing groundwater wetland approximately 60 feet in diameter requires a 90-foot-diameter opening in the forest. Trees can stop an excavator's swinging boom, so ensure that there is enough room for the machine to work. Remove some trees but do not remove all trees in an area. Leave some trees standing within 30 feet of the opening or clearance area; ask the operator to work around these trees. Leaving trees may slow the process, but it helps maintain desired shade over the water and provides a more natural appearance.

Encircle the 90-foot clearance area with ribbons. Show the operator the site and ask that the trees, except those marked for saving, and shrubs within the ribbons be cleared. Tell the operator to place removed trees outside of the ribbons in small piles so that they do not dominate the view. Strip and save the topsoil. The groundwater wetland is deepest in the center and gradually slopes up hill. Once the vegetation is removed, ask the operator to position the machine approximately 30 feet from the edge of the clearing, to extend the bucket towards the center of the cleared area, and to create a depression by drawing soil up to the machine. Deposit drawn soil between the machine and the edge of the clearing. After scraping an area, the operator moves the excavator over and repeats the procedure reaching inward again. The process continues until the circle is complete.

The most efficient way to construct a groundwater wetland is to pair an excavator with a dozer. In many situations, the dozer can do a faster job in leveling the soils removed by the excavator than can the excavator. Use the dozer to push drawn soils outwards from the edge of the clearing between larger trees, like spokes on a wheel, to further improve the shape and appearance of the wetland. A dozer also may be used to shape the depression pushing soil from the center outwards.

Using a construction level and rod, check the depth of the depression early in the process by comparing the center of the depression with the elevation of the surrounding ground to see if it is acceptable. If needed, ask the operator to set up and dig another round to make the depression deeper and to adjust the slope. See figure 196.

Figure 196—A dozer being used to shape a groundwater wetland in Kentucky's Menifee County. Daniel Boone National Forest.

Once the depression is made, use the excavator to place topsoil in the depression and spread excess soils around the lower outside edge of the depression. The wetland will blend into the surroundings and look like it has always been there. An experienced operator can create gradual slopes, feather out excess soil, and place woody debris with the skill of a sculptor. See figures 197 and 198.

Figure 197—An excavator being used to shape a groundwater wetland in Kentucky's Menifee County. Daniel Boone National Forest.

Figure 198—Restored groundwater wetland. This photo shows a restored ephemeral, groundwater-supplied wetland. It is being used by the boreal or Western toad for breeding. Arapaho-Roosevelt National Forest, Colorado.

Case Studies Involving Restoration of Vehicle Caused Disturbances to Wetlands

OHV damage to wetlands can be reversed. Case studies describing how individuals are tackling these problems are the best way to show how this is possible.

Jenny Creek and Yankee Doodle Lake Wetland Restoration, Arapaho-Roosevelt National Forest

Vehicles traveling off the designated route of Moffat Road and Boulder Wagon Road were causing ruts and erosion and threatening archeological resources near Yankee Doodle Lake and along Jenny Creek (Savery 2006). Hydrologist Theresa Savery knew it was time for action when she found a rainbow trout flopping in the road. Water from the lake was flowing down the unauthorized trail; this unmanaged OHV use had severely damaged the wetland surrounding the outflow from the lake and along the creek. Not only were aquatic plants trampled, but soils entering the lakeside wetland had formed a 5-foot-wide delta.

For years, people had been illegally driving overland to get closer to the lake for fishing and to go mudding in the wetland. To stop these activities, Forest Service staff efforts included controlling access and reducing the disturbance by blocking the area with berms, posting messages on fiberglass posts, and writing tickets. These efforts were unsuccessful. Visitors continually drove off of the designated routes into the wetlands, creating more illegal routes.

Savery was part of a team of Forest Service employees concerned with halting the damage and restoring the wetlands, high elevation willow carr, emergent wetlands, and streams. Personnel on the Boulder Ranger District knew that support from OHV users would be critical to the success of any plans to restore the wetland and lakeshore. District personnel held monthly meetings with OHV groups. Discussions with OHV users built trust and encouraged a commitment for taking action to improve the Jenny Creek area. The team heard that OHV users wanted to keep access to Yankee Doodle Lake open, and more importantly, they wanted to help.

A Forest Service team identified actions necessary for restoring wetland and wildlife habitat near Jenny Creek, with a secondary purpose of protecting the historic Moffat Road and Boulder/Rollins Wagon Road. Their plan consisted of obliterating approximately 100 feet of unauthorized trail that passed through the wetland, returning outflow from the lake into the wetland, tilling and planting 3 acres of disturbed upland and wetland, and building 1,200 feet of post-and-cable barrier along the trail and road to block access to the wetland.

To comply with the National Environmental Policy Act, analysis was completed for the proposed project in a decision memo. The action was categorically excluded from documentation in an environmental impact statement or environmental assessment under Forest Service Handbook Category 6 that includes wildlife habitat improvement activities, which do not include the use of herbicides or do not require more than 1 mile of low standard road construction. Had the actions been proposed from strictly a watershed improvement standpoint, it would have been necessary to prepare an environmental assessment. This would have cost the Forest Service significantly more time and money.

The Rising Sun 4-Wheel Drive Club of Colorado agreed to purchase $2,500 worth of supplies needed to build the barrier, which included 90 metal posts, 2,400 feet of 5/8-inch cable, and 120 80-pound bags of concrete. Their members volunteered on two separate weekends and worked alongside Forest Service employees to complete the job. Volunteers cleaned out predrilled holes, set the posts in concrete, and strung the cable. The Forest Service purchased the rest of the supplies needed with wildlife, fisheries, and watershed funds.

The Forest Service hired an equipment operator with a backhoe to obliterate the unauthorized trail, reshape the wetland, and scarify compacted soils. The operator was paid by the hour, which saved the expense of having to complete a topographic survey and detailed engineering drawings, which are generally needed for construction contracts. Savery worked with Brian Rasmussen, a recreation technician, to determine the scope of work. Rasmussen directed the backhoe operator to use onsite boulders and gravel to redirect the flow running down the road back into Jenny Creek and the wetland. An archaeologist was present during the trail obliteration and post-hole drilling work to monitor potential impacts to cultural resources and stop work as needed. He also dug in the area to record and collect artifacts for protection and to gather archaeological information. See figure 199.

Figure 199—Backhoe works to reverse compaction caused by unmanaged OHV traffic by scarifying soils on the shrub (willow-carr) wetland disturbed near Jenny Creek. Arapaho-Roosevelt National Forest (Brian Rasmussen photo).

To reduce the possibility of introducing unwanted nonnative plant species to the restoration, sterile wheat seed (Regreen) was spread on the tilled upland areas, and certified weed-free wheat straw was used to mulch exposed soils. Live willow branches were hand clipped from dense clumps near the site and tied in bundles, and these bundles were planted in the restored wetland using post-hole diggers and shovels. To help the willows take root and survive at the high elevation, volunteers and Forest Service employees removed the leaves from each branch before planting. Plugs of the sedge Carex aquatilis also were hand dug near the site and transplanted into the exposed soils on the restored wetland. The restoration work was completed by Forest Service personnel working side by side with a crew of volunteers representing the Rising Sun 4-Wheel Drive Club, Rocky Mountain Recreation Initiative, Colorado Rails and Trails, and the Sierra Club. See figure 200.

Figure 200—A recently restored high elevation willow-carr wetland near Jenny Creek. Newly planted willow bundles and sedge plugs are visible along the water’s edge. Arapaho-Roosevelt National Forest (Theresa Savery photo).

A partnership between the Forest Service and members of the Rising Sun 4-Wheel Drive Club continues. Volunteers patrol this remote area informing users of the importance of complying with Forest Service regulations. The partnership between the OHV group and the Forest Service has resulted in benefits to both parties. This is documented by positive stories the Rising Sun 4-Wheel Drive Club continues to be involved in annual maintenance. <http://www.risingsun4x4club.org/history.shtml>. See figure 201.

Figure 201—An overview of the restored wetland near Jenny Creek showing the post-and-cable barrier. Arapaho-Roosevelt National Forest (Brian Rasmussen photo).

Chippewa National Forest

The Land and Resource Management Plan completed for the Chippewa National Forest in 2003 contains direction for decommissioning 200 miles of roads by the year 2013. A high density of roads and the need to decrease maintenance costs were the main reasons for this program (USDA 2004). In 2006, the Walker Ranger District decommissioned a 1-mile section of Forest Road 2076 that included 0.4 miles of wetlands.

Luke Rutten, forest hydrologist, observed how a number of roads were affecting stream and wetland functions and realized that the road decommissioning program provided an excellent means for improving watersheds (Rutten 2006). Roads like 2076 that cross wetlands often cause dramatic changes to wetland vegetation. In this case, the road was 12 inches above the wetland. This caused areas upstream to become much wetter. It killed black spruce and tamarack trees and encouraged the growth of sedges and grasses. Also, it caused areas downstream to become drier, which resulted in a dense growth of shrubs and trees.

According to Rutten (2006), whoever built the road …“had basically built it by digging two parallel ditches, placing the material removed between the ditches to form the new road. Our restoration plans involved reversing what had been done by excavating the roadbed down to the elevation of the surrounding surface, then filling the ditches on either side with the excavated material.”

The Forest Service prepared a request for quotations, which contained specifications for decommissioning Forest Road 2076 along with some additional roads. Contract specifications required excavating the existing roadbed so it would be even with the surrounding, natural ground surface. The removed material was to be used to fill the ditches. The contractor expressed concern about the ground being so soft that he would sink into the wetland, so he used a small excavator with 5-foot-wide tracks for flotation to remove the road where it passed through the wetland. Fortunately, he did not get stuck and, according to Rutten, the project went well. “Actually it was a pretty simple operation” he said. “I’ve heard where experts worry about breaking up compacted soils, but from what I could see we didn’t have this problem.” There was no need to seed or mulch the loose exposed soils on the restored site. See figure 202.

Figure 202—This excavator is being used to remove a portion of a road that went through a wetland. (Luke Rutten photo)

Conclusions

A limited number of individuals who operate OHVs are damaging wetlands on public and private lands. Their actions are affecting plant and animal habitat and impairing the beauty of the landscape. Concerned managers from around the Nation are working to reduce OHV damage to wetlands. Managers are reversing the damage and lowering the probability of their recurrence. Highly effective restoration programs are being implemented that often involve OHV users in a process of identifying areas of concern and working together to take action that helps the environment.

CHAPTER 4 - MONITORING AND MAINTENANCE

Monitoring and maintenance are intertwined because monitoring may lead to maintenance. When figuring the cost of a project, always include money for monitoring because monitoring is critical for the project's success. Report monitoring results to a line officer or an official with the responsibility, authority, and resources to take any needed action steps. Create a mechanism to ensure the needed follow-up actions actually take place.

Monitor for ecosystem structure and function. Think about what triggered the restoration. Was it loss of soil moisture, composition, and strength; loss of plant cover and diversity; or absence of wildlife or a radical change in the type of wildlife? As the restoration matures, are ecosystem structure and function returning? Is the restoration site beginning to look like the reference site or adjacent landscape?

Besides finding out if any use has taken place on the restoration site, monitoring shows which methods are successful under what circumstances. These can be duplicated in the future because tracking these will eventually show a pattern of success and failure. Note the plants, mulch types, and so forth that are doing well and plants that did not survive or perform as planned. Note conditions, such as soil moisture, aspect, sun-to-shade ratio, and degree of slope, to determine if there is a correlation between these and plant health, mulch stability, and project success. In other words, note what worked, what did not, and why; what was cost effective; and what other factors were relevant to the restoration project.

Before beginning the restoration work, choose photo points that will be used throughout the process. It is all right to add points as the project is finished. See figure 203.

Figure 203—The figure shows photo points of a restoration site in the National Forests in Florida called Wire Grass. Point (a) was taken in 2008 and point (b) in 2010.

Begin monitoring immediately after finishing the project. Visit every day for the first 2 weeks or longer so that problems can be caught immediately; then taper off, going out every few days to once every few weeks. A side benefit of daily monitoring is that the public can see a Forest Service presence. Also, for the first few months, visit the area immediately after a storm to see if any work has been undone or is threatened.

When the mulch, seedlings, or transplants don't look right, decide, through a process of elimination, what has happened. Decide what actions to take, if any, to stop the deterioration or to replace what has been damaged or lost. Record conditions and actions taken to see what affect they have in the long run.

Check the condition of:

- Signs.
  - In place.
  - Legible.
- Barriers.
  - In place.
  - Effective.
- Water diversions.
  - In place.
  - Effective. No concentrated flow running through the restored area.
- Project area.
  - Mulch is in place.
  - Seeds are sprouting, vegetation is alive.
  - Erosion–water, wind.
  - User damage.
  - Animal and/or bugs eating plants.
  - Water is held in wetland as planned.

If a sign is missing or illegible, replace it. If barriers are ineffective, replace them. If water diversions have failed, replace them. If water is getting onto the treatment area from a previously undiscovered course, divert that water away from the treatment area, and so forth.

More specific questions for monitoring include:

Has the area been driven over, trampled, or grazed?

Is the installation functioning as designed?

Is the mulch too thick for seeds to sprout or so thin and the soil dries out when that wasn't the plan?

Are certain areas maturing more rapidly than others? Why?

Are seeds sprouting in the newly formed beds?

Which plants have invaded the site through natural succession?

What plants have sprouted in the second season?

Which areas are experiencing difficulty and why?

Is something occurring that is unexpected?

Which techniques are succeeding?

Are any of the structures failing?

Cover Monitoring Assistant

The Cover Monitoring Assistant (CMA) software program was developed to monitor ground cover in a series of photo transects (CMA). This has limited use for landscape application, but may be applicable in certain situations, such as when restoration is done under a court order or when threatened and endangered species are involved.

CMA is a software program for recording soil and vegetative cover information quickly from a batch of digital photographs taken in the field. The program overlays a set of points on each photograph, and the user assigns a cover code to each point. See figure 3.2. When all the photographs are evaluated, the program will summarize the data and also calculate means and confidence intervals for statistical reporting.

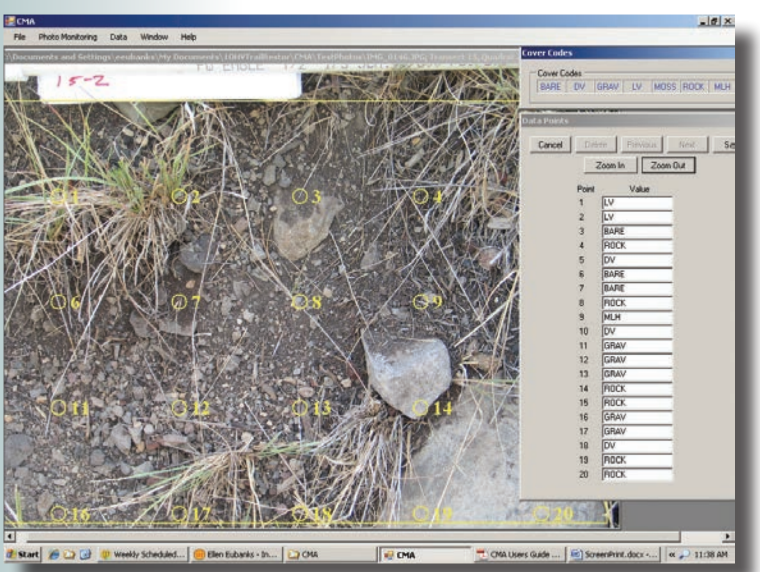


Figure 204—This photograph shows a grid and points overlaid over a photograph. What is visible at each data point is recorded in a cover code.

The CMA was developed for use with the Soil Cover and Species Cover monitoring protocols outlined in the publication “Roadside Revegetation: An Integrated Approach to Establishing Native Plants, Chapter 12: Monitoring Protocols” (Steinfeld 2008). The chapter details how to layout transects statistically and how to take electronic photographs of quadrants. An online copy of this chapter is available, or a hard copy of the manual is available by contacting the Federal Highway Administration’s Coordinated Technology Implementation Program.

The development of the CMA program was a cooperative effort between the Forest Service Pacific Northwest Region Restoration Team and the U.S. Department of Transportation, Federal Highway Administration, Western Federal Lands Highway Division.

GLOSSARY

Apical bud. The end of the stem where new growth appears.

Aquatic ecosystems. The stream channel, lake or estuary bed, water, biotic community, and the physical, chemical, and biological features that occur therein, which forms an interacting system that interacts with associated terrestrial ecosystems.

Aspect. The direction towards which a slope faces with respect to the compass or to the rays of the sun (Soil Science Society of America 2008).

Bankfull. The discharge that fills the stream channel without overflowing onto the flood plain.

Biological (soil) crust. Microorganisms, such as lichens, algae, cyanobacteria, and microfungi and nonvascular plants, such as mosses and lichens, which grow on or just below the soil surface. Synonyms: microbiotic crust and cryptogamic crust.

Braided. A trail or stream that forms an interlacing network of branching and recombining channels separated by branch islands or channel bars.

Canopy cover. The percentage of the ground covered by a vertical projection of the outermost perimeter of the natural spread of foliage of plants. Small openings within the canopy are included. Synonym: crown cover (USDA 1997).

Cation. An atom or atomic group that is positively charged because of a loss in electrons (Society 2008).

Cation exchange. The interchange between a cation in solution and another cation in the boundary layer between the solution and the surface of negatively charged material, such as clay or organic matter (Soil Science Society of America 2008).

Cation exchange capacity (CEC). The sum of exchangeable bases plus total soil acidity at a specific pH value, usually 7.0 or 8.0. When acidity is expressed as salt-extractable acidity, the cation exchange capacity is called the effective cation exchange capacity because this is considered to be the CEC of the exchanger at the native pH value. It is usually expressed in centimoles of charge per kilogram of exchanger (cmolc kg-1) or millimoles of charge per kilogram of exchanger [this has to do with mass] (Soil Science Society of America 2008).

Channel. A stream, river, or artificial waterway that periodically or continuously contains moving water. It has a definite bed and banks that confine the water.

Colluvial. Pertains to material or processes associated with transportation and/or deposition by mass movement (direct gravitational action) and local nonconcentrated runoff on side slopes and/or at the base of the slope.

Compaction layer. A near surface layer of dense soil caused by the repeated impact on or disturbance of the soil surface. When soil is compacted, soil grains are rearranged to decrease the void space and bring them into closer contact with one another, thereby increasing the bulk density (Soil Science Society of America 1997).

Duff. Partially decomposed plant litter. Duff consists of decomposing leaves and other organic material; no plant parts are recognizable. When moss is present, the duff layer is just below the green portion of the moss. The bottom of this layer is the point where topsoil begins.

Ecosystem function. (a) The process through which the constituent living and nonliving elements of ecosystems change and interact, including biogeochemical processes and succession. (b) A role of an ecosystem that is of value to society.

Ecotone. A relatively narrow overlapping zone between two ecological communities.

Erosion. In the general sense, the wearing away of the land by wind and water. Detachment and movement of soil or rock fragments by water, wind, ice, gravity; the land surface worn away by running water, wind, ice, or other geological agents, including such processes as gravitational creep (Society for Range Management 2014).

Evapotranspiration. Loss of water from the soil by evaporation and from plants through transpiration (gas exchange) (Webster's 1986).

Fascine/wattle. Bound, elongated, cylindrical bundle of branch cuttings or fabricated coconut fiber roll (6 to 8 inches in diameter) used to help prevent soil erosion. Live cuttings will root in moist soil offering greater slope protection.

Fill material. Soil that is placed at a specified location to bring the ground surface up to a desired elevation or angle of slope.

Flood plain. Any lowland that borders a stream or other water body and is inundated periodically by its waters.

Flow pattern. The path that water takes (i.e., accumulates) as it moves across the soil surface during overland flow.

Freeze/thaw process. When water freezes it expands. When moist soil freezes, the soil is pushed up. When the soil (water) thaws, the molecules shrink causing the soil to fall. Repeated freeze-thaw episodes move the dirt around quite a bit.

Function. The collective interactions of the animal and plant life of a particular region. The interactions between organisms and the physical environment, such as nutrient cycling, soil development, water budgeting, and flammability.

Ground water. Water contained in the voids of the saturated zone of geologic strata (the open spaces between the individual soil particles are filled with water). Above the ground-water table and below the ground surface, water in the soil does not fill all the pores.

Gully. A furrow, channel, or miniature valley, usually with steep sides through which water commonly flows during and immediately after rains or snowmelt (Society for Range Management 2014). Small channels eroded by concentrated waterflow.

Headcut. Abrupt elevation drops in the channel of a gully that accelerates erosion as it undercuts the gully floor and migrates upstream.

High-carbon mulch. Mulch, such as straw, slash, and nondecomposed plant material, or woody material used in restoration. Because of the wide carbon-to-nitrogen ratio, the organisms involved in the decay of the high-carbon material immobilize the limited nitrogen available to plants.

Humic acid. The dark-colored organic matter that can be extracted from the soil with dilute alkali and other reagents and that is precipitated by acidification to pH 1 to 2.

Humus. The well decomposed, more-or-less stable part of the organic matter in mineral soils. Humus is an organic soil material that also is one of the U.S. Department of Agriculture textures of muck (sapric soil material), mucky peat (hemic soil material), or peat (fibric soil material). Most likely it is muck. (Soil Science Society of America 2008).

Hydrologic function. The capacity of a site to safely release water from rainfall, run-on, and snowmelt; to resist a reduction in this capacity; and to recover this capacity following degradation.

Indicator. Components of a system whose characteristics (e.g., presence or absence, quantity, distribution) are used as an index of an attribute (e.g., rangeland health) that are too difficult, inconvenient, or expensive to measure.

Infiltration. The entry of water into the soil (Soil Science Society of America 1997).

Infiltration rate. The rate or speed (in millimeters per hour) at which water infiltrates the soil during a specified time period.

Key. Tying an object (meant to prevent movement) into a solid bank or an immovable object, such as a boulder.

Keyway. A longitudinal slot; a trench that spans the width of a plot of land filled with a material that extends above the soil surface when the material is installed in the trench.

Labile. A chemical compound readily transformed by microorganisms or readily available to plants (Soil Science Society of America 2008).

Lee side. The side opposite of the prevailing wind. This side of a plant is sheltered yet receives seed deposits.

Litter. The uppermost layer of organic debris on the soil surface. It is found above the duff layer and is essentially the freshly fallen or slightly decomposed vegetal material (Society for Range Management 2014).

Macro invertebrates. An invertebrate animal (without a backbone) large enough to be seen without magnification.

Monitoring. The orderly collection, analysis, and interpretation of resource data to evaluate progress toward meeting management objectives. The process must be conducted over time in order to determine whether or not management objectives are being met (Society for Range Management 2014).

Mycorrhizae fungus. The symbiotic relationship between the mycelium (mass of interwoven hyphae) of a fungus with the roots of a higher plant in which the hyphae (threads growing from the fungus) form an interwoven mass at the root tips or penetrate the parenchyma (thin-walled living cells) of the root.

Organic matter. Living plant tissue and decomposed or partially decomposed material from living organisms.

Overland flow. Water flowing over the surface of the land, as in runoff or overbank flows.

Plant community. Any assemblage of populations of plants in a common special arrangement.

Parent material. The unconsolidated and more or less chemically weathered mineral or organic matter from which the solum of soils are developed by pedogenic processes (processes of soil development). (Solum—(plural: soda)—A set of horizons that are related through the same cycle of pedogenic processes; the A, E, and B horizons) (Soil Science Society of America 2008).

Pedestal (erosional). Plants or rocks that appear elevated as a result of soil loss by wind or water erosion. Does not include plant or rock elevation as a result of nonerosional processes (i.e., frost heaving.

Proper functioning condition. The functioning condition of riparian-wetland areas is a result of interaction among geology, soil, water, and vegetation. Riparian-wetland areas are functioning properly when adequate vegetation is present to dissipate stream energy associated with high waterflows, thereby reducing erosion and improving water quality; filter sediment and aid flood plain development; improve floodwater retention and ground-water recharge; develop root masses that stabilize streambanks against cutting action; develop diverse ponding and channel characteristics to provide the habitat and the water depth, duration, and temperature necessary for fish production, waterfowl, breeding, and other uses; and support greater biodiversity (USDI, revised (1998). Riparian Area Management. TR-1735-15 1998. U.S. Department of the Interior, Bureau of Land Management).

Punch.

Hand punching: A spade or shovel is used to punch straw into the slope until all areas have straw standing perpendicular to the slope and embedded at least 4 inches into the slope. The straw should be punched about 12 inches apart.

Roller punching: A roller equipped with straight studs not less than 6 inches long, 4 to 6 inches wide, and approximately 1-inch thick is rolled over the slope.

Crimper punching: Like roller punching, the crimper has serrated disk blades about 4 to 8 inches apart, which force straw mulch into the soil. Crimping should be done in two directions with the final pass across the slope <http://www.co.nrcs.usda.gov/technical/eng/STRAWMULCHfactsheet.pdf>.

Quadrants. A usually rectangular plot used for ecological or population studies (Webster's 1986).

Recalcitrant. A stable component of soil organic matter. It stores nutrients (through a huge increase in cation exchange capacity), provides the habitat for soil organisms, and resists mineralization soil microbes.

Rhizomatous plant. A plant that develops clonal shoots by producing rhizomes. Rhizomes are horizontal underground stems that usually produce roots and shoots from nodes (Society for Range Management 2014).

Rill. A small, intermittent watercourse with steep sides, usually only several centimeters deep (Soil Science Society of America 1997). Rills generally are linear erosion features.

Riparian vegetation. Vegetation growing along banks of stream, rivers, and other water bodies tolerant to or more dependent on water than plants further upslope.

Runoff. The portion of precipitation or irrigation on an area that does not infiltrate, but instead is discharged by the area (Soil Science Society of America 1997).

Sediment. Soil particles that have been transported and/or deposited by wind or water action.

Shrub. A plant that has persistent, woody stems and a relatively low growth habit and generally produces several basal shoots instead of a single bole. It differs from a tree by its low stature (generally less than 5 meters, or 16 feet) and nonarborescent form (Society for Range Management 2014).

Sloughing. The downward slipping of a mass of soil, moving as a unit usually with backward rotation down a bank. Also called sloughing off or slumping. Sloughing is similar to a landslide.

Soil aggregates. A group of primary soil particles that cohere to each other more strongly than to other surrounding particles (Soil Science Society of America 1997).

Soil bioengineering. An applied science that combines structural, biological, and ecological concepts to construct living structures for erosion, sediment, and flood control. It is always based on sound engineering practices integrated with ecological principles.

Soil fractions. An active or labile fraction comprised of living—microorganisms and macroinvertebrates—and recently dead soil organisms and a stable or recalcitrant fraction.

Soil texture. The relative proportions of the various soil separates (sand, silt, and clay) in a soil (Soil Science Society of America 1997).

Species composition. The proportions of various plant species in relation to the total in a given area. It may be expressed in terms of cover, density, weight, and so forth (Society for Range Management 2014).

Standing dead vegetation. The total amount of dead plant material, in aboveground parts, per unit of space, at a given time (USDA 1997). This component includes all standing dead vegetation produced in the previous (not the current) growing season that is not detached from the plant and is still standing.

Structure. The spatial arrangement of the living and nonliving elements of an ecosystem.

Surface runoff. That portion of precipitation that moves over the ground toward a lower elevation and does not infiltrate the soil.

Tackifier. A product mixed with water and wood fiber mulch to form a hydromulch. The tackifier glues the mulch together once the water has evaporated.

Tile drain. Concrete, ceramic, plastic pipe, or related structure, placed at suitable depths and spacings in the soil or subsoil to enhance and/or accelerate drainage of water from the soil profile.

Tilth. The physical condition of soil as related to its ease of tillage, fitness as a seedbed, and impedance to seedling emergence and root penetration (Soil Science Society of America 2008).

Toe. The break in the slope where it meets flatter ground or at the foot of a streambank where it meets the streambed.

Tree. A woody, usually single-stemmed perennial plant that has a definite crown shape and reaches a mature height of at least 4 meters. The distinction between woody plants, known as trees, and those called shrubs is gradual. Some plants, such as oaks (Quercus spp.), may grow as either trees or shrubs (Soil Science Society of America 1999).

Vernal pool. A small depression, with a hard-panned floor, whose depth fluctuates with the season and rain pattern. It is dry part of the year. Vegetation within and adjacent to the pool is unique.

Watershed. An area of land surface defined by a topographic divide that collects precipitation into a stream. Sometimes referred to as a drainage basin.

Woody debris. Coarse wood material, such as twigs, branches, logs, trees, and roots that falls into streams.

Appendix A

Restoration of OHV-damaged Areas - A Ten-Step Checklist

prepared for

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by

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under

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1 Introduction

During field visits to Ranger Districts between April 6 and August 30, 2005, observations were made at 87 OHV restoration sites. Many of these projects were successful, but quite a few were either unsuccessful or only partially successful. It became apparent that the success or failure of OHV restoration projects was related to following a process consisting of a set of steps. In discussions with OHV managers, the idea of a checklist that could be followed when doing OHV restoration evolved.

This report presents that checklist as a set of steps to consider when planning and implementing an OHV restoration project. This is followed by a discussion of each step and why it is important.

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2 The Restoration Process

The goals of OHV restoration are to protect restored areas from erosion, reduce sediment delivery, restore soil hydrologic function, and reestablish a plant community with vegetation and cover comparable to the adjacent plant community.

Restoring OHV-damaged areas and closed OHV trails provides unique challenges not typically faced in other restoration projects. At OHV-disturbed sites, OHV traffic is the primary agent of disturbance. This means the treated site must be effectively closed to OHV traffic.

Although we may not always agree with their choices, OHVs are driven by thinking, decision-making, human beings. Where they decide to ride their OHVs can be strongly influenced by how a restoration project is implemented. The appearance of restoration or active management is often enough to keep traffic off restored areas or closed trails. Conversely, OHV damaged areas left untreated send the message that riding anywhere is acceptable.

OHV restoration projects cover a broad range of situations. They can be as simple as hand-raking duff and pine needles to obliterate OHV tracks, or as complex as reshaping the land surface with a large excavator or propagating and planting native plants. But whether the project is simple or complex, large or small, the same basic principles apply; it is just a matter of scale.

3 A Checklist for OHV Restoration

When planning and implementing a restoration project, few projects will require action under every one of the ten steps. However, each step should be considered to make sure the restoration process is complete. Taking a few minutes to inspect the site and think through the process before deciding which treatments to use will often make the difference between success and failure.

Each of the following ten steps deserves careful consideration. When applicable steps are ignored, the risk of failure increases.

1. Identify the Source of the Problem
2. Effectively Close the Area to OHV Traffic
3. Reshape the Land Surface to Its Original Contour
4. Disperse Concentrated Runoff
5. Prepare the Seedbed
6. Planting or Seeding
7. Stabilize the Surface
8. Signing
9. Enforcement and Monitoring
10. Remove Signs and Barriers

4 Discussion

4.1 IDENTIFY THE SOURCE OF THE PROBLEM

Most OHV restoration projects fall into one of two categories: (1) designated trails that have been closed and rerouted, and (2) damage caused by unauthorized traffic, which may include user-defined trails. In the first case, the source of the problem is usually level of use, location, or some site factor such as steepness, slope length, entrenchment, or wetness. In the second case, OHV traffic is the problem.

An important part of the analysis is to determine why the OHV use is occurring where it is. Riders always have some reason for riding where they do. If the underlying reason for the OHV traffic is not dealt with or designed for, it will be difficult to keep OHV traffic off the restored area. If the reason for riding in the area is compelling enough, OHV riders will find a way to ride there again.

Some of the reasons for unauthorized OHV traffic are related to how the OHV area is managed. For example, trails blocked by logs or snowdrifts, lack of maintenance, poor trail location or alignment, dead end trails, and poor signing and maps, may cause riders to leave a trail. Some reasons for unauthorized traffic that are not related to management include cut-offs to connect to a known trail nearby, primitive camping, no place to ride legally, latchkey kids riding from home in the urban-interface, and just plain exploratory riding.

The point is that if the underlying cause of the OHV traffic is not recognized and dealt with, it may be impossible to keep traffic off the restored site. Identifying the underlying cause will also affect the type of barriers used and other measures taken to keep traffic off the restored site.

4.2 EFFECTIVELY CLOSE THE AREA TO OHV TRAFFIC

There are four basic strategies for keeping OHV traffic off a restored site: (1) make it invisible; (2) effectively barricade the site; (3) make it obvious that restoration is taking place; and (4) make the restored site impossible or highly undesirable to ride on.

Making the restored site invisible (Photo 1) is a long-term goal of OHV restoration; to have the site blend in with the surrounding vegetation. But this can take time; and it may not be possible on some sites.

Barriers come in many forms and vary in effectiveness. Photos 2 to 7 in the Appendix show a few that have been effective. Ultimately, the type of barrier selected will be based on cost vs. effectiveness, and on the materials that are locally available. Where archaeology sites are involved, it may be necessary to use techniques that minimize soil disturbance. The key is to provide a barrier sufficient to exclude the traffic, but no more than is necessary. This can range from low rails and soil berms to fences and large boulders. The effects that barriers have on safety and on visual appearance should also be considered in selecting a barrier type. Just about any barrier can be breached by a very determined user—and some will take it as a challenge—so dealing with the underlying cause is important.

Making the restoration obvious by creating the appearance that restoration is taking place is sometimes a sufficient deterrent to traffic. Spreading straw, or native plantings in seedling protection tubes, can send the message that restoration is taking place. Effective signs (see Step 6) are also part of this strategy.

Making the restored site undesirable to ride on by roughening the surface or by scattering slash and dropping logs is an effective deterrent (Photo 8). This strategy works well in forested and brushy areas. Even a small amount of material can be effective. Stopping and getting off an OHV to open a closed trail increases the potential to be caught, not to mention the amount of work involved and the loss of riding time.

Managing the flow of OHV traffic past a restored area is another strategy that can help keep traffic off restored sites. Modifying the trail alignment to increase the speed of traffic or to include challenging turns will decrease the chance riders will notice the restored site. Anything that keeps the rider focused on the trail instead of looking at the scenery going by will help.

Treating all of a closed trail visible from an authorized route is also important. If a portion of a closed and restored trail is still visible, riders will make an effort to get to it, especially if the a trail is one they remember riding in the past. Treating the visible portion with slash and downed logs is an effective deterrent.

4.3 RESHAPE THE LAND SURFACE TO ITS ORIGINAL CONTOUR

It is almost impossible to effectively drain deeply entrenched (3 to 4 feet or more) trails (Photo 9), and reshaping the land surface to the contour should be done where possible. Reshaping deeply entrenched trails requires large, heavy equipment, such as a large excavator or a mid-sized dozer (Photo 10). Using equipment that is too small is a common mistake when trying to reshape steep slopes. Only large equipment is stable enough and powerful enough to negotiate steep slopes safely. A large excavator also has a long reach to more effectively pull in soil, slash, and large logs. Because large equipment is much faster than undersized equipment, it can also be more cost-effective. A skilled equipment operator and on-site supervision is essential on these projects.

If for some reason a large excavator cannot be used to reshape an entrenched trail back to the contour, or where there is no soil to pull in from the sides, the entrenched surface must be stabilized to protect it from concentrated water flow. Jute matting, well-anchored, is preferred over other products because it is tough and can be installed on uneven surfaces (Photo 11). Most other rolled blanket products require a smooth surface. If necessary, the matting can be augmented with straw wattles.

4.4 DISPERSE CONCENTRATED RUNOFF

Trails are linear features that tend to concentrate water, and the area or trail being restored must be protected from concentrated runoff. This is especially important where the treated site is deeply entrenched and has not been reshaped to the contour.

The source of concentrated runoff could be any upslope impervious surface such as a road, trail, old landing, staging area, or area of shallow, rocky soils. The source of concentrated flow could be hundreds of feet or more from the treated site, so some off-site investigation is necessary.

Failure to intercept and disperse concentrated runoff flowing onto a restoration site or trail is a common cause of failure. The treatment is to install a waterbreak that diverts flow away from the treated area.

If the trail being restored has been compacted, scarification or tillage may be needed. Tillage done up and down the slope can create subsurface slots that can lead to subsurface erosion by piping, especially if a rock ripper is used. Implements designed for tillage can sometimes also create subsurface slots.

4.5 PREPARE THE SEEDBED

Whether the site will be seeded, planted, or allowed to recover naturally, the need to prepare the seedbed should be assessed. The first step is to determine how much topsoil has been lost, and whether the soil is compacted. This can be done with a tile spade using an adjacent undisturbed soil as a reference.

If all of the topsoil has been lost, amendments may be needed. Amendments include fertilizer, compost, or topsoil “borrowed” from a nearby undisturbed site. If the soil is compacted, tillage or scarification may be needed. If the compacted soil is less than 3 or 4 inches deep, scarification with a harrow may be enough. If compaction is deeper, tillage may be necessary. An implement designed for tillage, such as a winged subsoiler or Forest Cultivator, is preferred over a rock ripper (which is designed to do just that—rip rocks, not to restore soil tilth). Compaction may not be deep in staging areas or broad areas of disturbance, but compaction is often deep on skid trails and old roadbeds.

On some Districts, "chunking" has been used effectively to restore OHV trails. Chunking is roughening the surface by working backwards up a trail with a small trail tractor, scooping and dumping small windrows of soil (Photo 12). This effectively closes the trail, restores hydrologic function, avoids the need for drainage, and creates a rough surface with micro sites where native plants can become established. It works well where the plant community consists of annual grasses and shrubs. The annual grasses provide cover quickly. Over time, the roughened surface settles and local plants invade the site.

Where it can be done, pulling in native topsoil from nearby or adjacent to the treated area is very effective, especially in forested areas and in areas with shrubs and annual grasses. The soil is a source of local seeds, soil arthropods, microorganisms, mycorrhizzae, and stable organic matter.

The use of fertilizer is controversial, and it probably should not be used widely. But fertilization should not be dismissed, either, because it is a valuable tool. The main objection to fertilizer is that it encourages invaders and thereby suppresses the growth of native species. However, the purpose of OHV restoration is to protect the restored site from erosion and to reestablish vegetation similar to the adjacent plant community. That adjacent plantcommunity may not be natives, or may not be adversely affected by fertilization.

Soil conditions and plant species will determine when fertilizer should be used as an amendment. Fertilizer should not be used in areas of sensitive plants. Sensitive plants often occupy harsh sites where competition is low, and fertilization can increase competition. For the same reason, fertilization should not be used where perennial native grasses are being encouraged.

Situations where fertilization could be considered are (1) broad areas where all the topsoil has been lost, (2) areas dominated by annual grasses, (3) forested situations where topsoil has been lost and the C:N ratio is wide because woody material has been added as mulch, and (5) when "bootstrapping" (see discussion that follows) to restore large disturbed sites.

If fertilizer is used, 16-20-0 S is the formulation of choice. The sulphur in this formulation is important in many California soils. Where there is concern about using fertilizer—such as near a watercourse—an organic or slow-release formulation can be used. In any case, fertilizer should be applied sparingly. The goal is to make the restored area as invisible as possible, and too much fertilizer could make the restored site greener and more lush than the surrounding area. Where used appropriately, a light fertilization will accelerate the establishment of vegetation and cover. The effects of fertilization will wear off in a year or so as nutrients are incorporated into the soil-plant system.

For the restoration of large areas, such as a staging areas and primitive campsites, "bootstrapping" is a good strategy. The concept is to heavily treat 10 to 15% of the area in small patches (30 to 100 square feet), and treat the remaining area less intensively. For example, 15% of the area may be treated with scarification or tillage, a mulch, some native soil “borrowed” from an adjacent undisturbed site, light fertilization, native plantings, and—if in a forested site—a few pieces of large woody material. The remaining 85% would be treated with scarification and a light mulch. The concept is to create small islands that will recover quickly and then serve as a seed source for filling in the remaining area. The islands serve as biological refuge sites for soil macro- and microorganisms and small animals. The visual and biological diversity created by this approach also allows the site to blend in to the surrounding landscape sooner.

Some plant species need to be scarified with fire for the seeds to germinate. Consult the local botanist for these special situations.

4.6 PLANTING OR SEEDING

When dealing with plant materials it is important to know the ecology of the plant species adjacent to the site being restored. Whether they are annuals, or perennials, whether the seeds are persistent in the soil, whether they require fire for scarification, whether they have rhizomes, whether they have mycorrhizal associations—all will affect how the restoration is designed.

Seeding is rarely used to restore OHV damaged sites because it is difficult to find an appropriate seed source. But, there may be special situations where seeding should be considered as an option. For example, sterile wheat or barley might be used as temporary cover to quickly stabilize a small area where mulch is not practical or desirable. Another example would be a very large disturbed area where seed that matches the adjacent plant community is available. The goal is to restore the site so it blends in with the adjacent plant community and does not stand out.

Where it can be done, planting native shrubs or trees is a good option. Although labor-intensive, planting native seedlings can accelerate restoration. If volunteers are available, propagating and planting native species can be team-building and can create ownership in the management of the area. In addition, even the most hard-hearted rider would think twice before riding an OHV through an area full of native seedlings in seedling protector tubes (Photo 13).

Where OHV activity has rutted wet areas, meadows, and the margins of lakes, sod plugs “borrowed” from adjacent areas can be an effective restoration technique. Using sod plugs is also labor-intensive and suitable as a volunteer project.

4.7 STABILIZE THE SURFACE

Because seeding is rarely used, it can take time for the local vegetation to invade and stabilize a restored site. An exception is where annual grasses are used to provide cover, with or without a boost of fertilizer. Until vegetation becomes established, protective cover is needed to stabilize the surface and protect the soil from erosion. Where the restored sites are closed trails, cover can often be provided by raking in duff and litter, or a little surface soil from along the edge of the trail.

Larger disturbed areas, such as staging areas or primitive campsites, will usually need some type of mulch. If access is good, hydro-mulching is an option, as is a straw blower with a tackifier. Usually, lack of access precludes these options and material for mulching must be hauled in by hand or on an ATV.

This narrows the choices down to wheat straw, rice straw, or native grass hay, which is available from native seed growers. Getting a weed-free source is important. Wheat straw is most visible, which may be an advantage (Photo 14). Rice straw blends in a little better and may last a little longer. Native seed hay is expensive, but more likely to be weed-free. Native hay may also contain some native seeds, which may or may not be desirable, depending on the situation. If a steep slope is involved, the mulch may be supplemented with straw wattles staked in across the slope.

Over application of mulch can suppress the establishment of vegetation and can decrease soil temperatures, altering soil biological and nutrient cycling processes. On some sites thick straw mulch and straw wattles can also increase rodent populations.

The high visibility of wheat straw may serve as a deterrent to traffic. Like native plantings, straw sends the message that restoration is in progress.

If all the other steps are followed, OHV-damaged areas do not usually require stabilization with rolled fiber products. An exception is deeply entrenched trails that cannot be reshaped to the contour. In this case, jute matting is the preferred option.

4.8 SIGNING

The signs I observed at restoration sites were inconsistent in shape, size, color, and wording. Many sent the wrong message. Brown carsonite stakes with a small yellow restoration sticker were commonly used at restoration sites. To a rider, a brown carsonite stake sends the message “trail”, or “trail junction.” This is not consistent with making restored trails invisible. If the rider does stop at the brown stake (to read the tiny restoration sticker) and sees a closed trail, the next thought might be “There was a trail here once; maybe if I get past this barrier I can find it.”

Restoration signs should send the message to riders that staying off restored sites and closed trails protects and preserves the opportunity to practice their sport. Restoration signs should also be positive in tone, and direct riders to places they can ride.

Photo 15 shows a restoration sign that sends a positive message; the sign in Photo 16 is not positive, but a little in-your-face. Photo 17 shows a sign with an appropriate shape and color for restoration.

Ideally, signing for OHV areas and trails should be standardized and consistent, at least within a state. Unfortunately, OHV signs are not even consistent within NFs, let alone within the Region or between agencies. This serves no one well.

4.9 ENFORCEMENT AND MONITORING

Keeping traffic off restored sites and trails may require additional patrols and law enforcement. OHV users are understandably upset when trails they have used are closed. Maintaining an effective closure is most important during the first year or two while vegetation is becoming established and riders are changing their use patterns.

Monitoring is also needed to evaluate the effectiveness of restoration treatments. Drainage and erosion control measures need to be assessed and corrective action taken as needed; barriers and signs also need to be assessed and repaired or replaced as needed. Because of the many variables involved—especially the human ones—it may take several seasons to fully restore an area.

4.10 REMOVE SIGNS AND BARRIERS

Signs and barriers are not a natural part of the landscape. When the site blends in with the adjacent landscape, or when the trail is no longer rideable, signs and barriers become a liability and should be removed (Photo 18). Signs that are no longer needed draw attention to the location of former trails. Signs that are obviously no longer needed, that have fallen down or are shot full of holes, and barriers that have deteriorated, all send the message that management is lacking, and maybe even patrols. Signs no longer needed also draw attention to closed trails that riders perceive as lost riding opportunities.

5 Summary

The intent of this report was to describe the processes and general concepts to consider when designing and implementing OHV restoration. The ten-step checklist provides a basic framework for developing a more comprehensive handbook for the restoration of OHV areas.

A restoration handbook based on the material in this report could be expanded, and the material covered under each of the ten steps more fully developed. The material should also be peer-reviewed. Other specialists such as botanists, archaeologists, and wildlife biologists could make contributions. It might also be desirable to include sections on sources of funding, making cost estimates, the use of volunteers, and environmental analysis as they relate to OHV restoration projects.

If a handbook were formatted in a loose-leaf three ring binder, each section could also be a good place to keep information on suppliers of materials and equipment. Design specifications for specific treatments, such as specifications for types of barriers, could also be included.

Many of the OHV managers and their staff are doing a good job at restoring OHV- damaged areas. But there are others who lack the experience and are learning by trial and error. While some experimentation is good, there is merit in starting with the techniques that have worked well for others. There is far too much OHV restoration work to be done to have the luxury of learning by doing.

The information in this report—and an expanded version as a handbook—needs to get out to the people on the ground actually doing the restoration work. Whether or not a handbook is the best way to do this remains to be seen. Other means of providing information on OHV restoration include workshops, presentations at conferences, publication, videos, and one-on-one training conducted in the field.

6 Appendix

6.1 APPENDIX 1 PHOTOGRAPHS

Photo 1. Restored trail that is almost invisible

Photo 2. Large boulders used as barriers

Photo 3. Fence designed avoid soil disturbance in archaeology site

Photo 4. Welded steel fence made from oil well casings

Photo 5. Barriers constructed of railroad ties and installed with rebar

Photo 6. Fence constructed with peeler cores

Photo 7. Temporary fence of steel posts with PVC over wire

Photo 8. Closed trail treated with tillage, roughening, and slash

Photo 9. Deeply entrenched trail will require reshaping with an excavator

Photo 10. Deeply entrenched trail reshaped using an large excavator

Photo 11. Entrenched trail stabilized with jute, straw wattles, and slash

Photo 12. Closed trail freshly treated by chunking

Photo 13. Native plant seedlings in seedling protector tubes

Photo 14. Decommissioned road with light application of straw

Photo 15. Restoration sign with positive message

Photo 16. Restoration sign that could be more positive

Photo 17. Sign with appropriate size, shape, and color for restoration

Photo 18. Restored area with barriers and signs removed

APPENDIX B

Sign Text at a Parking Lot for a Very Large Area

Watershed Restoration Big Silver Creek and Bassi Creek

A watershed restoration project was completed in this area to repair resource damage (soil compaction and erosion) that resulted from motorized vehicle use off National Forest System Roads. User-created routes in this area have been closed to allow recovery of the heavily damaged stream and riparian areas.

Dispersed camping in this area is still allowed.

Please help reduce impacts to Big Silver Creek and Bassi Creek. Keep motorized vehicles on National Forest System Roads. The use of motorized vehicles off of system roads can cause significant resource damage and impact streams and watershed resources. There is a Forest Order in effect for this area, which prohibits motorized vehicle use off National Forest System Roads.

Leave your camp area clean. Pack It In, Pack It Out. Trash and garbage must be packed out and disposed of properly. This includes food waste, packaging, and so forth. Burning or burying trash and garbage is not allowed. Dispose of human waste at least 200 feet from water, trails, and camp areas in cat holes 6 to 8 inches deep.

Respect Private Land Boundaries. Much of the land in this area is under private ownership. Access without permission constitutes trespass.

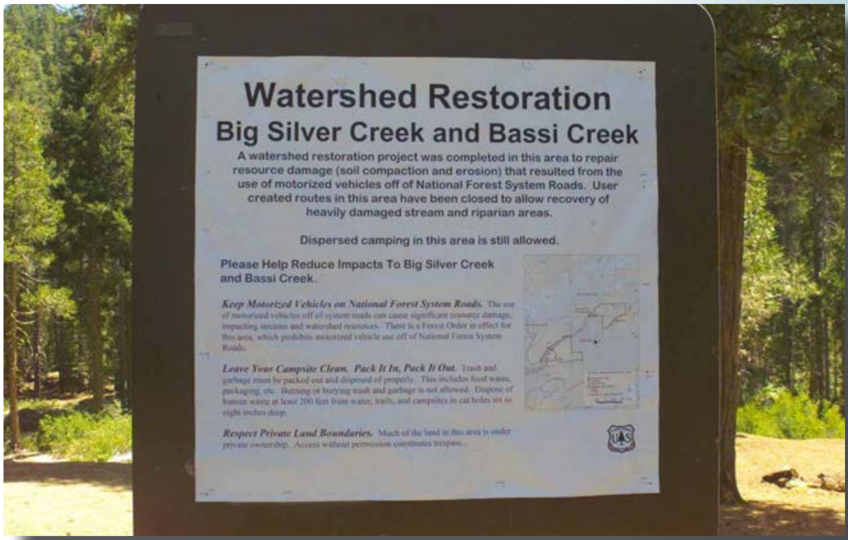

Figure B-1—This area and trailhead sign informs visitors about the watershed. It states why restoration work was needed (because of erosion from unauthorized trails), what was done, what activities are allowed, and what the expected user behaviors are, such as Pack It In, Pack It Out. It displays a map so there is no mistake about what area is being restored.

APPENDIX C
Metal fence quick-post bracing system

Use this no-dig barrier where there is a need for a fence, the ground is hard, and where there may be cultural resources that would be disturbed by digging post holes. Install this temporary barrier just before a restoration project begins. See figure C-1.

Figure C-1—The quick-post bracing system is holding up a gate.

General Brace Information: “Diagonal Brace–Using a diagonal brace instead of a horizontal brace saves time and money. The diagonal fence brace is structurally equal to the horizontal fence brace and is less costly for materials and installation, since one less hole has to be dug, one less post has to be purchased, and no measuring or fitting is required to install it. When used with a 4-foot-high fence, a single diagonal brace, 11 feet long along the ground, is equal or better than a double-panel horizontal fence brace 16 feet long. …it has the same lifting force on the corner post and the same reaction forces as a horizontal brace of the same size (i.e., length of brace on the ground).

“In the design and installation of a diagonal brace, several principles should be kept in mind:

1. Make the diagonal brace—as is also true with the horizontal brace—as long as possible; up to about 11 feet along the ground for a 4-foot-high fence. This is approximately 5.5 times the average wire height. Lengths of a diagonal beyond about 11 feet for a 4-foot-high fence add very little and are not necessary. The brace will be as effective as necessary with an 11-foot diagonal.

2. Be sure that the end of the diagonal brace in contact with the ground is free to move in the direction of the fence pull; it must not be blocked by a stake or fence post. [Reason: When the end of the diagonal bears against a stake or fence post and is not free to move in the direction of the fence pull, one-half to two-thirds of the total fence tension can be transmitted to the stake or fence post. This tension greatly reduces the ability of the corner post of the brace to resist pullout (failure).]

3. The diagonal brace can bear against the corner post in any direction from the middle of the post to the top. However, probably the best place to have a diagonal brace contact the corner post is at the top. [Reason: The maximum bending moment of the corner post—located at ground level where the brace wire is attached to the corner post—is the same whether the diagonal brace bears at the top or the middle of the corner post. However, the loading in the diagonal brace (compression) and the lower brace wire (tension) will be double when the diagonal brace nears against the middle corner post as compared to when the diagonal brace bears against the top of the corner post.]" (McKenzie 1983).

APPENDIX D
No-Dig Wooden Barrier Instructions

Use this no-dig barrier where there is a need to delineate a trail where the ground is hard and where there may be cultural resources that would be disturbed by digging post holes. Always check with the forest archaeologist before disturbing the ground even if it is something as slim as steel reinforcing bar (rebar). Install this temporary barrier just before a restoration project begins.

This information was provided by Jeff Applegate, off-highway-vehicle trails manager, Mendocino National Forest. This system is very efficient because the barriers can be made in advance, stored, and reused. The barrier is simple to build and simple to install (Applegate 2006). Do not use these barriers in wetlands or wet meadows due to the creosote in the ties. See figure D-1.

Figure D-1—No-dig temporary barrier used to delineate the trail edge (to help the user want to stay on the trail).

Materials and Tools

Construct the no-dig barrier from used, relay-grade railroad ties. Purchase the railroad ties in bulk for about $9 each from a lumber yard.

Materials

- Standard railroad ties, #1 or relay grade.

- Pressure-treated 8- by 8-inch by 8- or 10-foot-long hem-fir or Douglas-fir posts. See figure D-2.

- 5/8-inch steel rebar in 20-foot lengths.

Figure D-2—Stacked ties, hem-fir posts, and drilling template.

Tools

Chain saw.
Cutting torch.
Heavy-duty drill (1/2 horsepower).
5/8-inch bell-hangers drill bit.
Sledge hammer.
String line.
Drilling template.

Assembly

1. Cut the 8- by 8-inch pressure-treated wood (hem-fir) into 12-inch lengths using a chain saw. Yield is 8 to 10 support blocks per post.

2. Cut rebar into 30-inch lengths. Yield is 8 units per 20-foot stick.

3. Use a simple drilling template; set the railroad ties on top of the 8- by 8- by 12-inch blocks, which are placed lengthwise in the template with the outside edge of the block 12 inches from the end of the railroad tie (12.6 inches) on center.

4. The template consists of two plywood squares with a framed bunk to hold the 12-inch-long lengths of pressure treated hem-fir support blocks. Once the blocks are cut to length, they are put in the bunks on the two properly spaced templates. Place a railroad tie on top of the two hem-fir blocks. The templates allow for a 1-foot extension of the railroad tie beyond the outside edges of the two hem-fir blocks.

5. Drill vertically on center through the railroad tie and the pressure treated blocks with the 5/8-inch drill bell hangers bit.

6. Insert a 30-inch stick of rebar through the railroad tie and, with a sledge hammer, pound it through the tie and block until flush with the bottom on the block. This will leave about 12 to 14 inches of rebar sticking out of the lumber. See figure D-3.

At this point the no-dig barriers are ready to transport on a trailer to the job area.

Figure D-3—Assembling barriers. Rebar has been partially pounded into tie and block.

Installation

Transport the barriers to the job area.

Line up the barriers with hem-fir blocks so they are in contact with the ground. Simple eyeballing and a little leveling with a McLeod results in a good line up.

Use an 8- to 20-pound sledge hammer to pound the 12- to 14-inch length of rebar into the ground until it is flush with the top of the railroad tie. See figure D-4.

Figure D-4—Barrier being installed.

APPENDIX E

Anchors

Dead Stout Stakes

Dead stout stakes are used in many soil bioengineering techniques to anchor branches, excelsior, and erosion control blankets in place (see figure E-1). Purchased or cut stakes should be untreated 2- by 4-inch sound lumber 2.5 to 4 feet long. Cut each length diagonally across the 4-inch face to make two stakes from each length. Discard stakes that shatter when installed.

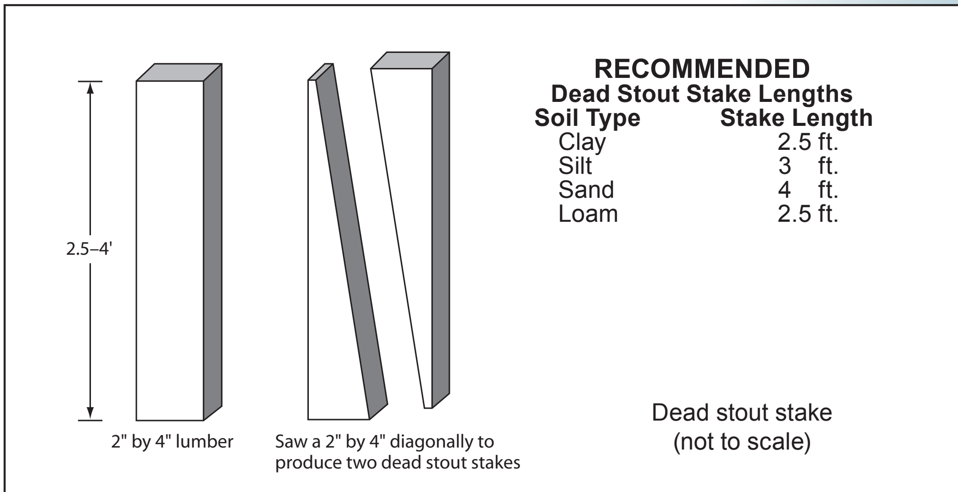

Figure E-1—Dead stout stakes.

Metal Staples

Metal staples are 11-gauge wire and vary in length from 6 to 10 inches. Use a shorter staple on a naturally compacted soil type, such as clay, and a longer staple for loose-sandy soil. Staples do not biodegrade per se, but do rust over time.

Duckbill Anchors

Use duckbill anchors to anchor heavy items to the bank or hillside, such as a section of plank retaining wall. Duckbills come in various sizes rated by the number of foot-pounds each duckbill will support. Work with a soil scientist and engineer to determine the soil rating(s) at the area.

Figure E-2—Duckbill Anchors.

Generally, a short cable with a loop on the end is attached to the center of the anchor. When placing an order for duckbills, specify the cable length or purchase the duckbill without the cable. Add the extensions at the area. The duckbill has a solid end with a star pattern. Purchase a customized bar that fits the star pattern or use a piece of rebar.

Installation: Insert a bar into the duckbill's star pattern, and insert the duckbill into the soil. Begin hammering with a post pounder, if available, and finish with a sledge hammer. Hammer the duckbill into the soil as far as possible or use an excavator's bucket to push the rod several feet into the ground. Remove the rod. If there is a loop at the end of the cable, insert a short metal bar through the loop and pull up, rotating the duckbill, making it somewhat parallel to the surface, and setting the anchor.

APPENDIX F

Fixed Structures

On steep slopes, a fixed structure, such as a row of large rocks or a retaining wall, acts to keep soil from slipping. Ask a geotechnical engineer about spacing. The hydrostatic pressure in the hillside is greater near the bottom of the slope, so place any keyways or retaining structures closer together near the bottom. Before beginning, mark placement and lengths of trenches (for retainers) across the slope.

Use heavy equipment to bring in the fill and to fill behind the wall. Do not use this equipment on wet soils.

Rock Structure

Use this method on slopes over 20 percent and where 2- to 3-foot-diameter rocks are at hand or can be obtained easily. The bottom row of rocks, or keyway, might be under several feet of soil and the top row under little soil. See figure F-1.

Figure F-1—This method was used on a hill climb gully approximately 20 feet wide and 8 feet deep. Lighter colored grass marks the fill area. Large rocks form keyways or retaining walls at intervals up the slope to keep the first few feet of soil in place.

Equipment and Inert Materials

- Excavator.
- Dozer.
- 2- to 3-foot-diameter rock.
- Mulch or erosion control blanket.
- Staples or stakes.

Installation

1. Dig a trench across the base of the incised area several feet in from the bottom of the slope. Extend the trench into the stable slope.

2. Partially bury 2- to 3-foot-diameter rock in the trench so about 75 percent of each rock is buried. Extend the rock across the trench and into the stable slope.

3. Place the first lift at a maximum of 1 foot (this might be less depending on the type of equipment used) between the bottom of the slope and the rock.

4. Compact each lift by driving a tracked vehicle over it or using a plate compactor. Match the density and moisture levels of adjacent undisturbed soil. Adjust the density and moisture as necessary.

5. As the soil lifts are added, rebuild the slope to grade. When the fill edge is near the spot for the next trench, dig another trench.

6. See numbers 1 through 5..

7. Leave the soil surface roughened to capture water and seeds.

8. Seed and mulch. Use mulch (page 53), hydromulch (page 57), or a loosely woven erosion control blanket (page 59) to hold the soil and seed in place. Punch or crimp loose mulch into the soil; staple or stake erosion control blanket to the slope.

9. In sandy, desert, and windy locations use erosion control blankets to lessen wind erosion.

Retaining walls

Create a keyway with a timber-lagging modular retaining wall with tie backs. Work can begin at the top or bottom of the area, whichever is closer to the access road. The bottom keyway might be under several feet of soil and the top row under little soil.

It may be necessary, on slopes over 20 percent, to tether equipment at the top of the slope. For example, at Carnegie State Vehicular Recreation Area in California, the slope is 60 percent. A Sweco dozer was used to distribute the soil in 6-inch lifts. For safety, the Sweco was attached by a cable to a John Deere 650 dozer. A sheep's foot was used to compact the soil. See figure F-2.

Figure F-2—Center of photo—The slope is 60 percent. A gully approximately 40 feet wide and 15 feet deep was caused by off highway vehicle use and exacerbated by weather conditions. Numerous rows of retaining walls are buried in the fill. Fill was brought in from catch basins on the area.

Modular retaining walls are durable. Order them to size. Each modular panel is made of treated wooden planks in a steel frame and rebar pilings.

Equipment and Inert Materials

- Excavator.
- Dozer.
- 4-foot by 1-inch rebar with chisel point.
- All-thread steel rods.
- Driving GAD (a steel bar).
- Prefabricated retaining walls.
- 1/4-inch screen or 1 1/4-inch local rock.
- Earth anchors, such as duckbill anchors.
- Mulch or erosion control blanket.
- Staples or stakes.

Installation

Retaining walls

Use a timber-lagging modular retaining wall with tie backs to create a structure. Modular retaining walls are durable and are ordered to size. Each modular panel is made of treated wooden planks in a steel frame that fits over rebar pilings. Steel all-thread rods fasten the earth anchors, such as duckbills, which anchor the walls. See photo on page 211.

Begin work at the top or bottom of the area, whichever is closest to the fill soil supply.

Installation

Workers need to access the front face, or downhill side, of the each wall section to set it into the trench and to install the earth anchors.

1. Dig a 6- to 12-inch-deep trench across the base of the incised area several feet in from the bottom of the slope. Extend the trench into the stable slope.

2. Beginning at one end of the trench, insert the rebar 4 feet into stable soil. Use the bucket of the excavator, a jack hammer, or sledge hammer to push the rods into the ground. Drill 1 to 2 inches into bedrock to set the rebar.

3. Set the H-beam over the rebar. Partially bury the base of the retaining wall at least 6 inches. If bedrock, set the H-beam on top of it.

4. Anchor the retaining wall to the slope using duckbill anchors and all-thread fasteners.

5. Use a hydraulic setting tool to set the anchors, such as a driving GAD (steel bar), to drive the duckbills 3 to 4 feet into the hillside. Cut the all-thread off.

6. Insert planks between H-beams; insert 1/4-inch pebbles between the planks to form "weep holes." Use rock available in area.

7. To ensure that the gaps stay open, line the back (slope-facing) of the wall with geotextile fabric and 1/4-inch screen or stack a 1/4-inch-diameter purchased drain rock behind the wall.

8. Between the start of the slope and the wall, place the first lift at a maximum of 1 foot (this might be less depending on the type of equipment used).

9. Compact each lift by driving a tracked vehicle over it or by using a plate compactor. Match the density and moisture levels of the adjacent undisturbed soil. Adjust the density and moisture as necessary.

10. As the soil lifts are added, the slope is rebuilt to grade. When the fill edge is near the spot for the next trench, dig another trench.

11. See numbers 1 through 10.

12. Leave the soil surface roughened to capture water and seeds.

13. Seed and mulch. Use mulch (page 53), hydromulch (page 57), or a loosely woven erosion control blanket (page 59) to hold the soil and seed in place. Punch or crimp loose mulch into the soil; staple or stake the erosion control blanket to the slope.

Figure F-3—Soldier-pile timber-lagging retaining wall with tie backs. This restoration began at the top of the hill because there was a road for truck access; it ended at the edge of a trail. If there were no trail, the wall would have been buried and the slope of the hillside continued.

Figure F-4—All-thread steel rod anchors retaining wall to hillside.

APPENDIX G
Plants and Climate

Soil type and microclimate are very important and may dictate whether or not the installation of live plant material survives. Local weather conditions dictate when to plant. Consult a botanist, soil scientist, or landscape architect for the best times to plant.

Live fascines, for example, are installed in shallow trenches and will not survive if planted on a hot dry bank. They might survive if planted at the water's edge, on very wet slopes, or if irrigated. The same would apply to a brush mattress in an arid climate; the basal ends of the mattress must always be in moist soil.

By streams and lakes, live posts should do well in most climates when planted deep enough to reach the dry season water table. Posts average 3 to 4 feet in length and can be up to 12 to 15 feet long (some of this length is above ground). If the depth of the dry season water table is elusive, install posts at least 2 feet deeper than the streambed. The same information applies to live stakes.

Plant Materials

Collecting

- Collect plant materials and seeds within the watershed or local drainage basin, roughly at the same elevation as the project area. It is important not to introduce nonnative- or native-plant materials and seeds from different gene pools.

- Know the genus and species of deciduous plants that grow well from cuttings before you cut (U.S. Department of Agriculture 1996).

- Cut plants when they are dormant.

- Track where plant material was collected, the vigor of the material, and its survival rate. Manage good collection areas. Let team members from other disciplines know about the harvest area and that the plants have special uses.

- Transplant herbaceous plants from nearby banks immediately. Be careful not to take too many from any one spot.

Harvesting and Storing Cuttings

Cutting lengths also will vary with species and source. They can be used within a day or two or stored through the winter.

- Harvest cuttings from branches that are at least 1 year old, but not older than 12 to 15 years. Shield cut branches from the sun at all times and keep them as cool as possible.

- DO NOT cut branches with old, heavily furrowed bark, diseased or insect-infested growth, dead or broken branches, basal shoots, or suckers (Hoag 1994).

- Consider the aesthetics of the plant when selecting cuttings, DO NOT cut off more than one-third of a single plant's branches. Avoid public use areas, such as campgrounds, picnic areas, fishing areas, roadways, and so on (Hoag 1993).

- Remove (by cutting) the apical bud at the top.

- Dip the top 1 to 2 inches of each post in a mixture of equal parts of latex paint and water or paraffin to seal it. This decreases desiccation and tells which end is the top (Hoag 1992).

- Store cuttings in a cool place, such as a walk-in refrigerator at between 34 to 45 °F, or in the dark for several months. Wrap cuttings in burlap or peat to keep them damp.

- Move cuttings outside (before planting) and soak the basal ends, or the entire piece, for at least 24 hours and up to 14 days. This brings the cuttings out of dormancy, leaves them well hydrated, and causes the root buds to swell.

Planting Live Materials

- Install the basal end, not the top; the buds always angle upward.

- Insert the cutting into the ground without tearing the bark. The bark shields the cambium layer, which is the vascular system for the plant. The cutting will not survive if it is damaged when the bark is torn.

- Avoid splintering or mashing the top of a cutting by using the wrong hammer. Use a dead blow hammer for installation.

- Ensure good soil-to-stem contact or the cutting will dry out and fail to sprout.

Bioengineering Techniques

Brush layering

Brush layering is the technique of laying cuttings on horizontal benches that follow the contour of an existing or filled bank (slope). Branches serve as tensile inclusions or earth-reinforcing units to provide shallow stability of slopes. The cuttings are oriented more or less perpendicular to the slope face. The portion of the brush that protrudes from the slope face assists in retarding runoff and reducing surface erosion. When used on a fillslope, this technique is similar to vegetated geogrids without the geotextile fabric. See figure G-1.

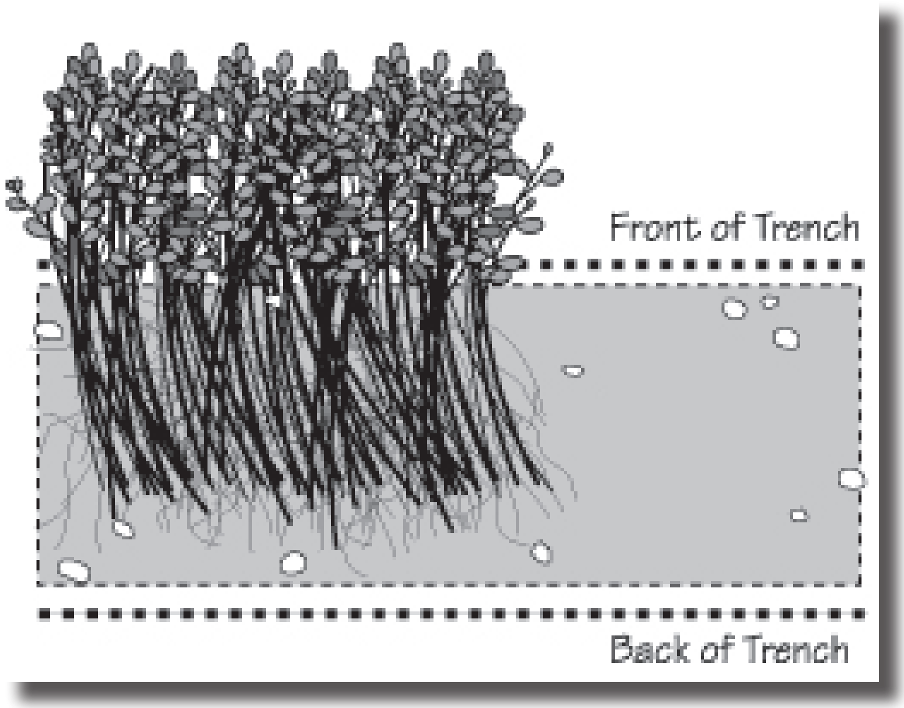

Figure G-1—Brush layering.

Applications and Effectiveness

- Breaks up the slope length into a series of shorter slopes separated by rows of brush layer.
- Dries excessively wet areas.
- In streams, works where the toe is not disturbed.
- Works on a slump and as a patch.
- Reinforces the soil with the unrooted branch stems.
- Reinforces the soil as roots develop, adding significant resistance to sliding or shear displacement.
- Traps debris on the slope.
- Aids infiltration on dry areas.
- Adjusts the area's microclimate, aiding seed germination and natural regeneration.
- May cause flow to wash soil from between lifts.
- Does not work on outside bends of streams.

Construction Guidelines

Install brush layering on an existing or filled slope. On an existing slope, cut a bench 2 to 3 feet deep and angled slightly down into the slope. On a fillslope, lay brush lifts into the bank as it is filled. Brush layer rows vary from 3 to 5 feet apart, depending upon the slope angle and overall stability.

Live material

- Branch cuttings should be 1/2 to 2 inches in diameter and long enough to reach the back of the bench and still protrude from the bank.
- Side branches should remain intact.
- Mix easy-to-root species, such as willow, dogwood, and poplar.

Installation

- Begin at the bottom of the slope and work up the bank.
- On streams, begin above the bankfull level, on lakes at the ordinary high-water mark.

On a cut bank:

- Excavate 2- to 3-foot-wide horizontal benches on the contour.

- Slope the bench so that the outside edge is higher than the inside.

- Arrange a 4- to 6-inch layer of live branch cuttings on the bench in a crisscross or overlapping configuration.

- Arrange 20 to 25 branches per yard.

- Extend one-quarter of the cutting's length beyond the slope face.

- Compact 2 to 4 inches of soil around the cuttings, then fill the remainder of the trench.

- Backfill each lower bench with the soil obtained from excavating the bench above.

- Place long straw or similar mulch material and seeds between rows on 3:1 or flatter slopes, use mulch, hydromulch, or an erosion control blanket on slopes steeper than 3:1 (Gray 1996). (This is optional.)

- Control or divert water at the top of the area to prevent exposed soil from being eroded away at the top of the slope. Otherwise, erosion is likely to occur on the slope before vegetation can protect it.

On fill bank:

- Build lifts until the desired height is reached.

- Install branches following instructions for the cut bank. See table G1.

Table G1—Slope distance

Slope distance between benches			
Slope	**Wet slopes (ft)**	**Dry slopes (ft)**	**Maximum slope length (ft)**
2:1 to 2.5:1	3	3	15
2.5:1 to 3:1	3	4	15
3.5:1 to 4:1	4	5	20

(Robbin B. Sotir & Associates, Inc.)

Geogrid Technology

Use geogrids to fill and rebuild short slopes. Geogrids are similar to the brush layering fill technique (page 211) except that an erosion control blanket is wrapped around each soil lift. In wet areas or climates, use vegetated geogrids placing branch cuttings between each lift. Begin at the bottom of the slope.

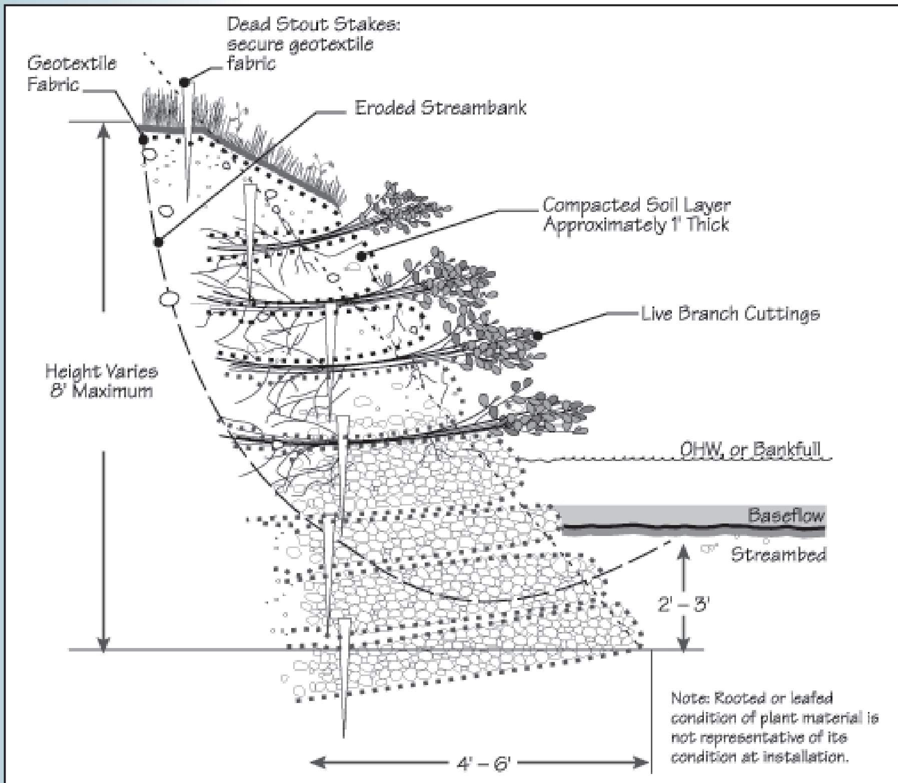

Figure G-2—Geogrid.

Applications and Effectiveness

Applications

- Benefits are similar to those of brush layering. Place a vegetated geogrid on a 1:1 or steeper streambank or lakeshore.
- On lakes and streams, use above and below the ordinary high-water mark or bankfull level, respectively.
- On streams, build only during low-flow conditions.
- On streams, use to restore outside bends where erosion is a problem.

Effectiveness

- Produces a newly constructed, well-reinforced slope.
- Captures sediment to further stabilize the slope.
- Enhances conditions for colonization of native vegetation.
- Produces rapid vegetative growth.

- Can be complex and expensive.

- Functions immediately.

Construction Guidelines

Live materials

- Use live branch cuttings that are brushy and root readily.

- Use cuttings 1/2 to 2 inches in diameter and 4 to 6 feet long.

Inert material

- Biodegradable erosion control blanket.

- Soil suitable for plant growth.

- Batter board (4 by 12 inches), the length of the geogrid, optional. This helps define the front edge of the lift during construction.

- Dead stout stakes to secure the erosion control blanket. Discard any stakes that shatter upon installation. (See page 211.

Installation

On streambanks: Rock Toe

- Dig a trench that is 2 to 3 feet below streambank elevation and 3 to 4 feet wide.

- Measure the width and length of the trench (lift), double the width, and add 12 inches (height of the lift) to the width. Cut a length of cloth. Install one lift before cutting all the pieces to be sure the lengths are correct.

- Fill the trench area 12 inches high with 2- to 3-inch-diameter rocks.

- Fold the fabric over the rock and stake every 2 feet along the length of the lift.

- Use branch cuttings.

- On streams, place at the ordinary high-water mark or bankfull level, a 6- to 8-inch layer of live branch cuttings on top of the rock-filled geogrid with the growing tips at right angles to the streamflow. The basal ends of branch cuttings should touch the back of the excavated slope.

On slopes

- Place a 6- to 8-inch layer of live branch cuttings on top of the soil-filled geogrid with the growing tips extending several inches beyond the slope face. The basal ends of branch cuttings should touch the back of the excavated slope.

- Cover the branches with a layer of soil. Wet the surface to wash soil down in between the branches. Add more soil until the majority of the stems are covered.

- Lay a batter board on edge at the front edge of a new lift. This is optional.
- Cover this layer of cuttings with cloth, leaving an overhang. Place a 12-inch lift of soil, suitable for plant growth, on top of the cloth before compacting it to ensure that there is good soil contact with the branches.

- Wrap the overhanging portion of the cloth over the compacted soil to form the completed cloth wrap. Once the cloth is pulled up over the soil, adjust the cloth to ensure that it forms the desired contour without overhanging the lift below.

- Stake down the cloth. Remove the batter board. Place cuttings after each lift is formed.

- Continue this process of rebuilding the bank with lifts, alternating lifts of cuttings and cloth wraps until the bank is restored to its original height.

- Match the final installation to the existing slope. Branch cuttings protrude only slightly from the lifts.

Live Fascine

A live fascine helps control surface erosion; roots from the sprouted fascine help stabilize the bank. A fascine is a long bundle of branch cuttings bound together in a cylindrical structure. Place each fascine in a shallow contour trench. See figure G-2. Dead fascines also are made of coconut fiber (coir logs).

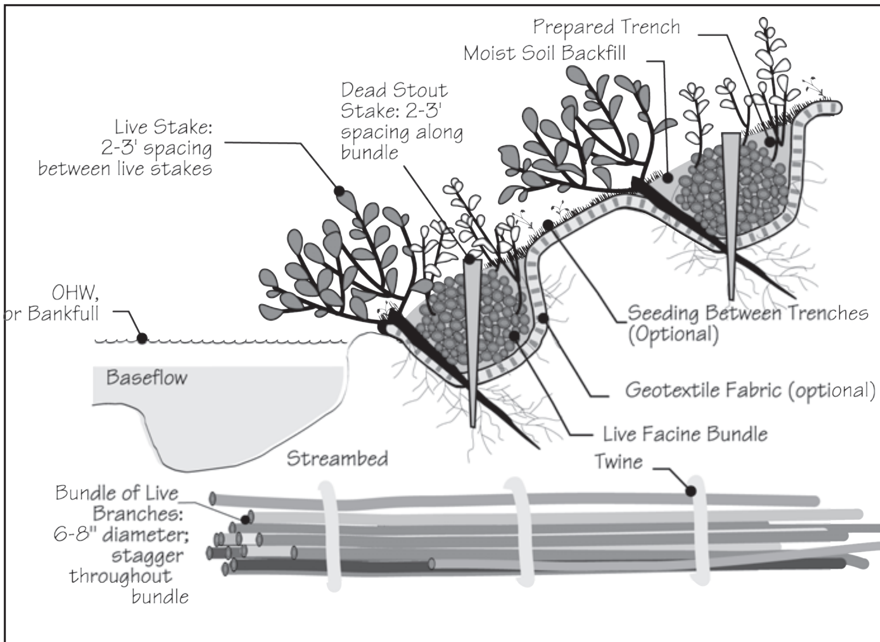

Figure G-3—Live facine.

Applications and Effectiveness

Applications

- Apply at the base of the slope and in contour rows up the slope.
- On lakes and streams, apply above the ordinary high-water mark or bankfull level except on very small drainage area areas.
- On lakes and streams in arid climates, use between the high- and low-water marks on the bank.

Effectiveness

- Reduces the slope length to a series of shorter slopes by creating small dam-like structures.
- Protects slopes from shallow slides (1- to 2-foot depth).
- Requires soil moisture or regular precipitation during the growing season to root and grow.

Construction Guidelines

Live materials

Cuttings (often called whips) must be from species, such as young willows or shrub dogwoods, that root easily and have long, straight branches.

Live material sizes and preparation

- Tie cuttings, 1/2 to 1 1/2 inches in diameter, together to form live fascine bundles that vary in length from 5 to 10 feet or more, depending on area conditions and handling limitations.

- Stagger the cuttings in the bundles so that tops are evenly distributed throughout the length of the uniformly sized live fascine. The completed bundles should be 6 to 8 inches in diameter.

- Ensure that live stakes are at least 2 1/2 feet long.

Inert materials

- Untreated twine for bundling fascines.

- Dead stout stakes. (See page 201.)

Installation

- Prepare the live fascine bundle and live stakes immediately before installation. If possible, have a fascine-tying team, a digging team, and a fascine-laying team. Team members can do double duty; everyone must know his/her role ahead of time.

- For longer fascines, jam the ends together before placing them into the trench.

- Begin at the base of the slope; mark contours before digging.

- Excavate a trench on the contour approximately 10 inches wide and 10 inches deep.

- Excavate trenches up the slope at 3- to 5-foot intervals. Place one or two rows over the top of the slope to break up overland flow, ideally diverting it. See table G2.

- Place the live fascine into the trench.

- Dig the next trench as the fascine is placed in the one below and use the excavated soil to partially cover the fascine.

- Place moist soil along the sides and top of the fascines. The top of the fascines should be slightly visible when the installation is completed.

- Place long straw and annual grasses or an erosion control blanket between the rows if the soil is loose. Secure the blanket.

- Drive dead stout stakes directly through the live fascine. Use extra stakes at fascine overlaps. Leave the top of the dead stout stakes flush with the installed fascine.

- Install live stakes on the downslope side of the fascine. Tamp the live stakes below and against the fascine between the previously installed dead stout stakes, leaving 3 inches protruding above the top of the ground. A fascine that fails to sprout will slow the raveling of a bank and catch sediment. This sediment rebuilds the bank and forms a natural seedbed. Sometimes a sacrificial fascine is installed in the water, knowing that it will not grow, but that it will lessen erosion and promote bank stability.

Table G2—Live Facine installation guidelines

Slope	Slope distance between trenches (ft)	Maximum slope length (ft)
1:1 to 1.5:1	3-4	15
1.5:1 to 2:1	4-5	20
2.1:1 to 2.5:1	5-6	30
2.5:1 to 3:1	6-8	40
3.5:1 to 4:1	8-9	50
4.5:1 to 5:1	9-10	60

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Live-Pole Drain—A Daisy Chain of Fascines
A live-pole drain is a series of fascines jammed together end-to-end and placed in the drainage or in the chevron pattern of a hillside. Use a live-pole drain on a wet bank to drain away excess moisture and stabilize the bank. Before the fascine takes root and leafs out, its structure slows water and traps sediment. As the live-pole drain comes to life, the roots of the branch cuttings in the fascine soak up moisture in the soil helping to prevent slumping and sliding; this stabilizes the slope.

The live-pole drain fascines generally are buried in 6-inch-deep trenches. Use them in a small 6-inch-deep gully. Live-pole drains will not work in large gullies. See Live Fascines for materials and instructions for fabrication and installation. See page 217.

Live Stake

Live stakes create a living root mat that stabilizes the soil by reinforcing and binding soil particles together and by extracting excess soil moisture. Most willow species root rapidly and begin to dry out an excessively wet bank soon after installation. Live, rootable stakes are inserted or tamped into the ground. If correctly prepared, handled, and placed, the live stake will root and grow.

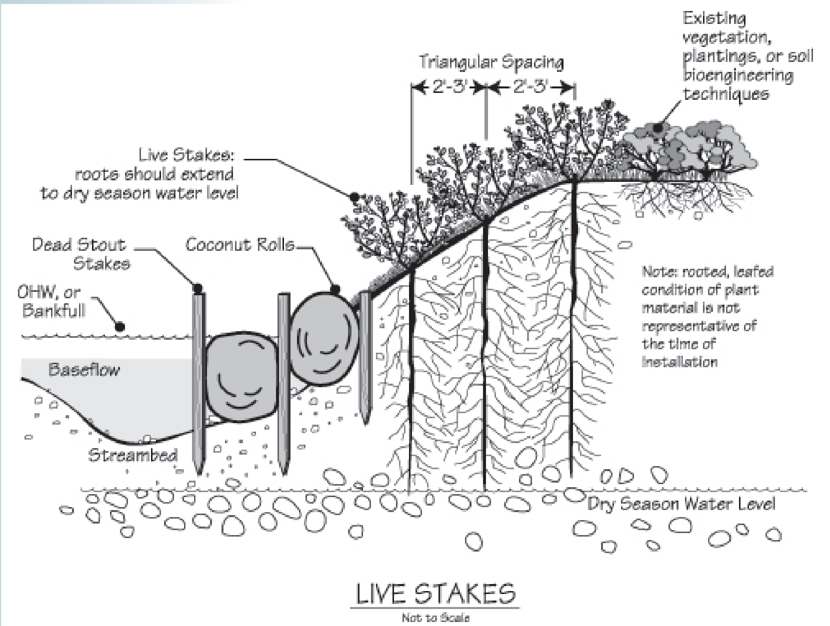

Figure G-3—Live stakes.

Application and Effectiveness

Application

Use stakes in the wetted zone of banks or where precipitation is likely to keep the soil moist during growing seasons.

Effectiveness

- Provides a technique where area conditions are uncomplicated, construction time is limited, and an inexpensive method is needed.
- Repairs small earth slips and slumps that frequently are wet.
- Enhances the performance of geotextile fabric by serving as pegs to hold fabric down.
- Enhances conditions for natural colonization of vegetation from the surrounding plant community.
- Produces streamside habitat.
- Stabilizes areas among other bioengineering techniques, such as live fascines.

Construction Guidelines

Live material sizes

The stakes generally are 1 to 2 inches in diameter and 2 to 3 feet long. The specific area requirements and available cutting source determine size.

Live material preparation

- Remove side branches, leaving the bark intact.

- Cut the basal ends at an angle or point for easy insertion into the soil. Cut the top square.

- Install materials the same day that they are prepared.

- Place according to species. For example, along many western streams, tree-type willow species are placed on the inside curves of point bars where more inundation occurs, while shrub willow species are planted on outside curves where the inundation period is minimal.

Installation

- Orient buds up.

- Install live stakes 2 to 3 feet apart using triangular spacing. The density of the installation will range from two to four stakes per square yard. Area variations may require slightly different spacing.

- Have a spacing pattern that allows for the variables of a fluctuating water level. The installation may be started at any point on the slope face.

- Install 4/5 of the length of the live stake into the ground and firmly pack the soil around it after installation.

- Remove and replace any stakes that split during installation.

- Use an iron bar to make a pilot hole in firm soil or use a waterjet stinger (Hoag et al. 2001).

- Dig in live stakes in hard rocky soil. Too many tamped-in stakes split or have their bark damaged by hammering and by hard rocky soils.

- Install the live stake slightly angled downstream.

- Tamp the stake into the ground with a dead blow hammer (hammer head filled with shot or sand).

- Install the erosion control blanket (optional) on slopes subject to erosive inundation. Install the stakes through the fabric.

- Plant on banks that will be moist during growing seasons or install longer stakes that reach the dry season water level.

Lakeshore. Live stakes offer no stability until they root into the shoreline area; however, over time they provide excellent soil reinforcement. To reduce failure until the roots establish themselves, enhance installations with a layer of erosion control blanket.

Live Post
Live posts form a permeable revetment. They reduce surface flow velocities and cause sediment deposition in the treated area. The roots help to stabilize a bank. Dormant posts are made of large cuttings installed in banks in square or triangular patterns. Unsuccessfully rooted posts also can provide some benefits by deflecting surface flow and trapping sediment.

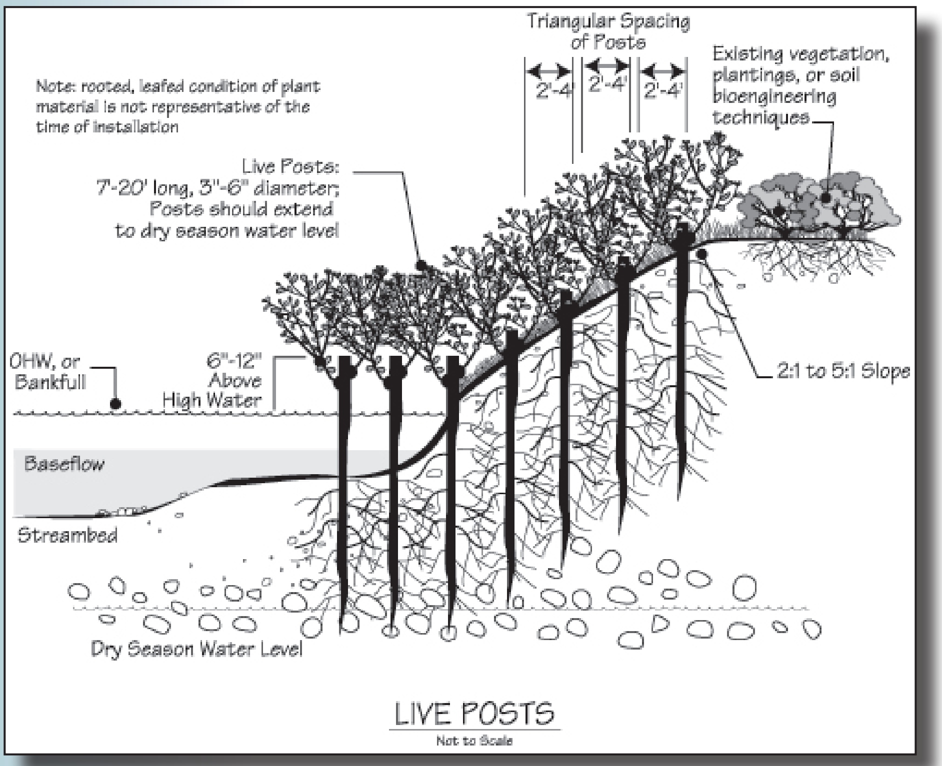

Figure G-4—Live posts.

Applications and Effectiveness

Applications

- Use on smaller nongravel streams. If high flows and ice are a problem, poles can be cut low to the ground.

- Use in combination with other soil bioengineering techniques.

- Install with a variety of methods including water jetting or mechanized stringers (Hoag et al. 2001) to form planting holes or by driving the posts directly with machine-mounted rams or pressed into the ground using the bucket of a backhoe. Place a metal cap atop the post when it is necessary to pound it into the ground.

Installation

- Taper the basal end of the post for easier insertion into the ground.

- Trim off all side branches and the apical bud (top).

- Dip the apical end into a mixture of equal parts water and latex white paint. This marks which end goes up and helps retain moisture in the post after installation.

- Insert one-half to two-thirds of the length of the post below the soil surface. Several inches of the post should be set into the dry season water level.

- Avoid excessive damage to the bark of the posts.

- Place two or more rows of posts spaced 2 to 4 feet apart using square or triangular spacing.

- When there is a hole, add compost to each hole before the post is installed.

- Apply on slopes 1:1 or less.

- Supplement the installation with other bioengineering techniques.

In riparian areas, along streambanks and lakeshores, install posts into the eroding bank at or just above the normal waterline. Ensure that posts are installed with buds pointing up.

Trench Pack

Trench packs act to break the force of moving water, diffuse overland flow, and trap sediment. They are deciduous branch cuttings placed vertically in trenches or holes. Select plant cuttings from the same zone in which they will be planted, such as at stream's edge, on the bank, or on the flood plain. Use dead branches to augment live material or use alone.

Figure G-4—Trench pack.

Applications and Effectiveness

Applications

- Pack into gullies to catch sediment.

- On lakes and streams, install at ordinary high-water mark or bankfull level to stabilize the toe and to provide good fish habitat (follow the contour of the bank); on flood plains, install perpendicular to or in the direction of the flood flow.
- Use on lakeshores to combat wind and waves.

Effectiveness

- Traps sediment.

- Reduces wind and water velocities.

- Provides a good barrier for rooted stock.

- Dries excessively wet areas through evapotranspiration.

- Reinforces soil with unrooted branch cuttings and, when rooted, with deep roots, adds resistance to sliding and shear displacement.

- Enhances conditions for colonization of native vegetation by creating surface stabilization and a microclimate conducive to plant growth.

Construction Guidelines

Live materials

- Use live deciduous material known for its good rooting structure 1 to 1 1/2 inches in diameter, with side branches attached. Mix species, if appropriate.

- Use cuttings long enough to reach the dry-season water level.

- Plant in fall: Branches should extend 2 to 3 feet above ground to provide immediate bank protection. In spring, trim the branches back to two buds above ground to stimulate root growth.

- Plant in spring: Plant with branches extending no more than 12 inches above ground or plant branches with at least two buds.

Inert material

- Augment the pack with dead material, such as conifer branches, if live plant material is unavailable to provide structural stability while the live material roots.

- Plant branches 3 to 4 feet deep if the planting is subjected to moving, erosive water. In other situations, at least one-half the length of the cutting should be in the ground.

Installation

- Dig a hole or trench, by hand or machine, 12 to 24 inches wide to the dry-season water level of the stream or lake. The trench can be any length; however, the ends of the trench must be tied into something solid or keyed into the bank.

- Place the branches in the trench, bud ends up. Pack branches to a 4-inch thickness.

- Tamp native soil around packed branches to ensure that they are in contact with the soil and not the air; air contact will stop growth.

- Construct a 2- to 4-inch water retention berm or basin on both sides of the trench.

- Wet the surface to wash soil down into the trench. Add more soil, if necessary, so that there is good soil-to-stem contact throughout.

Rooted Stock

Rooted stock provides instant leaf cover and habitat improvement. Rooted stock is a transplanted tree, woody shrub, or herbaceous plant with an established root system. It can be rooted cuttings balled with a burlap wrap, bare root, containerized plants, or sod or sedge harvested near the area and transplanted.

Effectiveness

- Offers immediate bank protection on wet slopes. The root system will invade the bank within weeks as opposed to the months it takes a cutting to establish a significant root system.

- May not reach the water table during the dry season because of short roots.

- Causes minimal area disturbance.

- Enhances conditions for natural colonization of surrounding plants.

Construction Guidelines

Plants should be from an adjacent area. If this is not possible, they should be indigenous to the area, from the same ecosystem, watershed, or climate zone, from the same or nearly the same elevation, and from within 100 miles of the area.

Native plants

- Select a random pattern for digging up native plants or for cutting slips (for nursery growing).

- Collect individual plants, clumps, and cuttings away from public view; take only healthy plants and only one-third of the mother plant for cuttings. Remove any weeds.

- Dig no deeper than 6 inches when harvesting plants to allow roots in the ground to grow back. Fill in any holes. Transplant the same day or keep roots wet for next-day planting.

- Split clumps of sedges into individual plants. Be sure the stems have roots attached.

Nursery stock

- Use cuttings from willows, other woody species and herbaceous plants, and seeds to grow nursery stock.

- Cut several inches off the tip of the cuttings before planting. The bud end draws too much energy away from stored reserves, reducing the chance of survival. Trim off any side branches.

- Allow 2 years or more for plants to produce enough woody growth to survive in the wild.

Installation

- Plant sedges and grasses by punching a hole in the soil's surface or use a spade to lift the soil. Insert the plant and tamp the soil around the roots. Tug slightly on the stem to be sure that it is secure.

- Loosen the root ball and cut away any circling roots for planting. If roots are tight, score the sides. Willow, dogwood, and cottonwood can be planted with the crown buried. Some nursery stock will need to be planted with the crown 0.5 to 2 inches above the soil surface (ask at the nursery). One way to do this is to plant the crown at the soil's surface level. When the plant is watered, the soil level will drop, exposing the crown.

- Install plants in a hole as deep as the root ball and twice as wide; backfill the hole with the native soil that was removed and any soil loosened from the root ball. Do not add topsoil. Remove air pockets around the plant by stepping on the soil.

- Build basins around the plants on slopes to catch rainfall.

- Wet and tamp the soil to squeeze out air bubbles. Add more soil after wetting, but keep the crown above ground level where necessary.

- Water the plants immediately after planting. If possible, slowly water each plant or the planted area using 10 to 20 gallons of water per plant.

- Clear weeds, grasses, and other competing plants in a 30-inch diameter around the stock to lessen competition.

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