CHAPTER 4

Managing and Restoring Riparian Environments

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CHAPTER 4

Managing and Restoring Riparian Environments

Blue flag iris

Introduction

Lakeshores, riverbanks and wetland fringes are impacted by public water access sites, canoeing and boating routes, and, to some extent, state trails.

The best protection for these riparian areas is achieved by maintaining a sufficient natural vegetation buffer that can withstand the erosive forces of wave action and stream current. These buffers must be enlarged in areas where runoff from parking lots, other hard surfaces and mowed turf could directly flow into a body of water. These enlarged natural vegetative buffers allow stormwater to infiltrate into the vegetation and soil rather than run off directly into the adjacent water body.

Shoreline or Streambank?

While shorelines and streambanks are both areas where land meets water, their geomorphological and biological makeup and function are very different. Any restoration work must be preceded by a thorough understanding and evaluation of each environment.

Characteristics of a Shoreline

❒ Surrounds an amorphous body of water, such as a lake.

❒ Is exposed to lapping motion of water.

❒ Is exposed to wave and ice action.

❒ Plant community makeup along the shoreline depends on each lake's chemistry (including rock, soil, climate and other factors).

❒ Requires an evaluation of water surface use and impact before restoration is attempted.

❒ Emergent vegetation, such as grasses and shrubs in the emergent zone, resists wave action, while roots hold soil particles in place. (See Figures 1 and 2, page 2.)

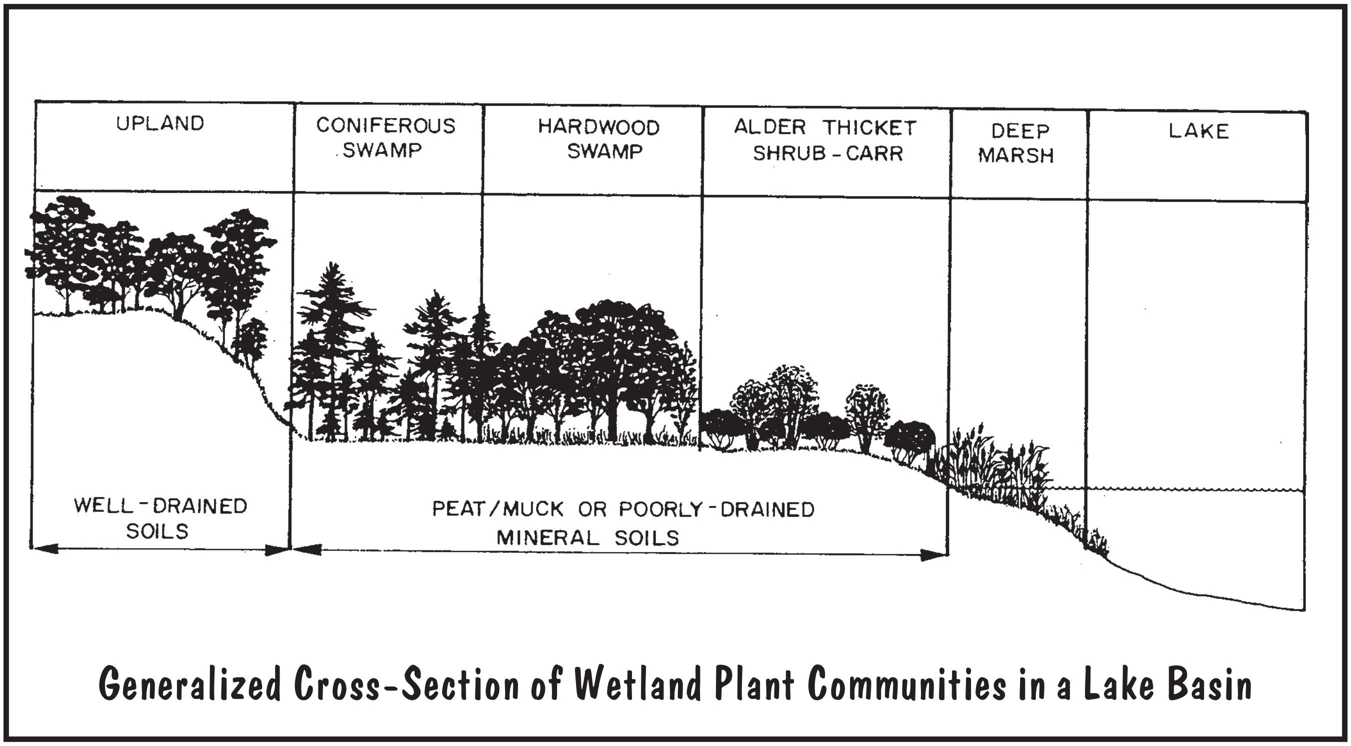


Figure 1: Generalized cross-section of wetland plant communities in a lake basin. From *Wetland Plants and Wetland Plant Communities,* by Steve D. Eggers and Donald M. Reed, U.S. Army Corps of Engineers, Second Edition, 1997. Reprinted with permission.

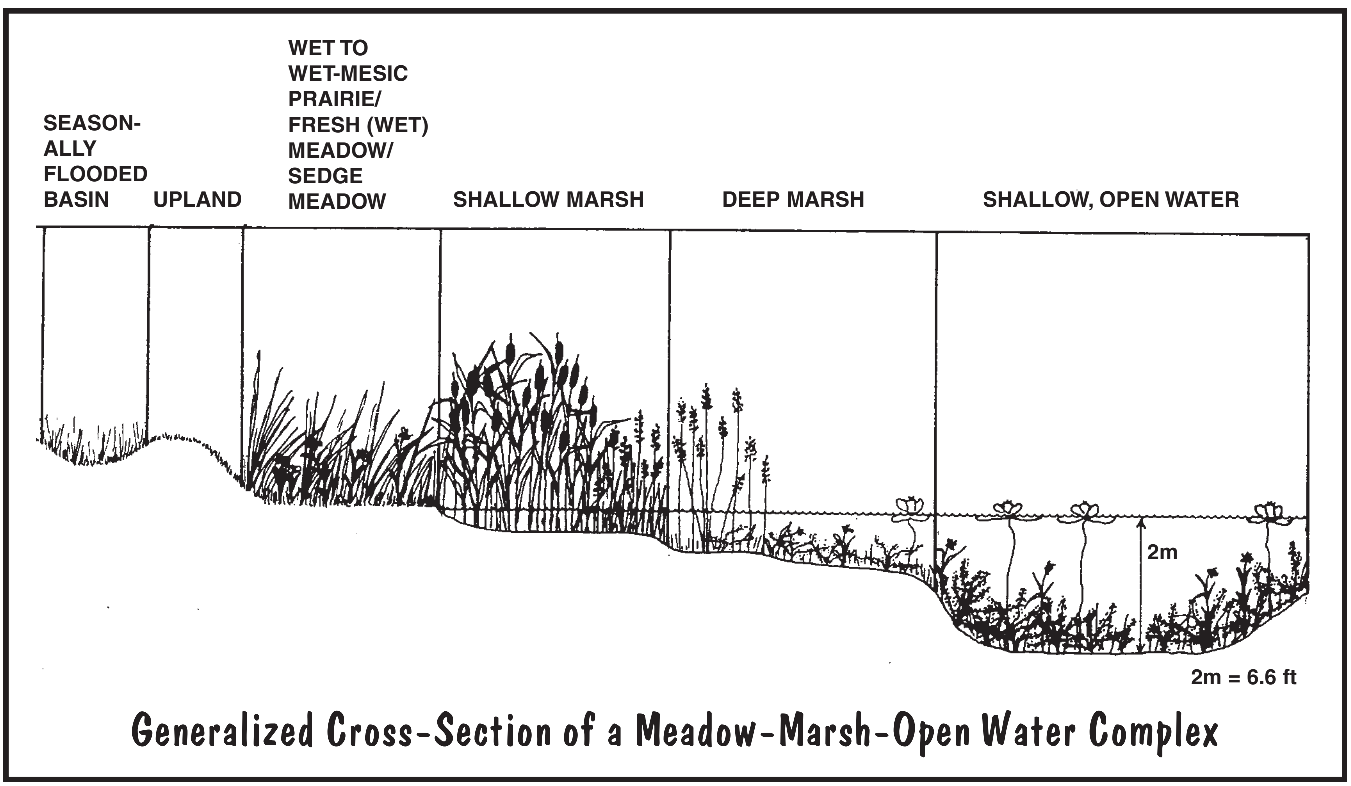


Figure 2: Generalized cross-section of a meadow-marsh-open water complex. From *Wetland Plants and Wetland Plant Communities,* by Steve D. Eggers and Donald M. Reed, U.S. Army Corps of Engineers, Second Edition, 1997. Reprinted with permission.

Characteristics of a Streambank

❒ Skirts a linear body of water.

❒ Is exposed to constant deposition of sediment and erosion of soil.

❒ Is exposed to constant fluctuation of quantity and velocity of water flow.

❒ Three major longitudinal zones determine the makeup of plant communities:

- Headwater zone: narrow channel
- Transfer zone: wide floodplain
- Depositon zone: flowing towards the mouth

❒ Requires a complex diagnostic process before restoration is attempted.

❒ Emergent vegetation, such as grasses and low shrubs at and near water level, reduces velocity, while roots hold soil particles in place. (See Figure 3.)

Generalized Cross-Section of Wetland Plant Communities in a River Valley

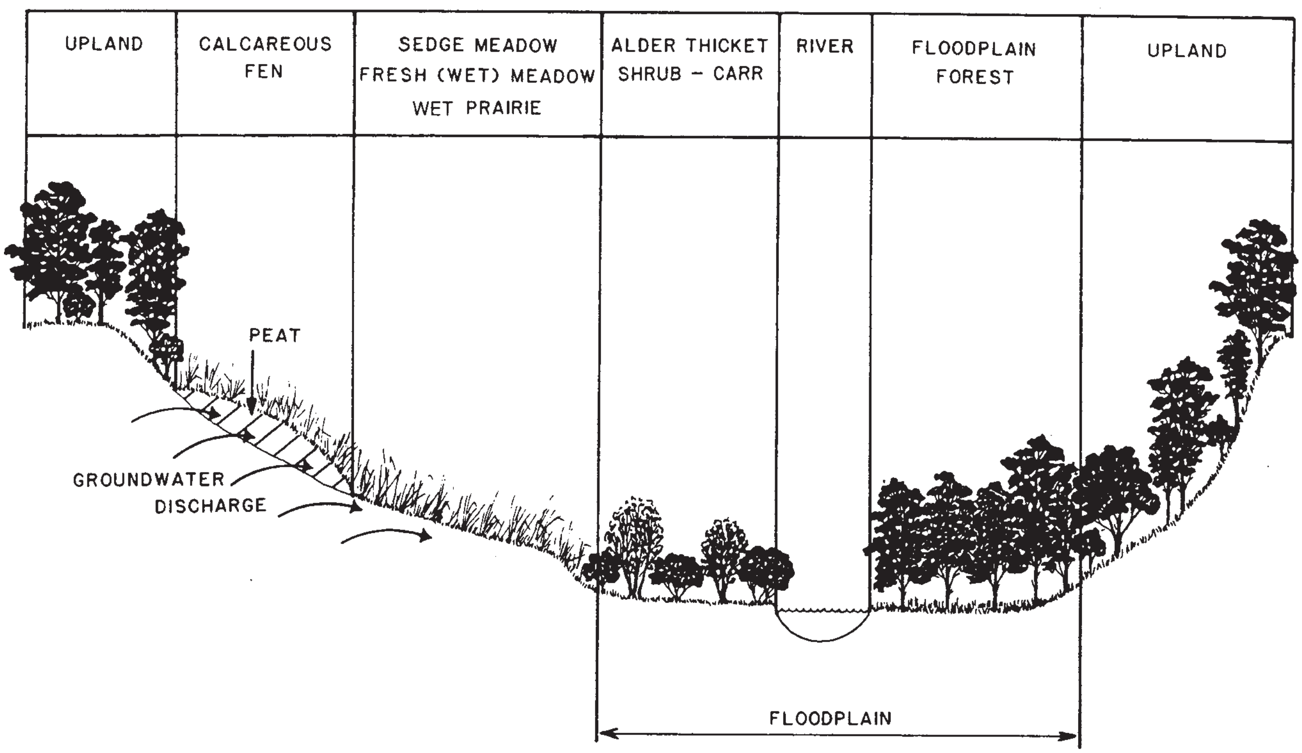


Figure 3: Generalized cross-section of wetland plant communities in a river valley. From *Wetland Plants and Wetland Plant Communities,* by Steve D. Eggers and Donald M. Reed, U.S. Army Corps of Engineers, Second Edition, 1997. Reprinted with permission.

Guiding Principle

To enhance the ecological quality of state trails,
canoeing and boating routes, and water access sites,
thereby increasing the quality of the recreational experience
and fostering trail user awareness and appreciation.

This principle can be achieved by:

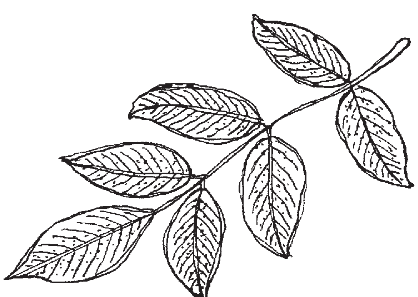
❒ **Preserving ecologically diverse riparian areas.**

❒ **Limiting the removal of natural vegetation** to the greatest extent possible.

❒ **Creating conditions that allow for natural recolonization** of native plants.

❒ **Re-establishing an ecologically functional shoreline/streambank** with locally native plants.

❒ **Interpreting plant communities** and associated management and restoration activities.



Green ash

Assessing Site-Specific Needs: Management, Restoration or Re-establishment?

When is management of a community sufficient? When is restoration the preferred approach? When is re-establishment needed?

Management means taking care of what's already there: encouraging and improving the continued growth and enhancement of natural communities already in place at a particular site. Management can also be considered a form of restoration—trying to improve a site ecologically.

Restoration represents a more intensive effort. It is a process of returning a degraded natural community to its original structure and species composition.

Areas in need of restoration usually offer the “basic ingredients” necessary to represent a natural community, but the quality of the overall community is less than what it should be. Restoration efforts focus on enhancing what’s already there, to improve the overall quality and long-term viability of the natural community.

Restoration can be thought of as nursing biodiversity back to health through such activities as exotic species control, interseeding, inter-planting, and prescribed burning.

Re-establishment represents the most intensive effort but is probably the least understood at this time. It is about attempting to re-establish a natural plant community that once existed in a specific location. This process is a beginning that gives us the opportunity to gain greater knowledge about the complexity of natural systems while actively participating in helping to heal the land, which is a satisfying activity in itself. DNR ecologists and resource managers can help identify a target community in a chosen location.

Conducting a Comprehensive Site Analysis

Conducting a comprehensive site analysis is the first step in evaluating a specific site. A site analysis should include the following steps:

❒ Learn about the biological history of the site.

- Refer to *The Natural Vegetation of Minnesota at the Time of the Public Land Survey: 1847-1907*.

- Consult Minnesota County Biological Survey (MCBS) maps and descriptions.

❒ Survey and evaluate existing vegetation on the site.

- Consult *Minnesota Native Plant Communities Classification, Version 2*

- Consult *Field Guide to the Native Plant Communities of Minnesota* 2004-2006

- Solicit help from a botanist or ecologist, or learn to identify plants.

❒ Determine whether any listed plant or animal species are present.

- Check the Minnesota listing.

- Solicit help from an ecologist.

❒ **Analyze soil types and characteristics.**

• Refer to *Soil Surveys by County: NRCS in Cooperation with Minnesota Agricultural Experiment Station*, from the U.S. Department of Agriculture.

• Conduct a soil sampling onsite.

• Determine soil compaction or disturbance.

• Determine content of organic matter and nutrient levels.

• Determine pH factor.

❒ **Determine soil moisture** gauged on a gradient from open water to saturated to wet.

❒ **Consider topographic features,** such as slope and aspect.

• Determine whether the site is hilly or level; identify degree of exposure to the sun (south, north, east or west).

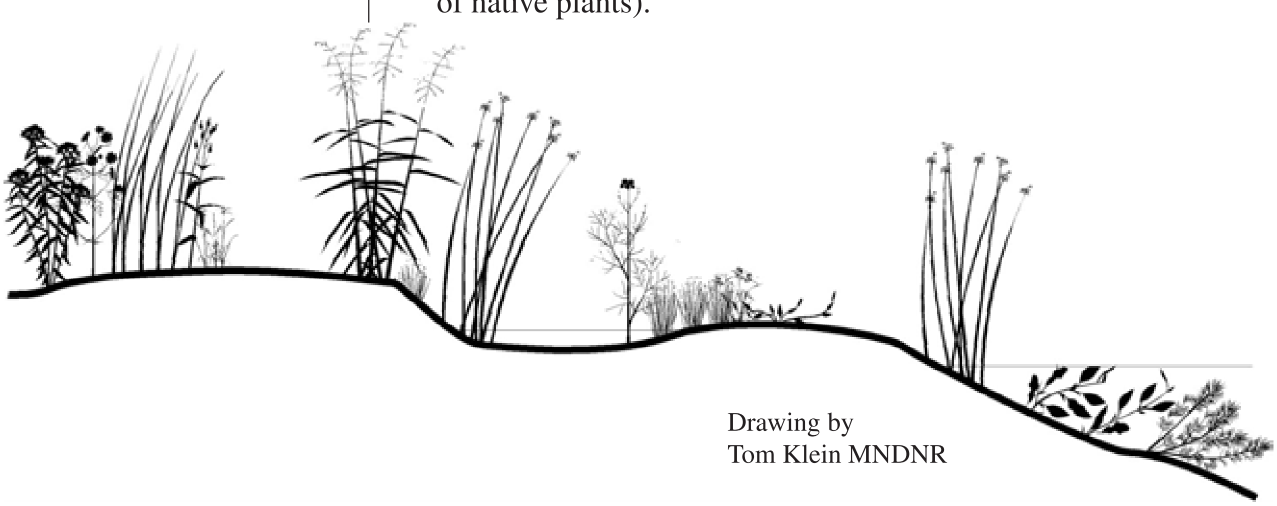
❒ **Consider the microclimatic conditions** of the site, within the regional context.

❒ **Select the appropriate plant species** according to site conditions and the specific landscape unit.

• Consult *Vascular Plants of Minnesota,* by G. B. Ownbey and T. Morley (1991).

• Consult the County Biological Survey database.

• Consult *Restore Your Shore* CD ROM (includes an encyclopedia of native plants).



Drawing by
Tom Klein MNDNR

Riprap and concrete create a physical barrier that disrupts continuous vegetation from the water's edge to the upland.

Choosing Bio-engineering Techniques over Riprap

The stabilization of riparian areas after a disturbance is essential in controlling negative impacts to the fragile riparian edge and the associated water body.

Using Bio-engineering Techniques

The use of bio-engineering (soft armor) techniques is the preferred alternative in most cases and should be applied to the greatest extent possible. These techniques combine mechanical elements (structures) and biological elements (plants), which function together in an integrated manner to blend ultimately into the native landscape, thereby providing ecologically functioning shorelines and streambanks.

Although initially more labor intensive than hard armor techniques, bio-engineering techniques are less expensive in regard to the use of material and energy.

Once established, the shoreline, streambank or any slope repaired with bio-engineering techniques continues to grow and become stronger. Diversity of plants and their flexibility, along with various root structures and their depth, hold soil in place. Roots also extract moisture from the soil via evapotranspiration. Plants and roots withstand the erosive forces of moving water and have indefinite life expectancy.

Bio-engineering techniques are effective both below and above the Ordinary High Water Line (OHWL). Techniques are tailored to the needs of each individual site.

Using Riprap

Structural protection with riprap or concrete is a typical "hard armor" technique that is still used too frequently today. Riprap and concrete create a physical barrier that disrupts continuous vegetation from the water's edge to the upland.

These techniques do not include the use of live vegetation and thereby forgo the gradual re-development of a naturalized shoreline. Hard armor, like concrete and rip-rap, will weaken with age, having a limited life expectancy.

Restoring and Re-establishing Native Plantings in Shallow Water Below the Ordinary High Water Line

Things To Remember

✔ Obtain required permits from DNR Divisions of Waters and Fisheries, and Corps of Engineers.

✔ Evaluate each site and select the appropriate site preparation method and plant species.

✔ Inventory nearby natural vegetation to guide species selection.

✔ Be mindful of potential native seedbank.

Permit Requirements

❒ **A permit is required** from the Corps of Engineers and the DNR Division of Waters to do any structural work in public waters below the Ordinary High Water Line (OHWL).

❒ **A permit is required** from the DNR Division of Fisheries for the following activities: using herbicides; physically removing plants; planting (either seeds or transplants); or harvesting plants below the OHWL.

❒ **A permit is required** from the DNR Division of Fisheries for placing temporary structures (such as wave breaks) below the OHWL.

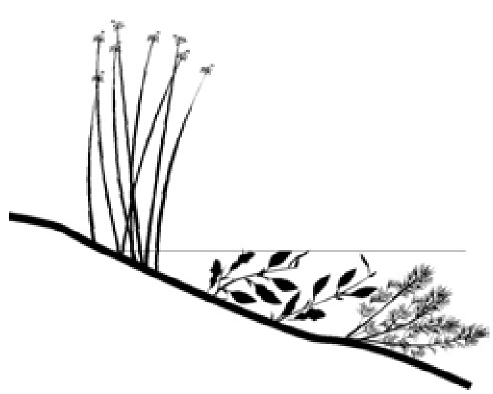
The Shallow Water Zone

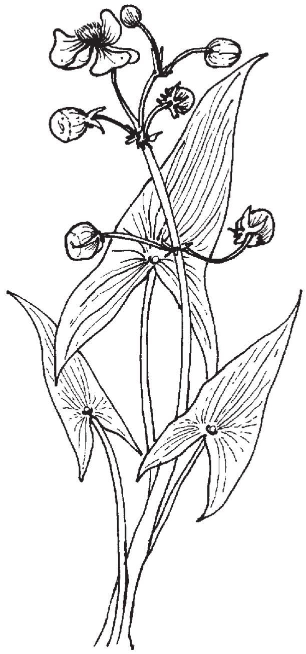
This area includes emergent, floating and submerged vegetation. These plants are naturally adapted to withstand wave action, ice action and flowing water. They also hold sediment in place and provide food for fish and other wildlife.

This zone is an important part of the shore ecosystem. Therefore, riparian restoration often includes planting below the OHWL.

Limited numbers of species grow within the emergent zone in broad, simple patterns. Because most plants will spread on their own, it is sufficient to plant them 1-2 feet apart.

A planting in this zone will be nearly maintenance free after plants are rooted. Any pattern of native plants that evolves is fine. Only exotic plants should be removed.





Common arrowhead

Emergent Native Plants for Shoreline Anchoring That Are Common Throughout Minnesota

(alphabetical by scientific name)

Forbs:

Sweet flag *Acorus calamus*
Mud plantain *Alisma subcordatum*
Water plantain *Alisma triviale*
Water hemlock *Cicuta maculata*
Blue flag iris *Iris versicolor*
Marsh-vetchling *Latyrus palustris*
Fringed loosestrife *Lysimachia ciliata*
Monkey flower *Mimulus ringens*
Yellow pond lily *Nuphar luteum ssp. variegatum*
Smartweed *Polygonum ssp*
Pickerelweed *Pontederia cordata*
Northern arrowhead *Sagittaria cuneata*
Common arrowhead *Sagittaria latifolia*
Water parsnip *Sium suave*
Giant bur-reed *Sparganium eurycarpum*
Bladderwort *Urticularia vulgaris*

Grasses, sedges and rushes:

American slough grass *Beckmannia syzigachne*
Blue-joint grass *Calamagrostis canadensis*
Bottlebrush sedge *Carex comosa*
Porcupine sedge *Carex hystericina*
Lake sedge *Carex lacustris*
Woolly sedge *Carex lanuginosa*
Fox sedge *Carex vulpinoidea*
Spike rush *Eleocharis spp*
Cotton grass *Eriphorum angustifolium*
Tall manna grass *Glyceria grandis*
Fowl manna grass *Glyceria striata*
Common rush *Juncus effusus*
Slender rush *Juncus tenuis*
Hardstem bulrush *Scirpus acutus*
River bulrush *Scirpus fluviatilis*
Softstem bulrush *Scirpus validus*
Cordgrass *Spartina pectinata*
Broad-leaved cattail *Typha latifolia*

Natural Recolonization of Native Plants

It may not always be necessary to plant shallow water areas, because natural colonization may occur over time from plant propagules and the seedb ank in the soil, especially if the restoration site is connected to natural wetlands or shorelines. High water levels and associated deposition of silt (which contains seed) can also result in natural colonization.

Best natural response occurs when sediments are exposed to the air through natural or sometimes artificial lowering of water level (drawdown). Oxidation stimulates seed germination. Plants will also recolonize naturally as a result of seed distribution by wind, waves and animals.

Winter Wetland/Shoreline Seeding

Wet sites are much more accessible when the ground is frozen. In addition, winter seeding replicates nature in several ways. The seed is dispersed and stratified during the winter months, as it would occur naturally. Early winter seeding is best, because stratification works best when seeds are in the soil through the winter months.


Monkey flower

Weather and site conditions will largely determine how successful the seeding will be. The ideal situation would be:

- ❐ No snow on the ground
- ❐ Low water levels, to be able to include plant species that will later be submerged
- ❐ Warm enough weather to allow the soil surface to be lightly cultivated for good seed/soil contact
- ❐ Bird migration season already completed, so that seeds won't be eaten

Species selection is a critical factor in the site's future sustainability and diversity. Average water levels determine which species will be most successful in which location. It is important to include in the mix both early successional species for quick establishment, as well as slow-to-establish, long-lived species for long-term cover.

Use of a clean mulch can help retain soil moisture and add organic matter.

Planting in Shallow Water

Site Preparation

It is essential to eliminate exotic and invasive plants from a site. This effort can prove to be a tedious process that often requires an entire growing season. Species such as reed canary grass and purple loosestrife need to be cut and treated with herbicides to eliminate the entire plant. (See Chapter 5: Controlling Exotic Species.)

It is essential to eliminate exotic and invasive plants from a site. This effort can prove to be a tedious process that often requires an entire growing season.

Soil preparation is generally not required. Bringing in organic substances or other soil amendments would only jeopardize the success of a planting by potentially introducing exotic plants and excessive weed growth.

It is best to select plant species that fit the site. If needed, secure the help of a botanist, ecologist or fisheries expert. Nearby natural sites can also provide a model.

Obtaining Plant Material

It is important to secure an appropriate plant source before attempting a restoration planting. (See page 27 for suppliers of native seeds and plants)

When purchasing plants from a nursery, it is important to determine the source of the plants. The seed source should be as local as possible but no further than 200 miles from the site, in order to protect and maintain regional genetic makeup.

There may be an opportunity to harvest native plants from a site that will be destroyed by development. These rescued plants should be planted immediately in a temporary bed, with top greens cut back to help plants recover more quickly. Then they should be cared for until the final site is ready to be planted. It is important to check each plant for potentially attached exotic plants.

Planting

Late spring, after water levels have lowered, is the best time to plant aquatic plants. It also gives the plants time to establish a good root system over the summer.

Planting depth is crucial for optimum growth. Plant them so that the surface of the root ball matches the existing soil surface on the site. If the plant was rootbound in the container it came in, carefully break up the root ball to allow the roots to spread more easily in the new environment.

A DNR permit is required to build and maintain wave-breaking devices until they can be removed.

Recommended spacing of plants is one plant per square foot on center. Groupings should be random, and plants should be arranged in groups on center, not in rows. There are no rows in nature.

Installing Wave-Breaking Devices To Protect a New Planting

After planting, temporary wave-breaking devices may be needed to protect a new planting until it is well rooted. Leaving such devices through one growing season is usually sufficient. If the shoreline is a naturally protected site, a wave-breaking device may not be needed.

These devices are placed in the water ahead of the plantings to break boat- and wind-created waves. They may be constructed of commercially available coconut fiber logs, hardwood brush, reusable plywood or plastic fencing. Hardwood debris (such as logs and coarse brush) and bulky plant material (such as cattails) can provide the same protection and may be available near the site.

The breakers should protrude a few inches above the normal water level. **A DNR permit is required** (see page 8 Permit Requirements) to build and maintain these structures until they can be removed. Wave breaks need maintenance, because scouring occurs around and beneath them.

Coconut fiber logs

Coconut fiber logs can be anchored offshore as a wave breaker, or they be laid directly against the shoreline, using stakes to hold them in place. Seedlings are then planted in the calm water behind.

Brush bundles

Brush bundles are probably the least expensive yet effective wave breakers. Brush bundles are constructed by using live or dead branches up to 1 inch in diameter. Bundled tightly with twine or wire, they are staked in place with wood stakes, and secured to one another with twine or wire. If brush is heavily branched, additional pruning of side branches is advised, so the brush can be bundled tightly.

Using Plant-Anchoring Devices To Support Plants and Seedlings

Plant-anchoring devices include mats, carpets, blankets or pallets made of coconut fiber (coir) or jute. They can be used instead of or in combination with wave breakers. They also give plants or seedlings the support and time to become firmly rooted.

These products are staked over a seeded area, or seedlings are planted in the open weave fabric. Some mats can be purchased pre-planted by arrangement with a nursery for quicker establishment of vegetation. Lower-density mats or those with an open weave are preferred, since they allow plants to sprout through the fabric more easily.

Coconut fiber carpet, mat or blanket (also known as coir) is also a useful anchoring material, due to its longevity in the environment. It biodegrades over a period of several years. Mats and blankets are useful on slopes for holding soil in place.

Jute is another material used as an anchoring device or for erosion control. It biodegrades more quickly than coconut fiber. Mats, carpets, pallets and blankets are available in varying thicknesses and densities. Thicker products are sold in mats and pallets; thinner products, such as netting and woven blankets, are sold in rolls.

Maintaining Aquatic Plantings

No long-term maintenance is required for aquatic plantings. If aquatic plants are adequately protected from wave action, they will quickly establish. Be sure to check regularly for invasive non-native species and remove them immediately.

Basic Principles To Avoid Erosion

❒ Do a careful site analysis, so that the development fits the site.

❒ Avoid extensive earthwork in erosion-prone soils.

❒ Preserve native vegetation to the greatest extent possible.

❒ Remove vegetation in small increments as needed.

❒ Install a silt fence wherever earthwork will occur near the water's edge.

❒ Do not leave soil exposed to wind or rain. Seed a quick growing cover crop and mulch immediately.

❒ Construct sediment basins to prevent eroded soil from leaving the site.

❒ Construct temporary dikes (straw bales) to slow runoff velocities and detain sediment.

❒ Maintain temporary control structures until a site is well vegetated.

Things To Remember

✔ Grade conservatively only what is needed to stabilize a site.

✔ Use bio-engineering techniques rather than riprap or other hard armor methods.

✔ Use plant material and seeds that are native to the region.

Stabilization of Riparian Environments at or above the OHWL and on Steep Upland Slopes

Soil erosion occurs when bare soil is exposed to heavy rain, snowmelt or uncontrolled runoff from construction sites or large impervious areas. It is of critical importance to protect the bank or shore of a water body with a silt fence before soil is exposed during the development of a site.

Even soil eroding from unvegetated upland slopes will eventually impact a water body negatively by contributing siltation, increased nutrients, and other pollutants. Water quality and wildlife habitat will be compromised by diminishing natural plant diversity, impacting fish and other organisms, and introducing exotic and invasive plants, which thrive in such disturbed environments.

Expedient temporary and permanent revegetation of open soil sites is equally important. The use of bio-engineering techniques should be given priority over the use of riprap on all relevant Trails and Waterways sites.

Benefits of Bio-engineering Installations

Common pussy willow

❒ They effectively stop erosion and build on the regenerative force of vegetation to protect and naturalize eroded shorelands, streambanks and upland slopes.

❒ They provide enough stability to a disturbed slope that natural invasion and colonization of native plants can take place and eventually take over the stabilizing role.

❒ They generally require minimal access for equipment and therefore cause relatively minor site disturbance.

Suitable Plant Material

Stakes and bundles of fast-rooting trees and shrubs are particularly suited to reinforcing soil with roots and drawing excess water from the soil through evapotranspiration, thereby minimizing downslope movement of earth masses. (See “Native Plant Species Recommended for Stabilizing Slopes,” page 25.)

Selected plant material should:

- Root easily
- Be long, straight, and flexible
- Be in plentiful supply near the project site

When installed properly, this fast-rooting material:

- Stabilizes the surface layer from wind, and gravitational and hydraulic forces

- Slows the movement of water and soil particles down the slope

- Traps sediment in the live brush and promotes infiltration of water

- Allows seeds to establish in the moister sediment, thereby allowing natural succession to take place

Shaping the Bank, Shore or Slope

Any shaping of a disturbed slope should be done very conservatively and only to stabilize it so that plants can take hold. Any unnecessary grading may also forgo the potential for natural recolonization of native plants.

Peachleaf willow

Selected Bio-engineering Techniques

The following bio-engineering techniques are recommended to help stabilize erosion-prone environments along shores and banks, as well as on upland slopes.

Erosion Control Fabrics

When to use: On slopes when soil needs to be held in place until plants establish from seed.

Method: Jute, coir, straw and wood fiber blankets are staked over a seeded area. Seedlings may be planted through slits in the fabric. Erosion control fabrics are also useful in combination with other methods, such as the installation of stakes, branch packing, fascines and brush layering.

Live Stakes

When to use: In areas of minor erosion or shallow sliding. Live stakes can also be used in combination with erosion control fabrics.

Method: To stabilize a slope, any bank overhang must first be removed, shaping the bank so it is stable. Live stakes are cut and planted on the site during the dormant season. Willows and cottonwood work well. For additional suitable plant materials, see "Native Plant Species Recommended for Stabilizing Slopes," page 25.

Stakes should be 2 to 3 feet long with a minimum diameter of 1/2 inch: The larger the diameter, the greater the food reserves. Side branches need to be cut off clean, and bark needs to be intact.

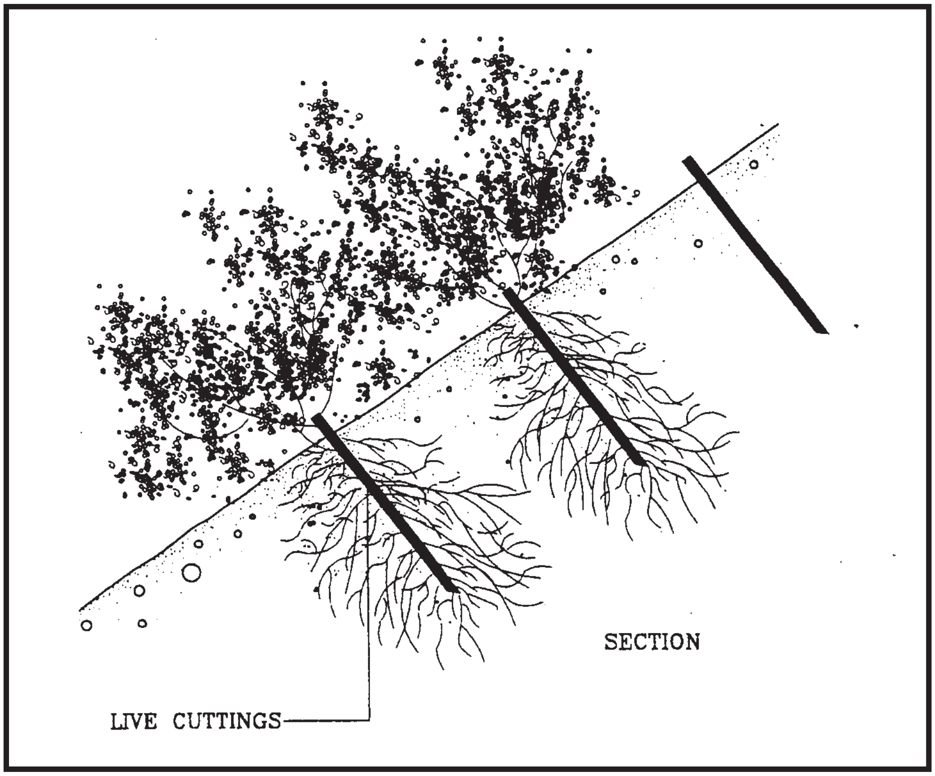
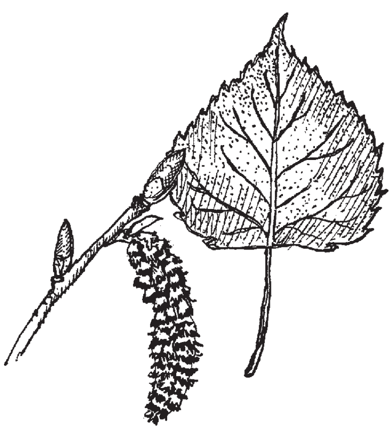


Figure 4: Schematic diagram of an established, growing live stake installation.
From *Biotechnical and Soil Bioengineering Slope Stabilization, A Practical Guide for Erosion Control,* by Donald H. Gray and Robbin B. Sotir, John Wiley & Sons, 1996. Reprinted by permission of John Wiley & Sons, Inc.

Tamp the live stake into the ground at right angles to the slope, using a mallet to avoid splitting the stake. At least two buds should be above the ground after planting, and 80% of the stake should be in the ground. The butt of the stake should be cut diagonally, for easier insertion. Soil must be firmly tamped around the stake. Install the stakes 2-3 feet apart, using triangular spacing. There should be 2-4 stakes per square yard. (See Figure 4.)



Cottonwood

Branch Packing

When to use: On small areas that have been scoured out or have slumped, leaving a void.

Method: Once the problem has been identified and corrected, alternate layers of live branches and backfill are installed, which will rapidly vegetate the scour. Slump areas should not exceed 4 feet in depth or width. For suitable plant materials, see "Native Plant Species Recommended for Stabilizing Slopes," page 25.

Live branch cuttings can range from 1/2 inch to 2 inches in diameter. They should be long enough to reach the undisturbed bank and should protrude slightly beyond the rebuilt slope face. Depending on the size of the scour/slump, wooden stakes should be 5-8 feet long, made from 3-inch to 4-inch diameter poles.

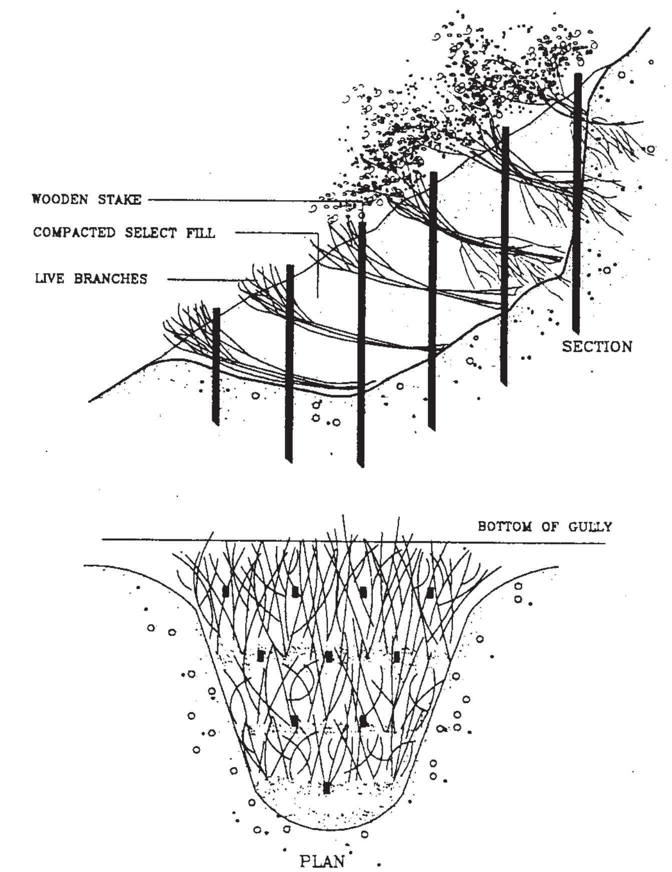


Figure 5: Schematic diagram of an established, growing branchpacking installation.
From *Biotechnical and Soil Bioengineering Slope Stabilization, A Practical Guide for Erosion Control,* by Donald H. Gray and Robbin B. Sotir, John Wiley & Sons, 1996. Reprinted by permission of John Wiley & Sons, Inc.

Starting at the lowest point, the stakes are driven 3 feet into the ground, 1 to 1 1/2 feet apart. A layer of live branches 4 to 6 feet thick is placed in the bottom between the stakes, with basal ends lower than growing tips. Each layer of branches is covered by a layer of soil, which is lightly compacted to ensure good soil contact. The final installation should match the existing slope profile, with growing tips protruding slightly. (See Figure 5.)

Live Fascines (Wattles)

When to use: Where minimum site disturbance is crucial, providing excellent protection against surficial erosion.

Method: Fascines are bundles (wattles) of dormant rootable plant material placed in shallow trenches on contour. Suitable plant material is listed in Table 1 on page 25. The bundles consist of live twigs of plant species that root easily. Dead material can be mixed in if there is a shortage of live twigs.

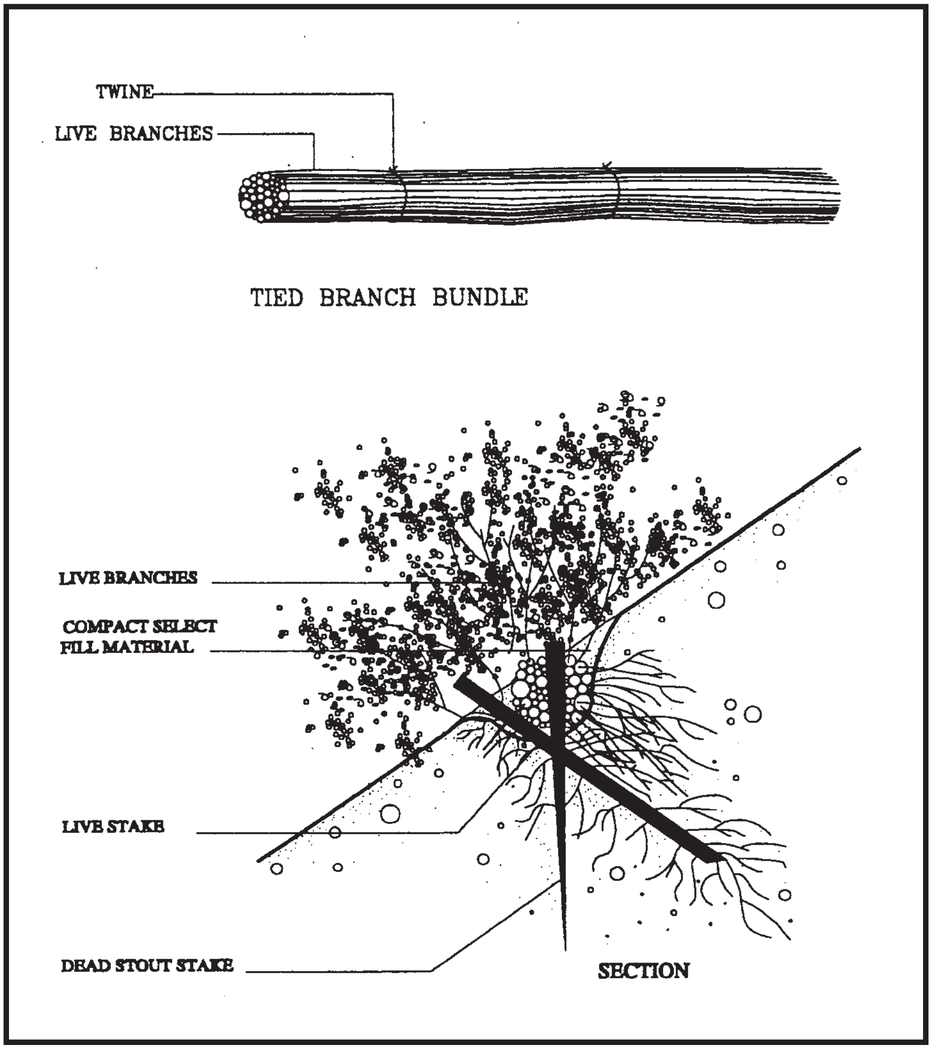


Figure 6: Schematic diagram of an established, growing live fascine installation, showing live fascine bundles (above) and method of placement in a slope (below). From *Biotechnical and Soil Bioengineering Slope Stabilization, A Practical Guide for Erosion Control,* by Donald H. Gray and Robbin B. Sotir, John Wiley & Sons, 1996. Reprinted by permission of John Wiley & Sons, Inc.

❒ While fascines may be installed in the fall, early spring may be better, when soil moisture is high and the growing season is ahead. Suitable material (see Table 1, page 25), consisting of twigs and branches 1 1/2 inches in diameter or less, is made into bundles 5-10 feet long. These bundles should be 6 to 8 inches in diameter, with all growing tips pointing in the same direction. The bundles are tied tightly with twine or wire. (See Figure 6.)

❒ Bundles should not be prepared more than 1 or 2 days before placing, and they should be stored covered and kept moist in a shady place. They should not be laid out on the slope exposed to sun and wind.

❒ Proper staking (using live stakes or tapered construction stakes) is essential to secure the bundles. Using live stakes of the same species as the bundles has the advantage that they will root and add to the plant cover.

❒ Work proceeds from the bottom of the slope to the top on contour. Vertical spacing of rows can range from 3 feet when working with a slope of maximum steepness of 2:1 (2 horizontal lengths to 1 vertical height) up to 10 feet, depending on the steepness of the slope and soil characteristics.

❒ Trenching should be done just prior to the laying of the bundles to minimize drying of the soil. The trench should be shallow, just slightly less than the diameter of the bundles.

❒ Bundles are placed into the trench. Bundles will be held in place by inert or live stakes driven through the bundles, about 2-3 feet on center. Extra stakes should be used at the connection points of the bundles.

❒ Bundles are covered with soil, leaving 10% of their surface exposed. Walking on the finished fascines will help work the soil in between the bundles for better soil contact for maximum root development.

❒ A completed fascine should resemble a slight terrace with a windrow of twigs protruding from the lower edge. If properly constructed, the bundles are neither so exposed as to encourage undercutting by runoff, nor so completely buried as to be overrun by water and silt. After fascine installation, planting and seeding of permanent vegetation can occur. On flatter slopes, use long straw for mulch between fascines; on steep slopes, use anchored jute or coir netting. Mulch effectively prevents raindrops from eroding bare soil.

Brush-Layering

When to use: Where deeper reinforcement of the soil is needed on upland slopes.

Method: Contour brush-layering is related to fascines on contour. But there are some differences:

❒ Branches are laid perpendicular to the slope on benches, with developing roots reaching deeper into the slope, and tips of branches protruding beyond the face of the slope. Protruding tips slow runoff velocity and filter sediment.

❒ Brush-layering can be used in fill slopes and cut slopes. Branches are not bundled but are spread out across the bench.

Installation of fill slopes

During embankment construction from the sole of the slope up, regular grading equipment can be used to haul and install the brush. Each layer of brush is covered with a layer of soil and then lightly compacted. These branches root along their length and act as immediate horizontal slope drains. (See Figure 7.)

Mulch should be placed between rows. Jute, coir or hold-down netting should be used on steeper slopes for better protection.

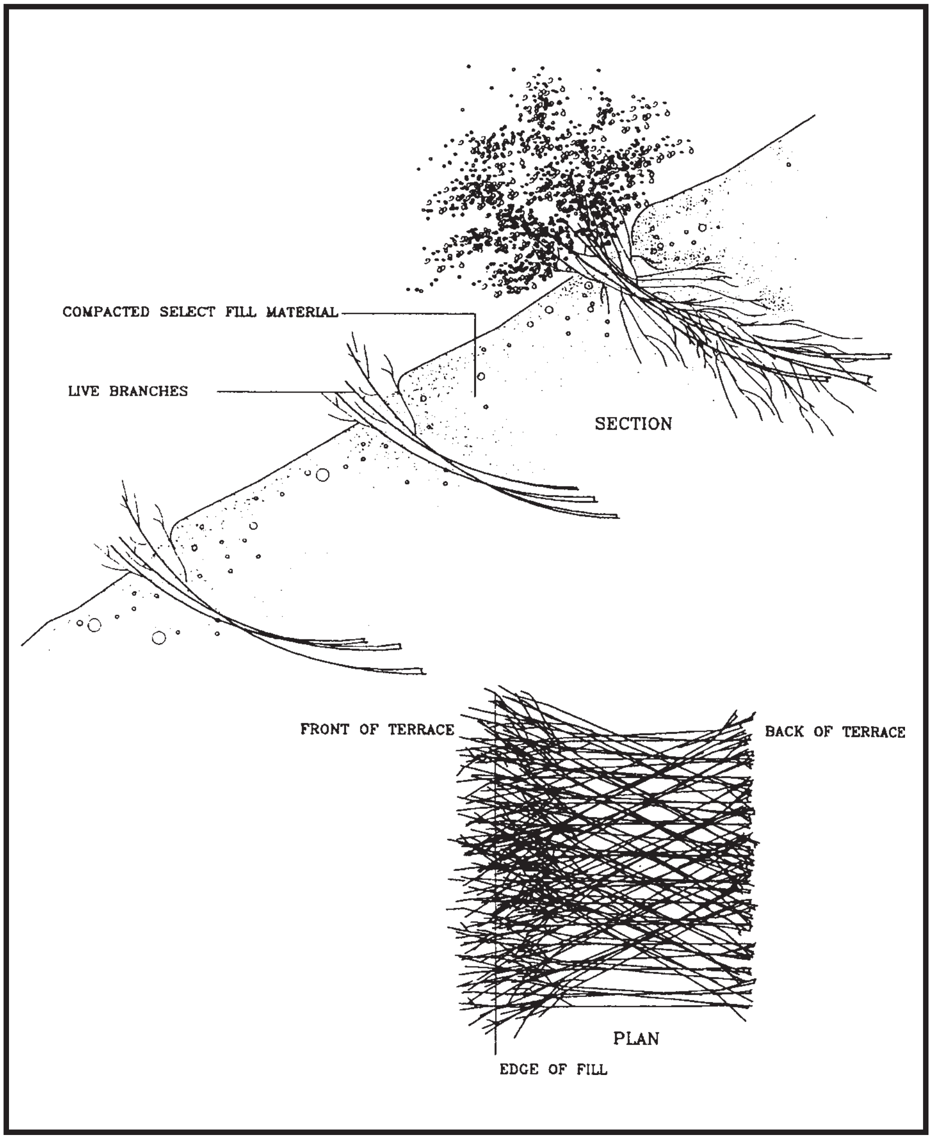


Figure 7: Schematic diagram of an established, growing fill slope brush layer installation, showing alternating layers of live cut brush inserted between lifts of soil. From *Biotechnical and Soil Bioengineering Slope Stabilization, A Practical Guide for Erosion Control,* by Donald H. Gray and Robbin B. Sotir, John Wiley & Sons, 1996. Reprinted by permission of John Wiley & Sons, Inc.

Installation of cut slopes

For remedial treatment of existing slopes, small benches are excavated. The branches are inserted into the slope perpendicular rather than parallel, which provides reinforcement that is better oriented and better able to resist shallow shearing.

The width of the benches ranges from 2-3 feet. Benches are angled back into the slope slightly. Live brush is placed on the bench, followed by backfilling and compacting soil.

Brush is cut into 3- to 4-foot lengths with stems of 3/4 inch to 2 inches in diameter. Brush should protrude to filter sediment from runoff and hold it on the slope. The slope should not be steeper than 2:1, with a spacing 3 to 5 feet between benches as steepness of slope decreases, depending on soil and site condition. (See Figure 8.)

Mulch should be placed between rows, as with fill slopes. Jute, coir or hold-down netting should be used on steeper slopes for better protection.

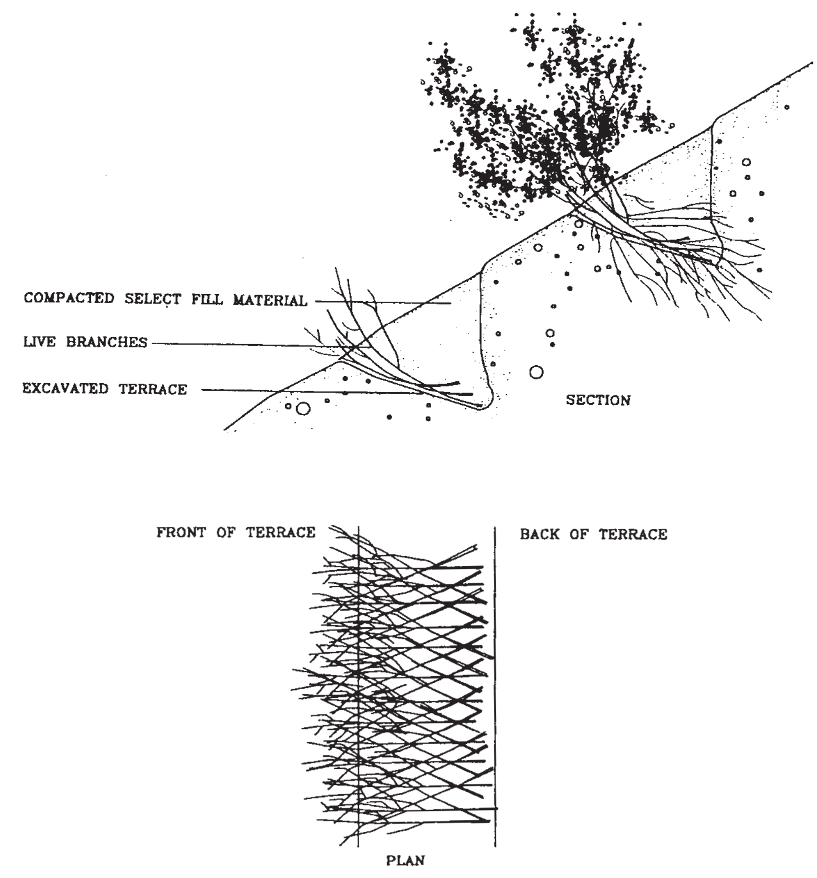


Figure 8: Schematic diagram of an established, growing cut slope brush layer installation, showing alternating layers of live cut brush placed on narrow benches or terraces excavated in the slope. From *Biotechnical and Soil Bioengineering Slope Stabilization, A Practical Guide for Erosion Control,* by Donald H. Gray and Robbin B. Sotir, John Wiley & Sons, 1996. Reprinted by permission of John Wiley & Sons, Inc.

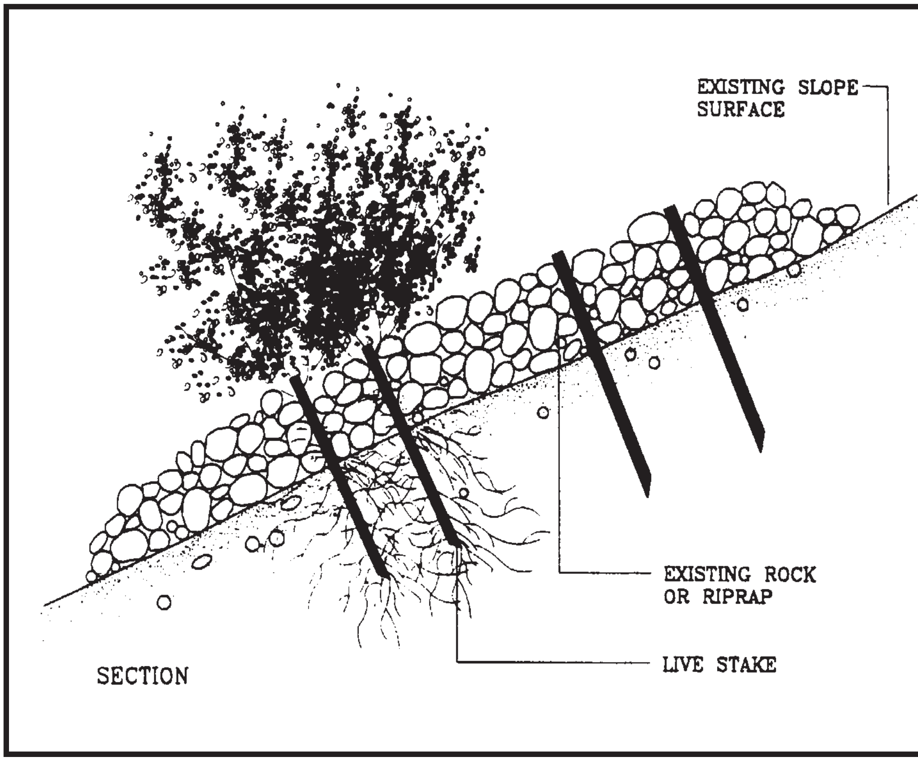


Figure 9: Schematic diagram of an established, growing vegetated riprap joint planting. From *Biotechnical and Soil Bioengineering Slope Stabilization, A Practical Guide for Erosion Control,* by Donald H. Gray and Robbin B. Sotir, John Wiley & Sons, 1996. Reprinted by permission of John Wiley & Sons, Inc.

Joint Plantings

When to use: Where plants can enhance existing or needed rock riprap.

Method: Live stakes are tamped into joints or openings between the rocks. Root systems provide a mat beneath the rock that holds soil in place. Survival rate of stakes can be low if stakes don't have good soil contact, and they are easily damaged as they are driven in between the rocks. (See Figure 9.)

Additional Bio-engineering Techniques

Additional bio-engineering techniques exist beyond those presented in this section. Local soil and water conservation district staff and DNR staff with experience in bio-engineering can provide assistance in the use of appropriate stabilization techniques for individual sites.

Treatment and Use of Plant Material Suitable for Bio-engineering Techniques

Pioneer species improve the conditions of disturbed sites, stabilizing and improving soil and micro-climate. Given time and stable conditions, the improved soil and microcli-matic conditions help long-lived plant species to establish on their own.

Speckled alder

Trees and shrubs used for cuttings in bio-engineering construction techniques are pioneer species (early successional species). Pioneer species improve the conditions of disturbed sites, stabilizing and improving soil and microclimate. Given time and stable conditions, the improved soil and microclimatic conditions help long-lived plant species to establish on their own. Planting is also an option if a natural seed source is nonexistent.

For instance, several species of willows will temporarily grow from cuttings in much less favorable soils, such as denuded lands and road fills. Although most willows naturally grow along moist/wet stream-sides and meadows or swales, they will grow for a few years in these less favorable environments, stabilizing the site before they die out.

Harvesting, Handling and Installation of Cuttings

❒ Cuttings used in bio-engineering construction must be native to the region and cut from local stock.

❒ Install cuttings only during the dormant season between September and April.

❒ Cut branches at the harvest site at 8-10 inches above the ground to assure healthy regeneration.

❒ Select healthy branches that are reasonably straight, and bind them into bundles.

❒ Make clean cuts. Avoid tearing and split ends. The butt ends should be cut to a point for ease of installation.

❒ Install cuttings preferably the same day they are cut and when the temperature is above 50 degrees Fahrenheit.

❒ If cuttings cannot be installed the same day they are cut, keep the branches moist (heeled in or in water), out of the wind and in the shade. Use within 2 days after cutting.

❒ Do not install cuttings that have already broken bud.

❒ Use onsite stockpiled soil as the planting medium if its quality is capable of supporting plant growth.

❒ Ensure that cuttings have a terminal bud scar within 1-2 inches of the top, and that at least two buds are above the ground after installation. Cuttings put out their greatest concentration of shoots and their strongest ones just below the terminal bud scar.

Native Plant Species Recommended for Stabilizing Slopes

Table 1 lists native species recommended for stabilizing slopes and provides useful information related to native regions, size and form, habitat value, root type and rooting ability. (See Minnesota ECS section map, below.)

Name	*Minnesota ECS sections*	*Size /Form*	*Habitat value*	*Root type*	*Rooting ability*
Boxelder *Acer negundo*	All	Large understory, 35-50' irregular	Excellent	Moderately deep and spreading laterals	Poor-fair
Speckled alder *Alnus inc. ssp. rugosa*	1-8	Small tree, 20-35' globular	Excellent	Shallow, narrow spreading	Fair
Silky dogwood *Cornus amomum*	5-9	Mid-height shrub, 6-12' globular,	Very good	Shallow lateral, fibrous	Very good
Gray dogwood *Cornus racemosa*	1, 3-9	Mid-height shrub, 6-12', obovoid	Very good	Shallow lateral, fibrous, suckering	Good
Redosier dogwood *Cornus sericea*	All	Mid-height shrub, 6-12', globular	Very good	Shallow lateral, fibrous, stoloniferous	Very good
Common ninebark *Physocarpus opulifolius*	1, 7	Mid-height shrub, 6-12' mound	Good	Shallow lateral, fibrous	Fair-good
Balsam poplar *Populus balsamifera*	1-8	Large canopy, 50-75'	Good	Shallow, fibrous	Very good
Cottonwood *Populus deltoides*	2-9	Large canopy, 75-100' obovoid	Good	Shallow, fibrous	Very good
Quaking aspen *Populus tremuloides*	All	Large understory, 35-50', columnar	Good	Shallow, fibrous, prolific sprouting	Fair
Allegheny blackberry *Rubus allegheniensis*	1, 2, 5-8	Small shrub, 3-6' mound	Very good	Shallow, fibrous, suckering	Good
Red raspberry *Rubus strigosus*	1-8	Small shrub, 3-6' mound	Very good	Shallow, fibrous, stoloniferous	Good
Sandbar willow *Salix exigua*	All	Mid-height shrub, 6-12'	Good	Shallow, fibrous, suckering	Fair-good
Peachleaf willow *Salix amygdaloides*	3-9	Large understory, 35-50', columnar	Good	Shallow, fibrous, extensive	Very good
Pussy willow *Salix discolor*	All	Small tree, 20-35' columnar	Good	Shallow, fibrous, extensive	Very good
Prairie willow *Salix humilis*	All	Medium shrub, 6-12' globular	Good	Shallow, fibrous	Good
Shining willow *Salix lucida*	1, 2, 5, 6	Large shrub, 12-20' globular	Good	Shallow lateral	Very good
Black willow *Salix nigra*	2, 5-9	Large understory, 35-50', columnar	Good	Shallow, divided into multitude of rootlets	Excellent
American elderberry *Sambucus canadensis*	3, 5-9	Medium shrub, 6-12' obovoid	Very good	Shallow lateral, stoloniferous, suckers	Good
Scarlet elder *Sambucus pubens*	1, 2, 5-9	Medium shrub, 6-12' obovoid	Very good	Deep laterals, fibrous	Fair-good
Meadowsweet spirea *Spirea alba*	All	Small shrub, 3-6' mound	Good	Shallow lateral, fibrous, suckering	Fairgood
Hardhack spirea *Spirea tomentosa*	5, 6, 8	Small shrub, 3-6' mound	Good	Shallow, fibrous, suckering	Fair
Wolfberry *Symphoricarpus occidentalis*	All	Small shrub, 3-4' mound	Good	Shallow, fibrous, colony forming	Good
Downy arrowwood *Viburnum rafinesquianum*	All	Small shrub, 3-6' obovoid to globular	Very good	Shallow lateral, fibrous	Fair-good
Nannyberry *Viburnum lentago*	All	Small tree, 20-35' obovoid	Good	Shallow, fibrous	Fair-good

Alphabetical by scientific name

Note: Some willow species—and balsam poplar in particular—should not be used in areas in close proximity to the trail tread. These species have stoloniferous roots and grow through the asphalt. This makes a trail unsafe for some uses and creates a maintenance problem.

Minnesota ECS Section

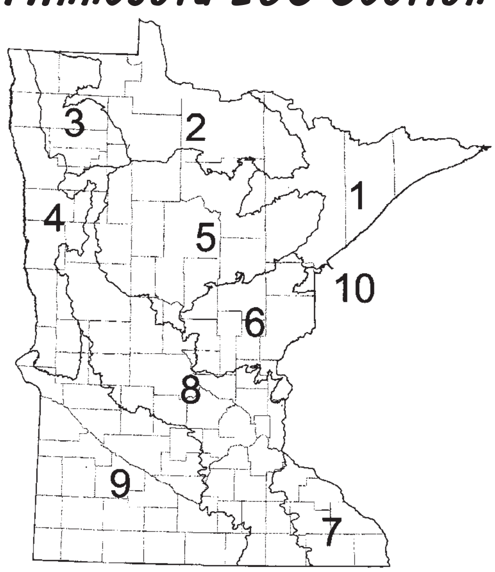


Figure 10: Minnesota ECS section map

1 Northern Superior Uplands
2 Northern Minnesota & Ontario Peatlands
3 Lake Agassiz, Aspen Parklands
4 Red River Valley
5 Northern Minnesota Drift & Lake Plains
6 Western Superior Uplands
7 Paleozoic Plateau
8 Minnesota & NE Iowa Morainal
9 North Central Glaciated Plains
10 Southern Superior Uplands

Monitoring of Restoration Sites

It is critical to monitor these sites, so that we can learn how natural systems respond and change over time. We need to use ecological knowledge, statistical inference and informed intuition to interpret these responses and changes. Our goal must be to design and implement a monitoring program that will best help us track our progress in striving for ecological functionality and increased diversity of species on these sites.

The following basic steps will help us get started:

- ❒ Inspect the site regularly.
- ❒ Control exotic species.
- ❒ Prune to reduce competition and stimulate new growth.
- ❒ Assure that temporary wave-breaking devices are in working order.
- ❒ Replace dead unrooted branches.
- ❒ Record and evaluate changes to each site annually.
- ❒ Adjust management activities as needed.

Plant Sources for Aquatic Forbs and Grasses

Look for nurseries that specialize in plants that grow in aquatic environments. Be sure to ask for source identification when purchasing seeds, propagules and plants. Some nurseries also offer contract growing plants for specific projects, from seeds collected from a nearby site.

For Suppliers of Native Seeds and Plants, go to:

http://www.dnr.state.mn.us/gardens/nativeplants/suppliers.html

Speckled alder

For Further Information

Biotechnical and Soil Bioengineering Slope Stabilization, A Practical Guide for Erosion Control, by Donald H. Gray and Robbin B. Sotir. John Wiley & Sons, New York, 1996.

Healthy Rivers: A Water Course, this CD ROM is an interactive tool to understand the ecology and management of river systems; produced by the Department of Natural Resources, 2004.

Lakescaping for Wildlife and Water Quality, by Carrol L. Henderson, Carolyn J. Dindorf and Fred J. Rozumalski. Nongame Wildlife Program Section of Wildlife, Minnesota Department of Natural Resources, St. Paul, Minnesota, 1999.

"Soil Bioengineering for Upland Slope Protection and Erosion Reduction," Chapter 18, *Engineering Field Handbook.* USDA Soil Conservation Service, 1992.

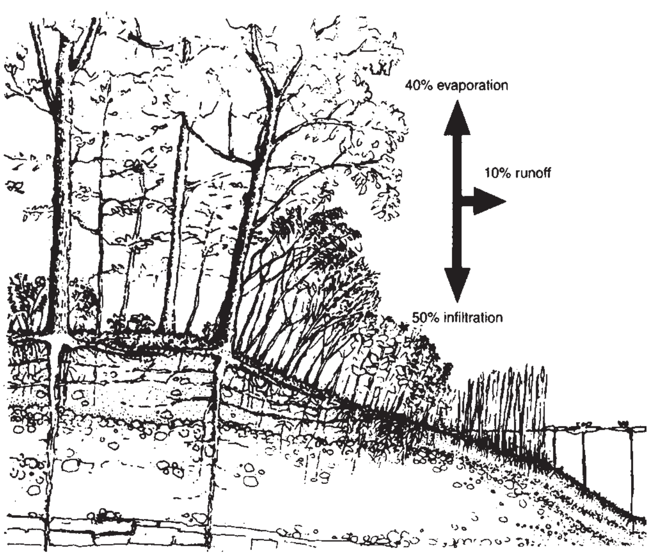
Stream Corridor Restoration: Principles, Processes and Practices. An interagency document produced in cooperation with 15 federal government agencies, 1998.

Wetland Plants and Plant Communities of Minnesota and Wisconsin, by Steve D. Eggers and Donald M. Reed. U.S. Army Corps of Engineers, St. Paul, Minnesota, Second Edition, 1997.

Restore Your Shore, CD ROM by the Minnesota Department ofNatural Resources. Copies are available through the Minnesota Bookstore; call 1-800-657-3757 for information 2001.

Natural Shoreline

Native shoreline vegetation preserved and restored



Degraded Shoreline

Water resources degraded by hard surfaces and reduced vegetation