TECHNICAL NOTES

US DEPT. OF AGRICULTURE NATURAL RESOURCES CONSERVATION SERVICE
Portland, OR September 2006

PLANT MATERIALS No. 38

SUGGESTIONS FOR INSTALLING HARDWOOD CUTTINGS (SLIPS, WHIPS, LIVE STAKES, POLES, POSTS) AND LIVE FASCINES (Pacific Northwest Region, West of Cascades)

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Introduction

Substantial information has been gathered and published in North America and Western Europe over the past 20 years regarding the application of soil bioengineering practices for streambank, shoreline, and roadside stabilization. Excellent guidebooks, instructional pamphlets, and technical reports are now available in libraries and on the internet. Soil bioengineering involves the use of both living and dead woody plant material, as well as herbaceous plants and plant parts. More than a dozen practices utilizing live woody components are classified as “soil bioengineering”, from simple “live stakes” and “post planting” to more complex and substantial methods such as “live crib wall” and “live slope grating”. While the techniques are diverse, the methods for obtaining and handling dormant woody material are essentially the same.

The focus of this report is limited to a review of practical methods for collecting, processing, storing and installing two of the simplest types of soil bioengineering practices: (a) hardwood cuttings, which includes slips, whips, live stakes, posts, and live posts and (b) live fascines including vertical bundles. Emphasis is on improving establishment, with bias toward species, experience, and conditions most relevant to western Oregon, Western Washington and northwestern California, USA. Guidelines regarding site assessment, planning, design, permitting, and monitoring required for riparian and shoreline stabilization projects, even simpler ones, are described elsewhere. An updated list of references and websites on soil bioengineering and related information is provided at the end. However, information must be adapted by practitioners to local and site specific conditions, climate, soils, species, regulations, Agency policies, and other factors.

A. Hardwood Cuttings: Slips, Whips, Live Stakes, Poles, and Posts

1. **Definitions:**
   - Hardwood cuttings: A generic term in plant propagation referring to segments of matured, dormant, woody stems or shoots with intact lateral buds. Hardwood cuttings are taken in the fall or winter between the time of leaf abscission (leaf fall) and spring bud break. They have the capability of forming adventitious roots below ground and growing into a normal woody plant from existing aerial buds. *Adventitious roots* are roots that arise from any plant part other than the typical location or primary root(s). Hardwood cuttings are usually produced from previous years shoots, but species that can also root from older wood are the most desirable for soil bioengineering. The following are types of hardwood cuttings differing primarily in size or age:
   - Slips: Normally synonymous with "cuttings", the term herein refers to shorter and younger hardwood cuttings that are directly pushed or inserted into the ground, manually or by machine. Slips are typically made from 1 to 2 year old stems and are 16 to 24 inches long with a width (caliper) of ¼ to ¾ inch. They are usually too weak or narrow to be treated as stakes. Their use is often limited to more benign sites such as the inner bank of small, low velocity stream curves were the hazard for wash out is low, plant competition reduced, and soil moisture is at or near the surface year round.
   - Whips: Hardwood cuttings that are slender like slips but flexible and much longer (2 to 5 ft). The material is usually one year old with a diameter of ¼ to ¾ inch. If the whips root readily, they may be suitable for use in branch mats and live silt fences. Or, they can be bundled into live fascines.
   - Live stakes: Hardwood cuttings made from thicker, sturdy tree limbs or older shoots that can withstand being tapped or pounded into the soil without cracking or breaking. The wood may range from 2 to 5 years old. Lengths are typically 2 ½ to 3 ft. and diameters are ½ to 1 ½ inches. Live stakes are used alone in streambank or shoreline revegetation projects or in combination with other practices to secure erosion blankets, mats, fascines or brush mattresses. A similar practice known as joint planting involves inserting live stakes 3 to 3 ½ ft. in length into previously placed rock rip rap.
   - Poles: Long, straight sections of dormant wood usually made from 2 to 4 year old boles, branches, or shoots with side branches removed. Diameter is between that of dormant live stakes and posts, typically 1 to 2 ½ inches. Lengths may be 5 to10 ft. Live poles are sometimes inserted into existing, taller vegetation such as reed canarygrass, where shorter cuttings would be shaded out, out competed, or planted too shallow to reach summer water tables or draw on sustained soil moisture.
   - Live posts: Thick sections of dormant tree trunks or straight branches that are placed, pushed, or pounded into pre-made holes following a specific pattern along the lower streambank or shoreline. Lengths vary from 4 to10 ft. (occasionally longer) with diameters of 2 ½ to 5 inches. Within the Pacific Northwest, they are primarily limited to native willow species and black cottonwood (refer to table 1). Live posts are also used along lake and

reservoir shorelines with wave action, as well as other sites with deep to highly fluctuating flood levels and water tables.

2. **Species and genetics:**
   - Trees and shrubs that root easily from dormant (hardwood) stems are required, therefore suitability is limited (Refer to table 1, Species list for western Oregon, western Washington, and northwestern California).
   - For live stakes, posts, and poles, species must be able to root from wood that is three or more years old.
   - For donor plants, avoid diseased specimens and do not over harvest a natural stand or individual tree. A better option is to obtain healthy stock from salvage sites, nursery cutting blocks (stooling beds), or other managed areas (Crowder and Darris 1999).
   - Use "local" stock if possible and take material from many plants for genetic diversity, especially for large projects. Local stock may be defined as material originating from the same stream, an adjacent watershed, or within the same ecoregion and within the same elevation band (low, medium, or high). On small scale projects, selected class and cultivar releases may also be appropriate because they may be well adapted, more competitive, demonstrate better form, contract fewer pests, or have proven growth and survival performance. However, their genetic base may be narrow. In such cases, it may be useful to use multiple varietal releases adapted to your region or a combination of local material and selected varieties.
3. **Timing:**
   - The planting window is October 15 to March 15 in western Oregon, western Washington, and northwestern California. Winters are mild and soils rarely freeze at lower elevations allowing for insertion of dormant cuttings. Avoid mid to late spring planting, even along immediate shorelines.
   - Within this window, fall (October 15 through November 30) is the best time to harvest, process, and plant. Ideally, install cuttings immediately after leaf drop and when rooting zone soil moisture is replenished by fall rains.
   - The advantages of fall planting are that it conveniently follows the summer construction season, stream levels are low so banks are still accessible, and cuttings will root in the soil during the fall and winter dormant season. Material will be partially rooted before ever leafing out in spring, thereby maximizing establishment potential. The disadvantage is that fall plantings may be damaged or destroyed by strong currents during winter flood events.
4. **Tools and Supplies:**
   - Hand pruners, lopping shears, pruning saws, hand axes, twine, tarps or sturdy plastic bags, shovels, manual augers and post hole diggers, various diameter steel bars (ideally with welded handle and footstep) steel "caps" for stakes and posts, dead blow hammers or rubber mallets, first aid kit, pocket knife, water buckets, properly diluted disinfectants for tools.
   - **Options:** chain saw and power auger or hole digger with safety gear, hedge shears, hoedads, planting bars, white latex paint diluted 50% with water, sharpshooter shovels, backhoe, and "stinger", "waterjet stinger" (hydrodrill), hammer drill, electric generator, wood fiber mulch, slow release fertilizer.

5. **Preparation of dormant cuttings:**
    - Use clean, disinfected cutting or pruning tools for harvesting and processing. Disinfect at the least after each species, variety, cultivar, or harvesting-processing date. Horticultural disinfectants used for tools include hydrogen dioxide products, quaternary ammonium chloride products, and alcohol (Smith 2006). Ten percent chlorine bleach is still recommended by some, but it can damage tools unless they are rinsed with clean water after treatment.
    - Cut the top (proximal) ends square or flat and the bottom (basal, distal) ends at a single, broad angle. Larger material can be fashioned to a point at the base with a hand axe.
    - Don't strip bark when removing side branches. This reduces survival and may attract insect or disease pests.
    - For shorter or smaller hardwood cuttings such as slips and whips, remove apical (end) buds and at least the top 4 to 8 inches of growth from the end of the branch, even if the stem diameter is adequate for a cutting. In certain cases such as long whips the ends can be left intact.
    - When fall planting, foliage that is still green and intact or tightly attached, should be stripped to minimize stress from transpiration. Foliage that has begun to abscise or turn yellow can be left alone.
6. **Pre-plant treatment and storage:**
    - Treatment with rooting compounds (plant growth regulators or hormones) prior to planting is rarely, if ever, beneficial with species that root easily from hardwood cuttings. Evidence is lacking for the benefit of rooting hormones on cuttings directly inserted in the wild (with the possible exception of snowberry and red elderberry). Willows are the least likely species to benefit.
    - Wrap materials in plastic or tarps and store in a cool, shaded area for as short a time as possible prior to planting. Don't let stock get warm or dry out at any time.
    - Keeping the basal ends submerged in the stream and shaded until planting is another good option. Don't hold material this way for more than 1 week.
    - The fresher the material the better, but hardwood cuttings can be stored under humid refrigeration (34 to 38ºF) for four to eight weeks without substantial loss in survival.
    - It is usually unnecessary to treat cuttings with fungicide during cold storage.
    - For cuttings that have been stored weeks and not pre-soaked, re-hydrating in water for several hours prior to planting is suggested by some.
    - **Optional treatments:**
        - Most species of willows as well as black cottonwood may benefit from pre-soaking in water for 2 to 6 days before planting. Soaking stimulates early development of root "initials", particularly in willows. Without specific experience for different species, do not soak for longer periods as callus tissue (undifferentiated nodules of tissue that forms on the sides or base of a cutting) or true roots may start forming too soon. They may sever and be "wasted" during planting unless the cuttings are planted more carefully or in slits, similar to small bareroot nursery stock. Tests have shown that room temperatures (65 to 72º F)

to be nearly ideal, as cooler temperatures take considerably longer and warmer water can promote disease, mortality, or rapid decay of the cuttings. Besides willows and cottonwood, snowberry and black twinberry will also respond to pre-soaking, but more slowly. They can be soaked for up to a month at room temperatures. Pre-soaking in general may work best for late winter or early spring plantings or when material must be stored on site for a few days before planting.

- Cold storage of cuttings with basal ends in moist wood shavings or moist peat can also stimulate root callusing or actual root formation in some species. As with pre-soaking, too long can be a disadvantage, so do not store basal ends in moist media for more than 4 weeks at cool temperatures (34º to 40ºF).
- Painting top ends of cuttings with non-toxic, 50% diluted, white latex paint is unlikely to reduce transpiration, inhibit disease infection, or increase success, but it helps identity the correct end to plant upright. Melted paraffin wax becomes brittle when hard and a poor choice for cuttings or stakes that must be tapped into the ground.

7. Planting methods:

- Planting into bare disturbed ground, weed barriers, wood fiber mulch, chemically killed vegetation, or scalped soil is best. Vegetative competition must be minimized beforehand and kept in check afterwards.
- Always observe wood polarity. Insert cuttings and stakes upright (buds pointing up) and perpendicular to the ground, unless the slope is minimal or flatter than 4 (horizontal) to1 (vertical). Poles and posts are usually planted true vertical.
- Two thirds to four fifths of the total length of the cutting should end up below ground for whips, live stakes, and slips. For cuttings, only 2 to 3 nodes or lateral buds need to be left exposed above the soil line, although some practitioners suggest at last 6 to 12 inches or more remain above ground.
- In drier environments, it is important that the cuttings or stakes be inserted deep enough to reach the lowest water table of the year or a layer of permanently moist soil. Survival will also improve if the top of the cutting, stake, post or whip is tall enough to avoid shade from the tallest surrounding vegetation.
- Cuttings, slips, and whips: manually push material into soft ground. If the ground is too hard it will be necessary to use solid steel or metal rods or rebar to create pilot holes. Rods fabricated with a handle bar are easier to pull out of the ground. Footplates or footsteps may be welded on as well. Match metal rod widths to cutting widths to minimize vertical air pockets. A hoedad or other slit type planting blade meant for bareroot stock can also be used for shorter cuttings, especially if they were soaked and nodule or root development has begun. The slit should be completely closed after insertion. To close any air gaps around cuttings, a tile spade or sharpshooter can also be inserted in the ground a few inches from the cutting and pulled laterally to compress the soil.
- Another option is the use of a ***waterjet stinger*** (Hoag et al. 2001). This is essentially the use of a high pressure water pump (80 psi or higher, 120

gallon/minute output) with a hose, handle, and to specially designed steel tip to hydrodrill planting holes for rapid planting of a large number of cuttings. It has the added advantage of creating moist to saturated conditions for longer periods around each cutting and a muddy slurry or column of liquefied soil which eliminates air pockets around the cuttings. Yet another method is the use of commercial grade electric ***hammer drill*** for creating pilot holes but special tips two ft. long or longer must be custom made.

- Live stakes: Use a 2 to 5 pound dead blow hammer (best) or rubber mallet to tap stakes. If the ground is too hard, place sturdy metal "caps" over the top to minimize damage and flaring. Dead blow hammers cause less damage than other types of hammers. Flared ("mushroomed") ends should be pruned or cut off after planting. Seventy to 80 percent of the stake should end up below ground. Two to four nodes or lateral buds should remain above the soil.
- Poles and posts: Manual or motorized augers or post hole diggers may be used to create holes. The ***stinger***, a tapered, solid steel bar mounted on a backhoe, is an effective way to push or punch large holes in the ground, especially, through rock rip-rap (Hoag and Ogle 1994). As with cuttings, steel "caps" may be needed over the top ends for protection during installation. If possible, fill gaps in the hole with loose soil, soil and water, or a soil slurry and tamp firmly to close openings.
- **Optional treatments:**
    - Mulch- rooting of non-willows species will benefit significantly from mulch (fine bark chips, wood fibers, duff, straw, leaves) around the base of each cutting. Organic mulch should be 2 to 3 inches thick.
    - Fertilizers- soluble fertilizers are never recommended. Surface fertilization will runoff into streams or encourage excessive weed growth. Any benefit from placing a small amount (4 to 8 grams) of slow release fertilizer directly in the planting hole is not established, but may be worth trying on nutrient poor soils, especially for species other than willows and black cottonwood. Other soil amendments are generally not used.
    - Native topsoil- small amounts of topsoil can be sprinkled into larger holes to introduce beneficial soil symbionts such as mycorrhizal fungi into the root zone.

8. **Weed and animal damage control and other follow up work:** Deer repellents, livestock exclusion, weed barriers, rodent and deer guards, mowing, herbicide treatments (according to label instructions and all applicable laws), replanting, re-scalping, and other follow up management or protective measures will probably be needed the first few years, as with any new tree or shrub planting. Monitoring should be conducted annually for at least five years after planting.

B. Live Fascines and Vertical Bundles

1. **Definitions:**
   - Live fascines are long bundles constructed from dormant cut branches that are cinched snuggly together along their length. These sausage-like structures are “planted” or installed into shallow trenches running parallel to or at a slight angle to the slope or stream. The term ”wattle” is sometimes used interchangeably with fascine, but wattle fences are an entirely different practice involving the weaving of live branches between stakes. Fascines often range in length from 4 to 8 ft., but can be made much longer. Typical diameter is 6 to 12 inches. They provide erosion control along the surface and break up slope lengths. Root development eventually provides deeper reinforcement within the stream or road bank, although dead fascines still provide some benefit. Installed with both dead wooden stakes and live stakes, they may be used alone or combination with fabrics and other soil bioengineering practices such as brush mattresses. Fascines are a relatively shallow surface treatment and may not perform well on summer dry sites without irrigation. Refer to guidebooks and manuals for appropriate applications and design (See reference list).
   - Vertical bundles are a variation on the use of live fascines and generally have similar dimensions, if not wider. They are installed perpendicular to the slope or stream rather than parallel to it. Not truly “vertical’, these long bundles are installed in shallow trenches along the face of the slope, increasing channel roughness and resistance during high stream flows. The branches eventually root and reinforce the streambank. Refer to guidebooks and manuals (reference list) for appropriate applications and design.
2. **Species and genetics:**
   - Trees and shrubs that root easily from dormant (hardwood) stems are required, therefore suitability is limited (Refer to page 9, part C. Species list for western Oregon, and western Washington, and northwestern California).
   - It is helpful but not required for species to root from wood that is over two years old.
   - Avoid diseased specimens and do not over harvest a natural stand or individual tree. A better option is to obtain healthy stock from salvage sites, nursery cutting blocks (stooling beds), or other managed areas if possible (Crowder and Darris 1999).
   - Take material from many plants in order to maximize genetic diversity, especially for large projects. On small scale projects, selected class and cultivar releases may also be appropriate because they can be well adapted, more competitive, demonstrate better form, or have proven performance. However, their genetic base may be narrow. It is useful to mix in local stock and use multiple species and multiple varietal or pre-varietal releases.
3. **Timing:**
   - Where winters are milder, fall (October 15 to November 30) is the best time to harvest, process, and install fascines. Ideally, cut and install immediately after leaf drop and when rooting zone soil moisture is replenished by fall rains.

Due to shallow installation depths, winter and early spring plantings are not recommended.

- The advantages of fall planting are that installation conveniently follows the summer construction season, stream levels are low so banks are still accessible, and branches will root in the soil during the fall and winter dormant season. Material will be partially rooted before ever leafing out in spring, thereby maximizing establishment potential.

4. Tools and Supplies:

- Hand pruners, lopping shears, pruning saws, hand axes, biodegradable, 2 or 3 ply sisal baling twine (or cord, narrow gauge wire), tarps, spades and shovels, dead stout stakes 2 to 3 ft. long, wedge shaped, made from diagonally cut untreated wooden 2x4s], dead blow hammers (or rubber mallets), sledge hammers, water buckets, first aid kit, pocket knife, disinfectant for tools.
- **Options:** chain saw with safety gear, saw horses, wooden lathe, jute netting, erosion fabrics, wood fiber or other mulch, hedge shears, scrapper/chopper, hoe/rake, pick mattock, imported loose topsoil, water pump and hose, native grass seed. Refer also to the tool and supply list for cuttings and stakes.

4. Construction:

- As with cuttings, use clean, disinfected cutting and pruning tools for harvest and processing. Disinfect between each species, variety, or harvesting-processing date. Suitable products contain hydrogen dioxide, quaternary ammonium chloride salts, or alcohol (Smith 2006).
- Generally, pliable side branches can be left intact and the material will still compress into a tight bundle when firmly tied. However, if branch angles are broad and stiff, side limbs should be removed. The more gaps left within the bundle, the more work it is to insert soil and the greater likelihood air pockets will remain. Long whips from cutting blocks make excellent tight bundles for many willows and black cottonwood.
- Don't strip bark when removing side branches. It unknown whether longitudinal cuts or other stem "injury" will stimulate more stem rooting in certain species planted directly in the wild. It may do more harm than good.
- Saw horses with lathe attached to the legs to form "V" shaped notches make effective "platforms" for holding branches and tying the bundles during assembly.
- Use shoots and limbs with a diameter of ½ to 1 ½ inches.
- When fall planting, foliage that is still green and intact or tightly attached, should be stripped to minimize stress from transpiration. Foliage that has begun to abscise or yellow can be left alone.
- A substantial amount of woody plant materials is required. Forty branches or more may be required to make a single live fascine, depending on the thickness of each stem or limb and the amount of intact side branches.
- Fascines- stack the limbs in a staggered fashion running in both directions. Form bundles of uniform width (6 to 12 inch diameter) that are 4 to 20 ft long.

- Vertical bundles-stack the limbs in one direction with their basal ends lined up evenly at one end of the bundle. Finished bundles should be 6 to18 inches thick and 6 ft long or more: preferably up to or just longer than slope length.
- Tie the bundles with sisal baling twine or cord. Circle the bundle, form a slip (running) knot at one end, pull the other end through the loop, synch tightly, then tie the loose end with two half hitch knots. Tie at 1 ½ to 2 ft. intervals.
- As an option, after the bundle is formed and tied, hedge shears can be used to cut off the finer ends and apical buds. For longer bundles, branch tips can be removed before assembly.
- If performance of a species on a site is uncertain, one option is to mix two to three willow species into one bundle. The same can be done with slower rooting, slower growing shrubs. Mixing fast rooting willows with slower rooting shrubs is not recommended.

5. Pre-plant treatment and storage:

- It is impractical and unnecessary to treat fascines or bundles with rooting compounds (plant growth regulators or hormones). Quantities of such compounds are environmentally unsafe.
- For bundles not made on site that require transporting, wet down limbs and wrap or cover bundles in plastic or tarps. Once on site, store in a cool, shaded area for as short a time as possible prior to planting. Do not let fascines get warm in the sun or dry out at any time.
- Keeping the basal ends or entire bundle submerged in the stream and shaded until planting the same day is another good option.
- The fresher the material the better, but bundles can be stored under refrigeration (34 to 38ºF) for 4 to 8 weeks without substantial loss in survival. Large walk-in coolers or refrigerated rooms are ideal. Bundles can be loosely wrapped or left uncovered if humidity is high. Storage of basal ends in moist wood shavings or moist peat will stimulate root callusing in some willow species after 4 weeks. Stored material may benefit from re-hydration (pre-soaking) just prior to installation.
- **Option:** Most species of willows and black cottonwood can benefit from optional pre-soaking in room temperature (65 to 72ºF) water for 2 to 6 days to stimulate early development of root “initials”. In cooler stream water, soaking can be done for up to 10 days. If possible, immerse the entire fascine in water. For vertical bundles, only the section to be buried in soil should be immersed. Monitor and don’t soak for too long. After time, calluses (nodules of tissue that forms on the sides or base of a cutting) or true roots may start forming. If so, the roots may be severed and “wasted” during installation and establishment diminished. The response of species other than willows and cottonwood to prolonged soaking is not well defined. However, black twinberry and snowberry have rooted in water and saturated soils. Basal ends of these species, along with redosier dogwood, can be safely soaked in room temperature water for up to 30 days. However, quick installation after harvest is usually more desirable than soaking for these species.

6. **Installation methods:**
   - A site specific plan, drawings, permit (if required), proper equipment, and trained work crew should be in place. Refer to manuals and guidebooks for recommended applications, locations, design, orientation, placement, and spacing based on objectives, slope length, slope grade (steepness), fluvial geomorphology (stream dynamics), hydrology, hydraulics, and soil cohesiveness.
   - Manually excavate a trench that is slightly shallower than the width of the bundle but about the same diameter.
   - Fascines- excavate trenches along the contour of the slope or a slight angle to reduce soil rilling and improve drainage. For multiple rows, start at the lowest designated contour and work upslope.
   - Vertical bundles- excavate trenches perpendicular to the slope at the designated spacing. The bottom end can be installed low enough on the bank to draw summer moisture from the stream, shoreline, or water table. Sometimes this practice is also designed so the top 1 to 2 ft. of the bundle protrudes in the air above the crest of the slope.
   - Lay the fascine or bundle in the trench and fill any spaces along the sides with soil. Tamp soil firmly in place. Next, cover the top of the bundle with loose soil and tamp it with a shovel to filter soil downward to fill any interior gaps between limbs. Overtime the soil settles, often requiring a return visit and additional soil placement in and around the bundle.
   - If the planting soil is high in clay, it may be necessary to borrow or import loose topsoil that is hopefully low in weed seed. Loose soil is easier to work into the gaps and air spaces. Native topsoil also contains beneficial root symbionts such as mycorrhizal fungi. Water and soil slurry can also be used to help fill interior gaps with soil.
   - Branches along the top edge of the bundle must remain exposed to light.
   - Drive dead stout stakes directly down the center of the bundles at 2 to 3 ft. intervals. The top 2 to 3 inches of the stake should remain above ground. Use additional stakes to join bundles that overlap end to end.
   - For fascines, live stakes are often added on the down slope side of the bundle, midway between each dead stake.
   - **Optional treatments:**
     - Erosion fabric- Jute netting, a thin layer of coir, or other fabric is often laid down on the soil surface between and extending underneath the bundles or fascines prior to installation. This application usually applies to slopes 2 (horizontal) to 1 (vertical) or steeper. Some suggest that the fabric cover the bundle rather than extending beneath it.
     - Mulch- on 3 (H) to 1 (V) or flatter slopes, straw or wood fiber mulch is often placed between rows of bundles. In addition, rooting of non-willows species will benefit from a thin layer of mulch (fine bark, duff, straw, leaves) along side and over the bundle. However, the upper edge of branches in the bundle should still remain slightly exposed.
     - Native grass seed- in some cases, a fast establishing native grass such as blue wildrye (*Elymus glaucus*) or slender wildrye (*Elymus*

trachycaulus) is sown at a moderate rate (5 to 10 lbs/ac) between fascines and before mulch, fabric, or jute netting is applied. To reduce competition, avoid placing seed within 1 ½ ft. of the bundles. Slender hairgrass (*Deschampsia elongata*) at 2 to 3 lbs/ac is another good choice. It is shorter in stature and longevity than the first two grasses and less likely to be as competitive for light. Both blue wildrye and slender hairgrass will tolerate intermediate shade and intermittent winter inundation as long as some foliage remains exposed.

- o Irrigation-On droughty sites, shallow planted bundles and fascines will benefit from periodic irrigation during the first year dry season, if available. Gasoline powered water pumps and hoses work well. Observe water rights.
- o Soluble fertilizers are never recommended. Surface fertilization will runoff into streams or encourage excessive weed growth. Do not fertilize willow and cottonwood bundles, even with slow release fertilizer. For slower rooting trees and shrubs, any benefit from placing a small amount of slow release fertilizer directly into the trench on infertile sites is not well established.

7. **Weed and animal damage control and other follow up work:** Deer repellents, livestock exclusion, mowing, irrigation, herbicide treatments (according to label instructions and all applicable laws), replanting, stake and soil replacement, and other follow up management or repairs will probably be needed the first few years. Monitor annually for five years or more. One of biggest reasons for failure is the lack of maintenance the first few years following installation.

C. Tree and Shrub Species for Soil Bioengineering Practices in Western Oregon, Western Washington, and Northwestern California

Species	*Cuttings, slips, whips*	*Live stakes, poles, posts*	*Bundles, Fascines**	*Remarks*
Sitka willow *Salix sitchensis*	Excellent	Excellent	Excellent	Very common. Rapid early growth. Produces long straight shoots.
Pacific willow *Salix lucida* spp. *lasiandra*	Very good	Very good	Very good	Common. Very flood tolerant. Susceptible to certain diseases. Can be brittle when pounded.
Coast or Hooker's willow *Salix hookeriana*	Excellent	Very good	Excellent	Rapid growth. Competes well with weeds. Coastal populations may have more tolerance to salinity (soil, air).
Erect or strap leaf willow *Salix ligulifolia*	Excellent	Excellent	Excellent	Competes well with herbaceous vegetation. Can be short lived.
Arroyo willow *Salix lasiolepis*	Excellent	Excellent	Excellent	Rapid growth and large size at maturity. Competitive.
Northwest willow *Salix sessilifolia*	Very good	Very good	Very good	Suckers. Does well on coarser soils and sandbars.
Coyote willow *Salix exigua*	Good	Good	Very good	Suckers freely to form thickets.
Columbia river willow *Salix fluviatilis*	Very good	Very good	Very good	Suckers slowly. Does well on coarser soils and sandbars. Short-lived.
Piper willow *Salix piperi*	Excellent	Very good	Excellent	Same species as Coast willow, but found more inland. Often long lived.
Scouler's willow *Salix scouleriana*	Good	Good	Fair to very good.	Some clones or populations may not root as fast as others. Test first. Tolerates shadier, drier, more upland sites vs. other willows.
Black cottonwood *Populus balsamifera* ssp. *trichocarpa*	Good	Very good	Very good	Fast growing, tall tree. Some clones or populations root better than others.
Redosier dogwood *Cornus sericea*	Good	Fair	Good	Low lying branches will root in contact with soil. Tolerates sun, part shade, and wet soils but not permanent flooding.
Douglas spiraea *Spiraea douglasii*	Good	Poor (too thin)	Good	Freely suckers. Can be weedy from seed. Tolerates long term soil saturation and flooding. Found in full sun.
Common snowberry *Symphoricarpos albus*	Good	Poor (too thin)	Fair to good	Intermediate tolerance to shade and wetter soils. Freely suckers. Needs good soil to root. Best if fall planted.
Black twinberry *Lonicera involucrata*	Good	Fair to good (stakes only)	Fair	Best if fall planted, mulched. Intermediate tolerance to shade, wetter soils. Takes shade or sun.
Coyote brush *Baccharis pilularis*	Fair to good	Fair (stakes only)	Fair to good	Evergreen. May have some salinity tolerance. Needs good drainage. Don't strip or remove all foliage. Full sun
Pacific ninebark *Physocarpus capitatus*	Fair	Fair (stakes only)	Fair	Best if fall planted, mulched. Needs good soil quality and drainage. Tolerates partial shade to full sun.
Red elderberry *Sambucus racemosa*	Fair	??	Poor to fair	Best if fall planted, mulched. Roots well in partial shade with good soil. New shoots are too soft for stakes.
Salmonberry *Rubus spectabilis*	Fair	Poor	Good	Best if fall planted. Use in moist, shaded habitat. Freely suckers. Roots best from 1 year old cuttings. Competes with trees.
Lewis mock orange *Philadelphus lewisii*	Fair	??	Fair	Best if fall planted, mulched, and soils are courser and looser for maximum rooting. Needs drainage. Prefers partial shade.

Other practices such as brush mattresses, branch packing, and brush layering may equally apply.

D. References for Soil Bioengineering Techniques

Books

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