Live Stakes

Live stakes (figure 3–62) create a living root mat that stabilizes the soil by reinforcing it and extracting excess moisture. Most willow species develop roots rapidly and begin drying out excessively wet banks soon after the willows have been planted. Live, vegetative cuttings that can be rooted are inserted or tamped into the ground. If a live stake is prepared, handled, and placed correctly, it will root and grow.

Applications for Live Stakes

Use stakes in the wetted zone of banks or where precipitation is likely to keep the soil moist during growing seasons.

Live stakes can:

- Be used where site conditions are uncomplicated, construction time is limited, and an inexpensive method of stabilization is needed.
- Repair small earth slips and slumps that get wet frequently.

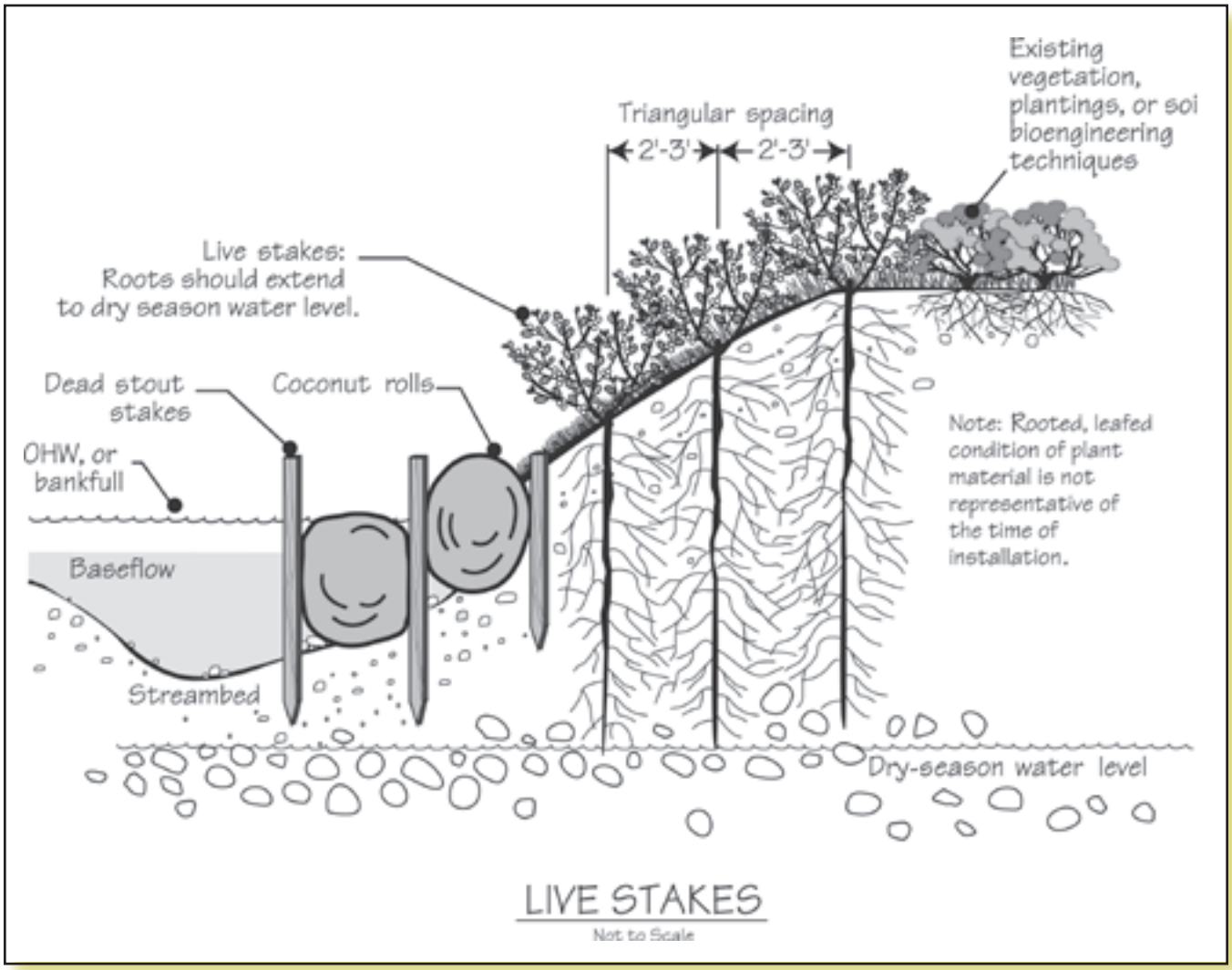

Figure 3–62—Live stakes create a living root mat (Eubanks and Meadows 2002). *OHW* stands for ordinary high water.

- Enhance the performance of geotextile fabric by serving as pegs to hold the fabric down.
- Enhance conditions for natural colonization of vegetation from the surrounding plant community.
- Produce streamside habitat.
- Be used with other bioengineering techniques, such as live fascines (long bundles of branch cuttings).

Materials for Live Stakes

The stakes generally are 1 to 2 inches (about 25 to 51 millimeters) in diameter and 2 to 3 feet (610 to 910 millimeters) long. The specific site requirements and available sources of cuttings will determine the sizes.

- Remove the side branches, leaving the bark intact.
- Cut the basal ends at an angle or a point so they can be inserted into the soil easily. The top should be cut square.
- Install materials the same day that they are prepared.
- Place stakes in locations that are appropriate for the particular species. For example, along many western streams, tree-type willow species are placed on the inside curves of point bars where they are likely to be inundated, while shrub-type willow species are planted on the outside curves of point bars where they are not likely to be inundated as long.

Installing Live Stakes

- Insert stakes with the buds up.
- Install live stakes 2 to 3 feet (610 to 910 millimeters) apart, using triangular spacing. The density of the installation will range from two to four stakes per square yard. Site variations may require slightly different spacing. The spacing pattern should allow for a fluctuating water level. The installation may be started at any point on the slope face.
- Install four-fifths of the length of the live stake into the ground and firmly pack the soil around the stake after installation.
- Remove and replace any stakes that split during installation.
- In firm soil, use an iron bar to make a pilot hole (Hoag and others 2001).
- Dig in live stakes unless the soil is fine and loose. Tamped-in stakes are likely to split or have their bark damaged by hammering or by the hard, rocky soils they're driven into.
- Install the live stake at an angle slightly downstream.
- Tamp the stake into the ground with a dead-blow hammer (head is filled with shot or sand).
- Install geotextile fabric (optional) on slopes subject to erosion. Install the stakes through the fabric.
- Plant stakes on banks that will be moist during the growing season or install longer stakes that will reach the water level during the dry season.

Live stakes do not increase soil stability until they begin rooting. Over time, they provide excellent soil reinforcement. To reduce the possibility that a bank might fail before the roots establish themselves, cover installations with a layer of long straw mulch topped with jute mesh or, in more critical areas, a geotextile fabric.

Live Posts

Live posts (figure 3–63) form a permeable revetment (retaining wall). They reduce stream velocities, allowing sediment to be deposited in the treated area. Their roots help to stabilize the bank. Dormant posts are made of large cuttings installed in streambanks in square or triangular patterns (see figure 3–60). Posts at spacings of about 4 feet (1.2 meters) also can provide some benefits by deflecting higher streamflows and trapping sediment, even if the posts do not root successfully.

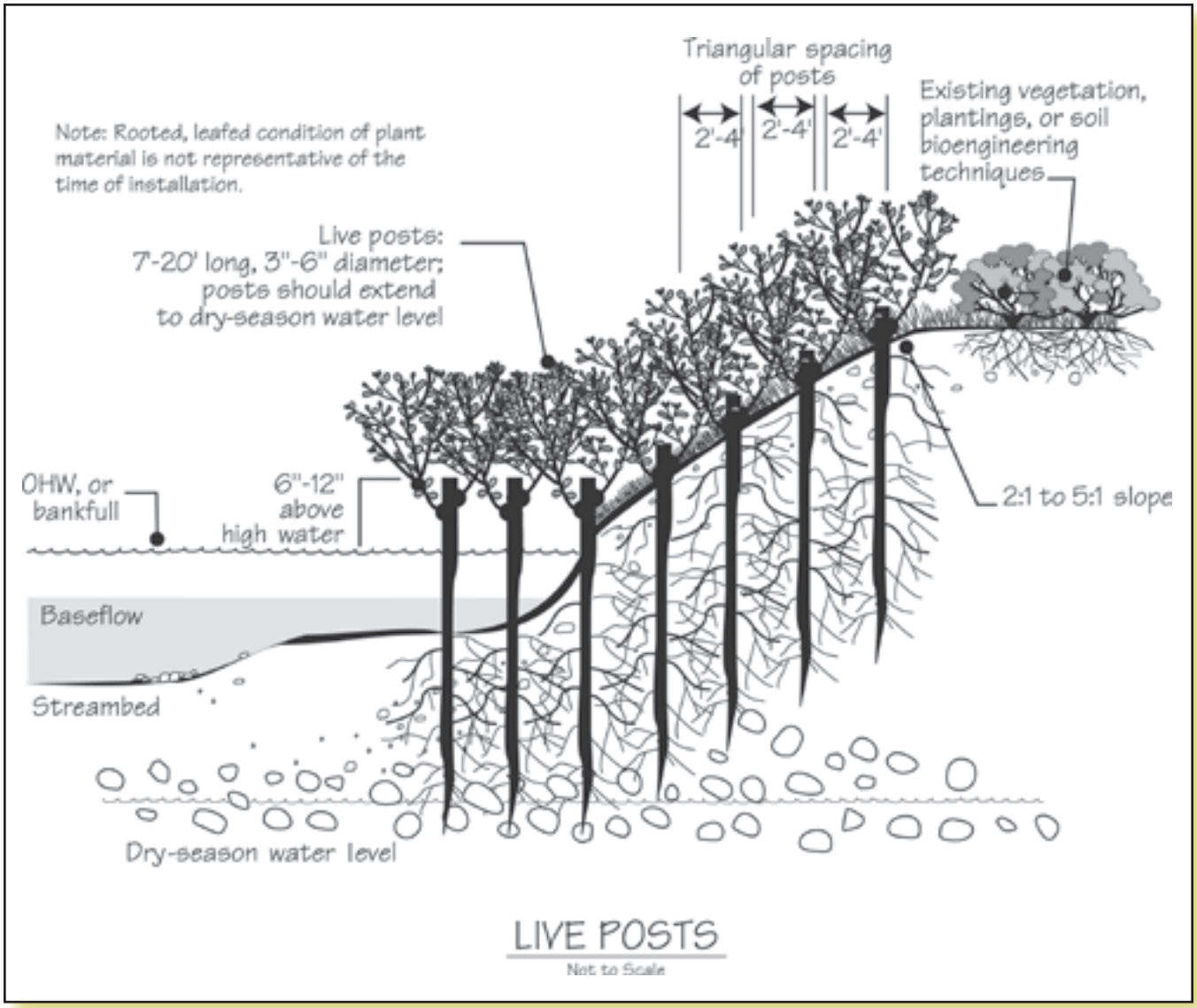

Figure 3–63—Live posts reduce stream velocities, allowing sediment to be deposited (Eubanks and Meadows 2002). *OHW* stands for ordinary high water.

Applications for Live Posts

Live posts:

- Are well-suited to smaller streams that do not have a lot of gravel. If high flows and ice are a problem, posts can be cut low to the ground.
- Can be used with other soil bioengineering techniques.
- Can be installed by a variety of methods, including using a waterjet stinger (Hoag and others 2001) to form planting holes or by driving the posts directly with machine-mounted rams. Place a metal cap on top of the post when it is being pounded into the ground.

Effectiveness of Live Posts

Live posts:

- Quickly reestablish riparian vegetation.
- Enhance conditions for colonization by native species.
- Repair themselves. For example, posts damaged by beavers often develop multiple stems.

Materials for Live Posts

Live posts can be from 7 to 20 feet (2 to 6 meters) long and from 3 to 6 inches (about 76 to 152 millimeters) in diameter. Avoid overharvesting posts from one plant or one area. Select a plant species that will root readily and that is appropriate to the site conditions. Willow and poplar posts have been successful.

Installing Live Posts

- Taper the bottom end of the post so it will be easier to insert into the ground.
- Trim off all the side branches and the apical (top) bud.
- Dip the top end of the post into a mixture of equal parts of water and white latex paint. The paint helps mark the end that goes up and helps retain moisture in the post after it has been installed.

Brush Layering

Brush layering is the technique of laying cuttings on horizontal benches that follow the contour of an existing or filled bank (slope). Brush layers provide shallow stability for slopes.

The cuttings are oriented more or less perpendicular to the slope face as shown in figures 3–64, 3–65, and 3–66. The portion of the brush that protrudes from the slope face helps slow runoff and reduce surface erosion. When brush layering is used on a fill slope, it is similar to the use of vegetated geogrids without the geotextile fabric.

Brush layering does not work on the outside of bends and may direct current between the brush layers, washing out the soil there.

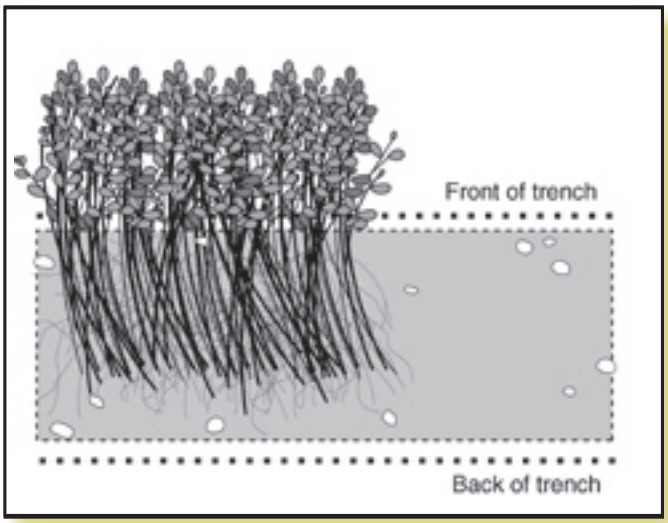

Figure 3–64—With brush layering, live branches are inserted into trenches roughly perpendicular to the slope. Normally, dormant branches are used. They are shown here with leaves so it is clear how the branches are oriented (Eubanks and Meadows 2002).

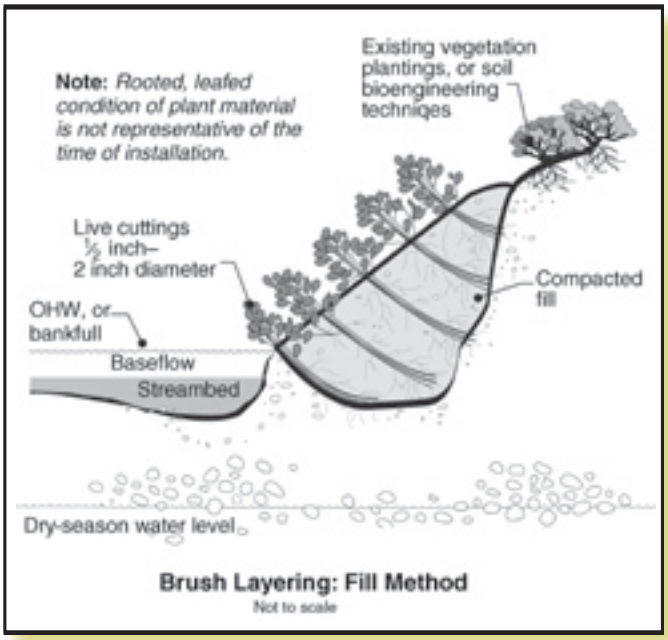

Figure 3–65—This cutaway view shows branches laid into trenches that contour the slope (Eubanks and Meadows 2002). *OHW* stands for ordinary high water.

Figure 3–66—Brush layering can be used to repair an alcove where the bank has washed away (Eubanks and Meadows 2002).

Applications for Brush Layering and Their Effectiveness

Brush layering:

- Breaks up the slope into a series of shorter slopes separated by rows of brush layers.
- Dries excessively wet sites.
- Works where the toe of the slope 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 prevent the soil from sliding or experiencing shear displacement.
- Traps debris on the slope.
- Aids infiltration on dry sites.
- Adjusts the site's microclimate, aiding seed germination and natural regeneration.
- Can be used to treat a gully (figure 3–67).

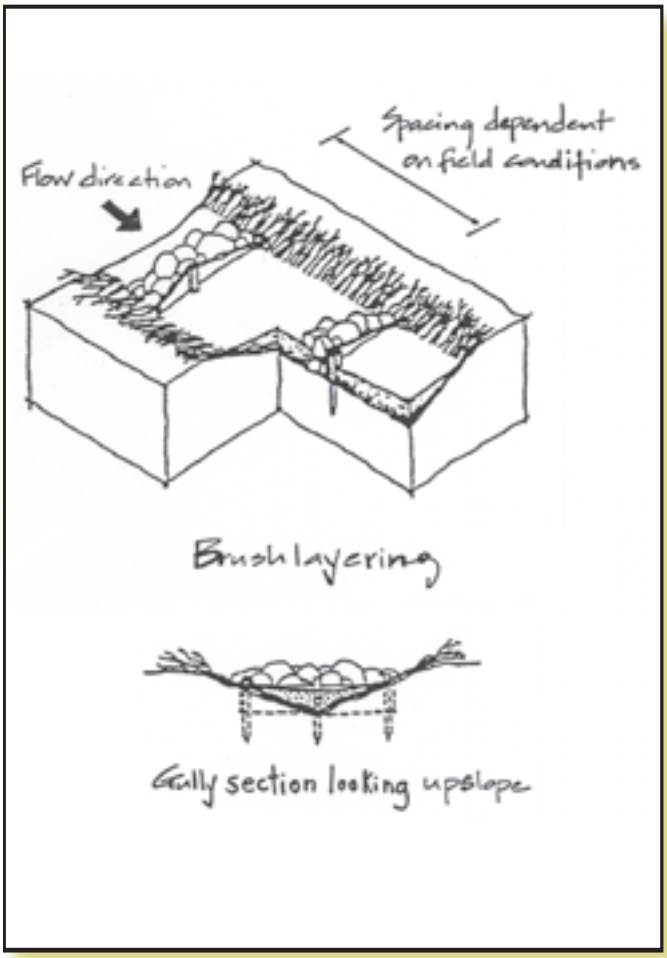

Figure 3–67—A gully can be treated with brush layering. Drawings courtesy of Lisa Lewis (Lewis and Ogg 1996).

Installing Brush Layering

Brush layering can be installed on an existing or filled slope. On an existing slope, a bench is cut 2 to 3 feet (610 to 910 millimeters) deep and angled slightly down into the slope. On a fillslope, brush layers are laid into the bank as it is filled.

Live Cribwalls

A live cribwall is used to rebuild a bank that is nearly vertical (figure 3–68). The cribwall consists of a boxlike interlocking arrangement of untreated log or timber members. The structure is filled with rock at the bottom and with soil beginning at the ordinary high-water mark or water level when the stream is bankfull. Layers of live branch cuttings root inside the crib structure and extend into the slope. Once the live cuttings root and become established, vegetation gradually takes over the structural functions of the wood members. Live cribwalls should be tilted back if the system is built on an evenly sloped surface.

Applications for Live Cribwalls

Live cribwalls are:

- Appropriate at the base of a slope where a low wall may be required to stabilize the toe of the slope and to reduce its steepness.
- Appropriate above and below the water level where stable streambeds exist.
- Useful where space is limited and a more vertical structure is required.
- Useful in maintaining a natural streambank appearance.
- Useful for controlling bank erosion on fast-flowing streams.

Effectiveness of Live Cribwalls

Live cribwalls are:

- Complex and expensive.
- Effective on the outside bends of streams where currents are strong.
- Effective in locations where an eroding bank may eventually form a split channel.

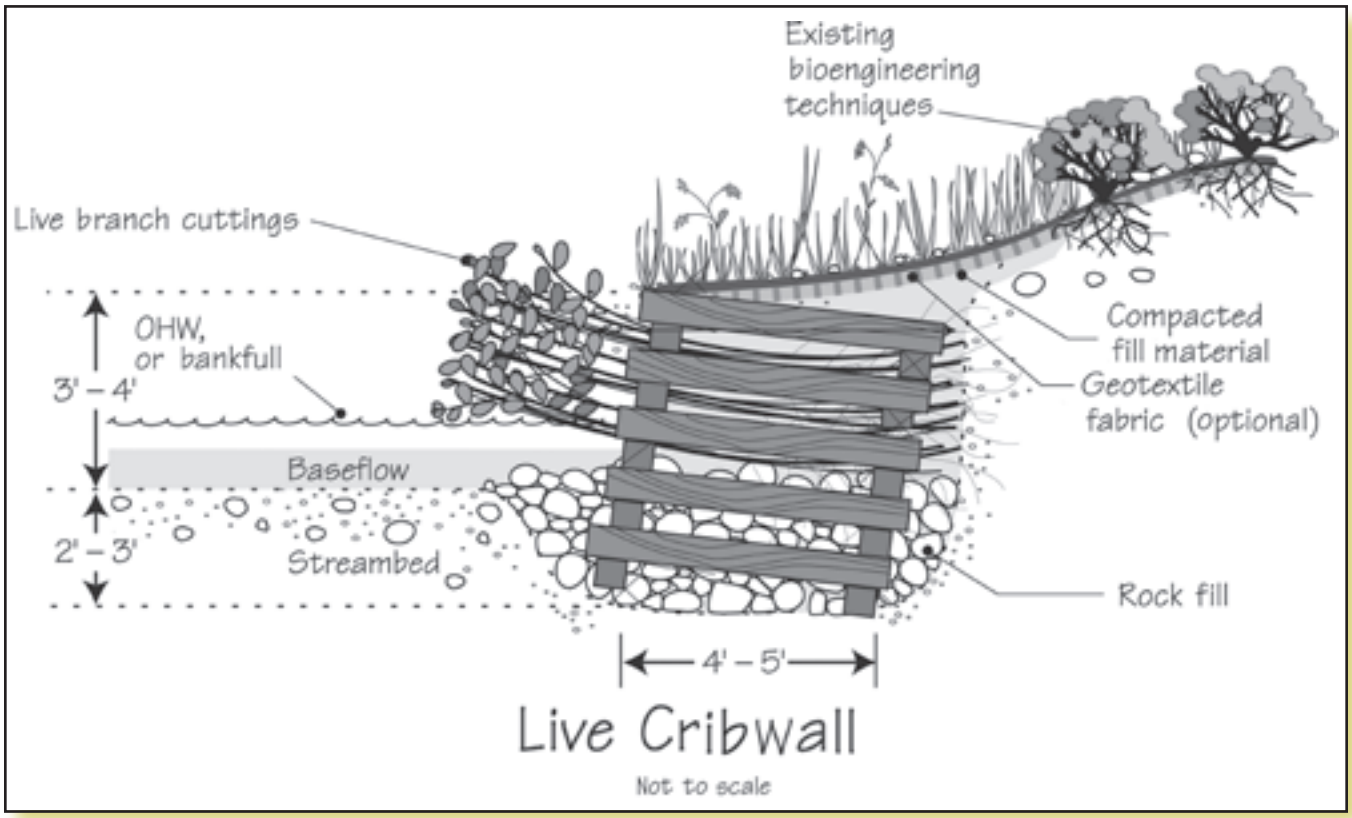

Figure 3–68—Installing live cribwalls (Eubanks and Meadows 2002). *OHW* stands for ordinary high water.

- An excellent way of providing habitat.
- A way of providing long-term stability and immediate protection from erosion.

Live Materials for Cribwalls

Live branch cuttings should be from 0.5 to 2.5 inches (13 to 64 millimeters) in diameter and long enough to reach the back of the wooden crib structure.

Inert Materials for Cribwalls

- Logs or untreated timbers should range from 4 to 6 inches (100 to 150 millimeters) in diameter. Lengths will vary with the size of the crib structure.
- Large nails or reinforcement bars are required to tie the logs or timbers together.
- Fill rock should be 6 inches (150 millimeters) in diameter.

Installing Live Cribwalls

- Excavate the base of the streambank from 2 to 3 feet (610 to 910 millimeters) below the existing streambed, creating a stable foundation from 5 to 6 feet (1.5 to 1.8 meters) wide.
- Excavate the back of the stable foundation closest to the slope from 6 to 12 inches (150 to 310 millimeters) lower than the front of the foundation to make the structure more stable.
- Place the first course of logs or timbers at the front and back of the excavated foundation, about 4 to 5 feet (1.2 to 1.5 meters) apart and parallel to the slope.
- Place the next course of logs or timbers at right angles (perpendicular to the slope) on top of the previous course, overhanging the front and back of the previous course by 3 to 6 inches (about 80 to 150 millimeters). Each course of the live cribwall is placed in the same manner and secured to the preceding course with nails or reinforcement bars.
- Place rock fill in the openings in the bottom of the crib structure until it reaches the existing elevation of the streambed. In some cases, rocks need to be placed in front of the structure for added toe support, especially in outside stream meanders. A log revetment may be an alternative to a rock toe.
- Place the first layer of cuttings on top of the rock material at the base-flow water level. Change the rock fill to soil fill at this point. Ensure that the basal ends of some of the cuttings contact undisturbed soil at the back of the cribwall.
- Place live branch cuttings at each course with their buds oriented toward the stream. Place the basal ends of the live branch cuttings so that they reach undisturbed soil at the back of the cribwall with the growing tips protruding slightly past the front of the cribwall. Cover the cuttings with soil and compact the soil. Wet each soil layer.
- Use an engineering analysis to determine the appropriate dimensions. The live cribwall structure, including the section below the streambed, should not be more than 7 feet high (about 2 meters).
- Do not make a single constructed unit any longer than 20 feet (about 6 meters).

Live Fascines or Wattles

A fascine is a long bundle of branch cuttings bound together to form a cylindrical structure. Live fascines (figures 3–69a and 69b) help control surface erosion. Roots from sprouted fascines help stabilize the bank. Fascines should be placed in a shallow contour trench on a dry slope and at an angle on a wet slope to reduce erosion and shallow sliding.

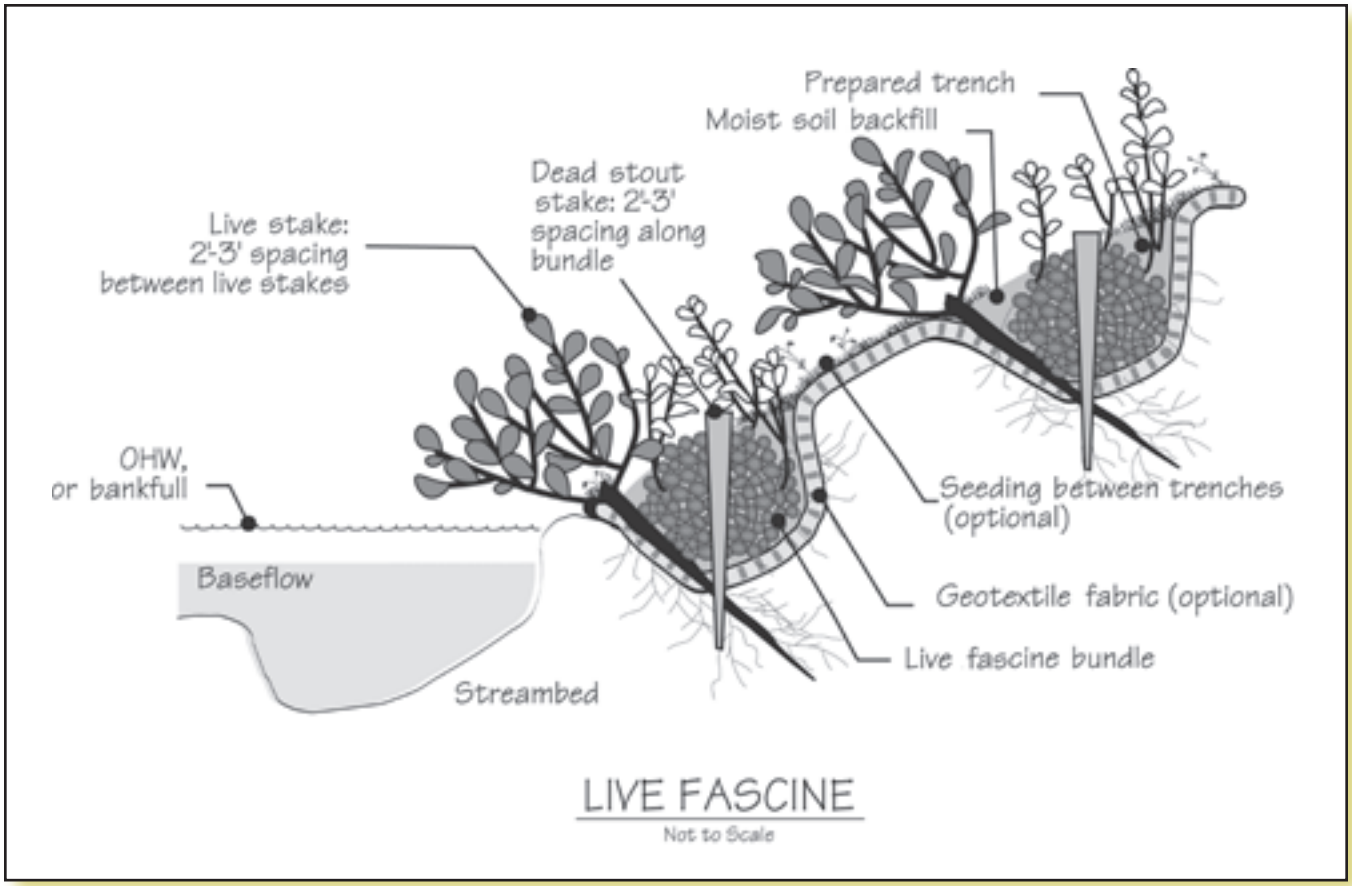

Figure 3–69a—Installing live fascines (Eubanks and Meadows 2002). *OHW* stands for ordinary high water.

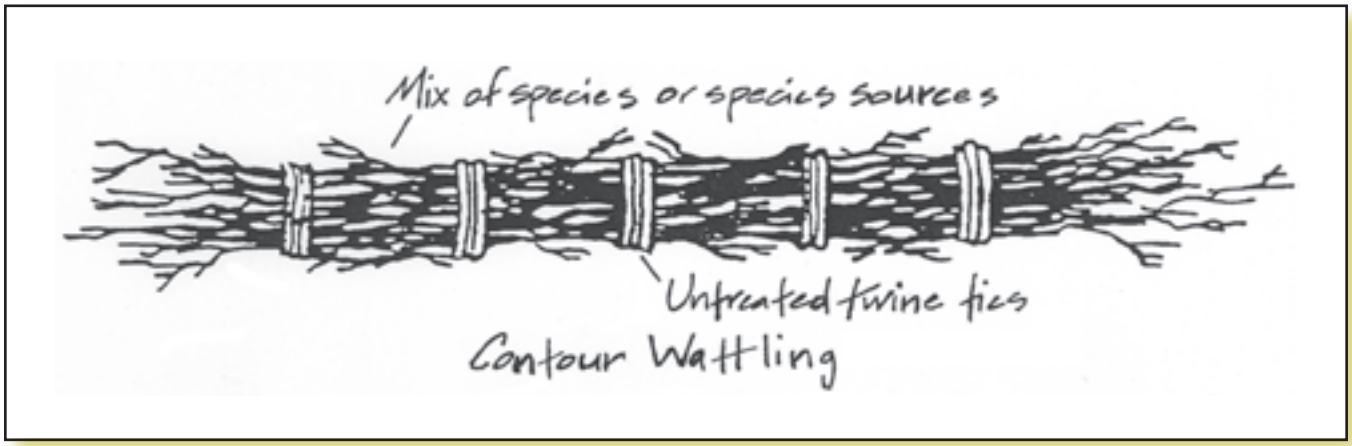

Figure 3–69b—The fascines are long bundles of branch cuttings. Drawing courtesy of Lisa Lewis (Lewis and Ogg 1996).

Applications for Live Fascines

- Install fascines above the ordinary high-water (OHW) mark or the water level when the stream is bankfull, except along small drainage areas (less than 2,000 acres, or about 809 hectares).
- Install fascines between the high- and low-water marks on the bank in arid climates.

Effectiveness of Fascines

Fascines:

- Trap and hold soil on a streambank using small dam-like structures to create a series of short slopes.
- Protect slopes from shallow slides up to 1 or 2 feet (300 to 610 millimeters) deep.
- Require soil moisture or regular precipitation during the growing season.
- Cause minimal site disturbances when properly installed.
- Offer immediate protection from surface erosion.
- Enhance conditions for colonization of native vegetation by stabilizing the surface and creating a microclimate conductive to plant growth.
- Serve to facilitate drainage when installed at an angle.

Live Materials for Live Fascines

Cuttings must be from species (such as young willows or shrub dogwoods) that root easily and have long, straight branches.

- Tie cuttings that are ½ to 1½ inches (13 to 38 millimeters) in diameter together to form live fascine bundles that are 5 to 10 feet (1.5 to 3.1 meters) long or longer, depending on site conditions and handling limitations.
- Stagger the cuttings in the bundle so that the tops are evenly distributed throughout the length of the live fascine. The completed bundles should be 6 to 8 inches (about 150 to 200 millimeters) in diameter.
- Ensure that the live stakes anchoring the fascine are at least 2½ feet (760 millimeters) long.
- Table 3–10 has spacing recommendations for live fascines.

Table 3–10—Spacing for live fascines.

Soils			
Slope steepness	**Fill** ft (m)	**Erosive** ft (m)	**Nonerosive** ft (m)
Flatter than 3:1	3 to 5 (0.9 to 1.5)	5 to 7 (1.5 to 2.1)	3 to 5 (0.9 to 1.5)
Steeper than 3:1	3* (0.9)	3 to 5 (0.9 to 1.5)	Not recommended

** Not recommended alone.*

Inert Materials for Live Fascines

- Use untreated twine to tie the fascines.
- Use dead stakes. Make stout, dead stakes from ½- to 4-foot- (0.15- to 1.22-meter-) long, sound, untreated, 2- by 4-inch- (50- by 100-millimeter-) lumber. Cut each board diagonally across the 4-inch (100-millimeter) face to make two stakes. Use only sound lumber. Discard any stakes that shatter when they are installed.

Installing Live Fascines

- 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; all members must know their roles ahead of time.
- Jam the ends of fascines together, for longer fascines, before placing them into the trench.

- Begin at the base of the slope, marking contours before digging.
- Excavate a trench on the contour about 10 inches (about 250 millimeters) wide and 10 inches (about 250 millimeters) deep.
- Excavate trenches up the slope at 3- to 5-foot (0.9- to 1.5-meter) intervals. Where possible, place one or two rows of fascines over the top of the slope to break up sheet runoff.

Erosion-Control Blanket Logs

Make your own logs out of erosion-control blankets. These logs can reinforce a streambank without much site disturbance. Each log is 1 to 2 feet (310 to 610 millimeters) in diameter and made out of erosion-control blankets or jute, straw, and lengths of branch cuttings (figure 3–70). The logs are placed along streambanks to armor them. They can be from a few feet long up to 100 feet (31 meters) long.

Figure 3–70—Live fascines rolled into erosion-control blankets can be used as "logs" to stabilize erosion along streambanks (Eubanks and Meadows 2002).

Applications for Erosion-Control Blanket Logs

- Make logs in the field (figure 3–71) to meet needs on the site.
- Apply logs at the ordinary high-water mark or the water level when the stream is bankfull.
- Stack logs to cover more of the bank; on smaller streams a single string of logs may suffice.
- String logs together along the banks, overlapping logs and molding them to the curvature of the streambank.
- Plant logs with rooted stock, sedges, and other plants between the logs and the bank.

Figure 3–71—Erosion-control blanket logs are prepared by rolling out the erosion-control blanket, adding a layer of loose straw, and rolling a live fascine into the blanket.

Effectiveness of Erosion-Control Blanket Logs

Erosion-control blanket logs:

- Armor the toe of the bank effectively while plants take root.
- Protect slopes from shallow slides or from being undermined, while trapping sediment that encourages plant growth within and behind the log.
- Retain moisture in the log, which aids vegetative growth.
- Provide an inexpensive method for stabilizing banks.

Live Materials for Erosion-Control Blanket Logs

- Collect straight branch cuttings, 0.5 to 1 inch (13 to 25 millimeters) in diameter and from 4 to 7 feet (1.2 to 2.1 meters) long, from species that root easily from cuttings (such as willow, dogwood, and cottonwood).
- Use live stakes.

Inert Materials for Erosion-Control Blanket Logs

Inert materials that will be needed to install erosion-control blanket logs include:

- Straw.
- Untreated twine to tie the logs as they are made.
- Cable and duckbill anchors.
- $^{5}/_{16}$-inch (8-millimeter) cable and cable clips.
- Coconut and jute mat—sold by the square foot in rolls 8 feet (2.4 meters) wide and up to 1,000 feet (304 meters) long. Mesh with openings of $^{3}/_{8}$ to $^{1}/_{2}$ inch (10 to 13 millimeters) has been used successfully.

Use stout, dead stakes to secure the log. Make stout, dead stakes from sound, untreated, 2- by 4-inch (50- by 100-millimeter) lumber that is 2 $^{1}/_{2}$ to 4 feet (about 0.8 to 1.2 meters) long. Cut each stake diagonally across the 4-inch (100-millimeter) face to make two stakes. Use only new, sound lumber. Discard any stakes that shatter when they are being installed.

Installing Erosion-Control Blanket Logs

- Cut the mat to the length required for each segment plus 2 feet (610 millimeters). The mat will be 8 feet (2.4 meters) wide.
- Lay the mat flat and cover it with a layer of straw, leaving 1 foot (310 millimeters) of mat at each end of the 8-foot (2.4-meter) edge uncovered.
- Place the cuttings lengthwise along one long edge, three to four stems together.
- Fold the empty edges inward, along the 8-foot (2.4-meter) border, onto the straw.
- Roll up the mat, starting at the edge opposite the cuttings.
- Tie the roll in several places to secure its shape. Use twine or loose coconut strands from the matting as ties.
- Place the log in position on the streambank at the average water level with the cuttings against the bank.
- Start at the downstream end of a section of logs. Place the first log and overlap it with the next one by 1$^{1}/_{2}$ feet (460 millimeters). Overlap the logs so that the new log is on the stream side of the original log. One log about 70 to 100 feet (21 to 31 meters) long is stronger than several shorter logs.
- Secure the log with cable spaced every 2 to 2½ feet (610 to 760 millimeters). Wrap the cable around the log and secure the cable by driving a duckbill into the bank. Be sure the anchor is in firm soil.
- Drive live stakes through the log to help anchor it and to add more plant material.
- Use stout, dead stakes, if desired, to anchor the log in placid settings.
- Key in the upstream and downstream ends.

Trench Packs

Trench packs act to break the force of moving water and to trap sediment. They are deciduous branch cuttings placed vertically in trenches or holes (figure 3–72). Plant cuttings should be selected from the same zone in which they will be planted, such as at the stream's edge, on the bank, or on the floodplain.

Applications for Trench Packs

- Install trench packs at the ordinary high-water mark or the level of the water when the stream is bankfull to stabilize the toe of slopes and to provide good fish habitat.
- Use trench packs on lakeshores to reduce erosion caused by wind and waves.
- Use trench packs in gullies to catch sediment.

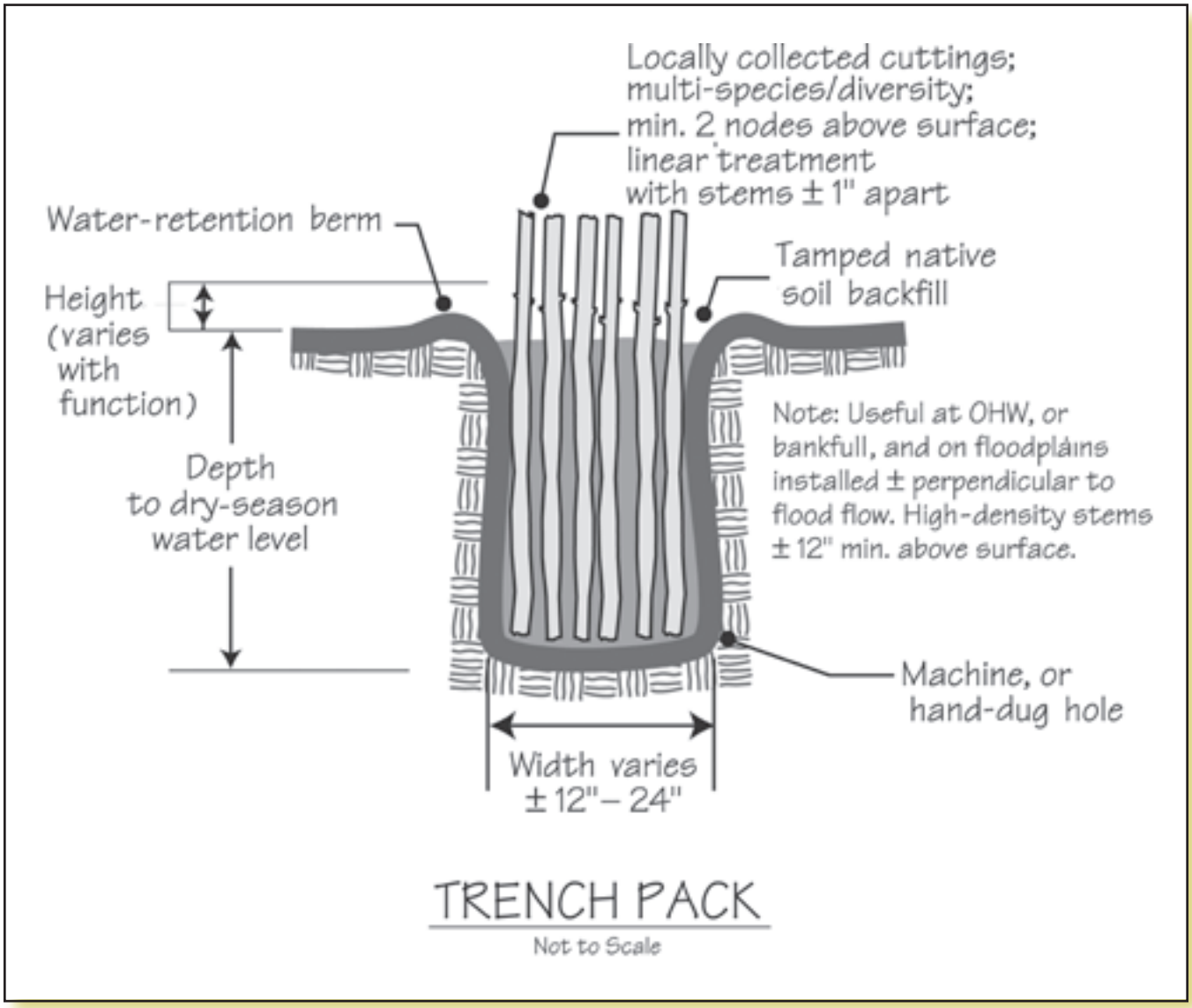

Figure 3–72—Installing trench packs (Eubanks and Meadows 2002). *OHW* stands for ordinary high water.

Effectiveness of Trench Packs

Trench packs:

- Trap sediment.
- Reduce the velocity of wind and water.
- Provide a good barrier for rooted stock.
- Dry excessively wet sites through evapotranspiration (pumping water through the roots to the leaves and into the air).
- Reinforce soil with unrooted branch cuttings. Deep roots help keep the soil from sliding and help keep the bank from sloughing.
- Enhance conditions for colonization of native vegetation by creating a stable surface and a microclimate conducive to plant growth.

Live Materials for Trench Packs

Use live deciduous material about 1 to 1½ inches (25 to 38 millimeters) in diameter, known for its good rooting structure. Leave side branches attached. Mix different species, if appropriate.

Use cuttings that are long enough to reach the water level during the dry season.

For fall planting, branches should extend 2 to 3 feet (610 to 910 millimeters) above the ground to provide immediate bank protection. The following spring, trim the branches back to two buds above the ground, stimulating root growth.

For spring planting, branches should not extend more than 12 inches (305 millimeters) above the ground and branches should not have more than two buds.

Inert Materials for Trench Packs

- Augment the pack with dead material, such as conifer branches, if live plants will not provide enough structural stability before they root.
- Plant branches 3 to 4 feet (0.91 to 1.22 meters) 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.

Installing Trench Packs

- Dig a hole or trench 12 to 24 inches (305 to 610 millimeters) wide to the water level of the stream or lake during the dry season. Although the trench can be of any length, the ends of the trench must be tied into something solid or keyed into the bank.

Woven Checkdams

Woven checkdams are constructed of woody stem material that will sprout and form a live structure (figure 3–73). The ends of each stem are toed into the channel bottom and banks (Prunuske 1987).

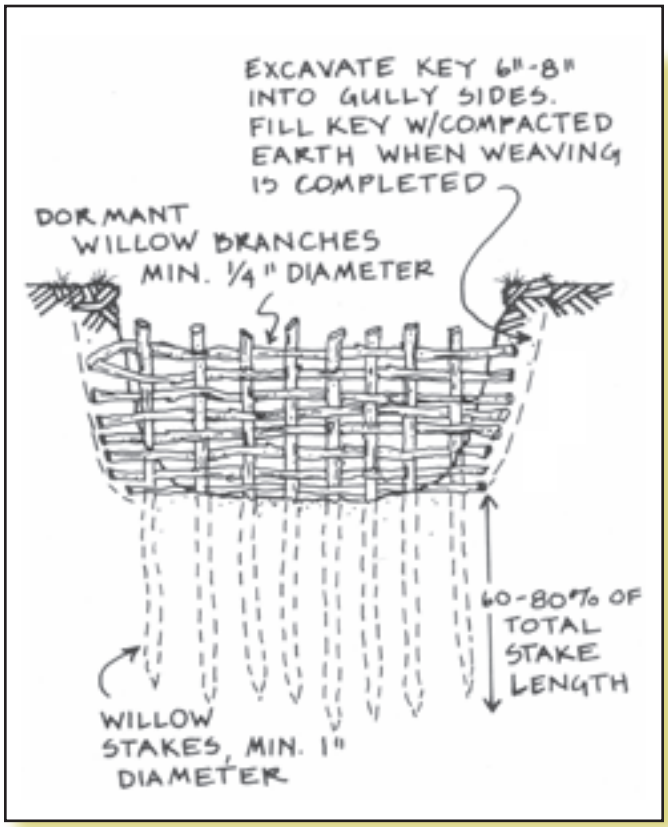

Figure 3–73—Installing woven checkdams. Drawing courtesy of Susan Pinkerton (Prunuske 1987).

Applications for Woven Checkdams

Checkdams:

- Allow water to move through the checkdam.
- Are used for gullies where storm flows have been diverted.
- Are used for gullies where the channel is cut deeper than needed for extreme storm flows.

Effectiveness of Woven Checkdams

Checkdams:

- Trap sediment.
- Slow water and wind.
- Enhance conditions for colonization of native vegetation by creating a stable surface and a microclimate conducive to plant growth.

Live Materials for Woven Checkdams

- Use live, dormant deciduous material known for its good rooting structure.
- Install materials the same day that they are prepared.
- Vertical stakes should be at least 3 inches (76 millimeters) in diameter (larger for a tall dam), and 2½ times longer than the desired height of the checkdam. Use cuttings long enough to reach the water level during the dry season. Cut the basal ends at an angle or point so they can be inserted into the soil easily. The top should be cut square.
- Horizontal cuttings should be at least ¼ inch (6 millimeters) in diameter and 12 inches (305 millimeters) longer than the width of gully being repaired.

Installing Woven Checkdams

- Excavate a key 6 to 8 inches (150 to 200 millimeters) deep into the sides of the gully.
- Strip the vertical stakes of all their side branches.
- Drive vertical stakes into the gully bottom with 60 to 80 percent of each stake anchored underground.
- Weave horizontal cuttings between the vertical stakes, inserting 6 inches (150 millimeters) of the horizontal stakes at either end into the key.
- Fill the key with compacted soil after the stakes have been woven.
- Because water will flow through the dam, structures to dissipate energy are not needed. Add an apron if substantial flow is anticipated.

3.5 Using Soil Binders

Soil binders, also called tackifiers, aggregate the top layer of the soil to reduce dust and prevent surface erosion. The slurry used in soil binders is made from wood products, plaster, petroleum, or other materials. Seed can be mixed into the slurry for hydroseeding. Soil binders commonly are used on raw road cutbanks and fill slopes after construction projects. They are applied with large motorized sprayers. Soil binders typically would not be included in a wilderness or backcountry project, because the projects are smaller and motorized equipment may not be allowed.

Binders are applied after a project's earthwork is complete. Binders sometimes inhibit water infiltration and prevent seeds on the surface from becoming established, because they dry up. In such cases, binders could interfere with restoration goals (Belnap and Furman 1997). The use of soil binders may merit further research as a way of addressing challenging situations.