SOIL BIOENGINEERING

(ft,)
CODE 926

DEFINITION

Treatment used to reinforce the soil and reduce erosion of slopes using live plant materials alone or in conjunction with simple structures.

PURPOSE

The purpose of this practice standard is to provide structural support and permanent vegetative cover for slope protection and erosion control using living plant materials alone or in combination with stakes or rocks, as structural components.

CONDITIONS WHERE PRACTICE APPLIES

This practice applies to the following conditions:

1. Natural streambanks
2. Channel sideslopes
3. Cut and fill slope stabilization
4. Any earthen slope where erosion can occur or has occurred

Soil bioengineering is not applicable when conventional vegetative practices will adequately control erosion.

Soil bioengineering techniques used on natural streambanks or channel sideslopes require special design considerations found in Chapter 16 of the NRCS Engineering Field Handbook (part 650.1601)
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CRITERIA

Soil Bioengineering Techniques:

Live Stakes – Live staking shall consist of the insertion and tamping of live, rootable vegetative cuttings into the ground, which will take root and grow. Live stakes shall be ½ to 1½ inches in diameter and 2 to 3 feet long. The top end of the live stake shall be cut square, and the basal (butt) end shall be cut at an angle. The live stakes shall be fresh, healthy and straight, with side branches removed. The live stakes shall be soaked for 24 hours prior to installation and shall be kept cool and moist until installed.

The live stakes shall be installed at a right angle to the slope 2 to 3 feet apart with approximately one fifth of the stake protruding from the slope. A pilot hole shall be used for installation in firm soils. A dead blow mallet should be used to drive the live stakes to reduce injury to the plant materials. See Figure 1.

Live Fascine – Live fascine shall consist of long bundles of live branch cuttings bound together into sausage-like structures six to eight inches in diameter. The live fascine shall be installed in shallow contour trenches.

Live and dead stakes shall be used to keep the bundles in place. Dead stakes shall be installed vertically every two to three feet in the middle of the trench (through the bundles). Dead stakes shall be made of untreated 2 by 4 lumber 2½ feet long, cut diagonally to make two stakes from each length (or other untreated wood cut to equivalent dimensions). Live stakes shall meet the criteria in the Live Stake section of this practice standard and shall be installed between the dead stakes perpendicular to the slope. Backfill shall be placed in the trench and compacted, leaving the top of the live fascine visible. The procedure shall be repeated as needed up the slope. Suitable erosion control measures shall be used between rows. See Figure 2.

Live Fascine Installation Guidelines

Slope	Slope Distance between trenches (ft)	Max. Slope length (ft)
1:1 to 1.5:1	3 – 4	15
1.5:1 to 2:1	4 – 5	20
2:1 to 2.5:1	5 – 6	30
2.5:1 to 3:1	6 – 8	40
3:1 to 4:1	8 – 9	50
4:1 to 5:1	9 – 10	60

(NRCS Engineering Field Handbook)

Branchpacking – Branchpacking shall consist of alternating layers of live branch cuttings and compacted backfill with stakes for stability used to repair small localized slumps and holes in slopes. Live branch cuttings shall be ½ to 2 inches in diameter and long enough to reach the back of the trench while extending slightly beyond the slope face. Wood stakes shall be 3 to 4 inch diameter poles or 2 by 4 lumber cut in half diagonally. The stakes shall be installed 3 to 4 feet into the ground every 1 to 2 feet starting at the bottom of the trench. A six-inch layer of live branch cuttings shall be placed in a crisscross pattern perpendicular to the slope between the stakes followed by compacted backfill placed in 6 to 8 inch lifts. This shall be repeated up the slope, as needed. See Figure 3.

Brushlayer – For brushlayer installation, live branch cuttings with side branches intact shall be placed crisscrossed or overlapping oriented perpendicular to the slope in excavated benches a minimum of two to three feet wide. Branch cuttings shall be ½ to 2 inches in diameter and long enough to reach the back of the bench with the tips extending slightly beyond the fill. Benches shall be backfilled and compacted, working up the slope.

Brushlayer Installation Guidelines

Slope	Slope Distance between benches		Max. Slope length (ft)
	wet (ft)	dry (ft)	
2:1 to 2.5:1	3	3	15
2.5:1 to 3:1	3	4	15
3:1 to 4:1	4	5	20

(NRCS Engineering Field Handbook)

Live Gully Repair – Alternating layers of live branch cuttings and compacted soil shall be used to repair small rills and gullies (generally up to 2 feet wide, 1 foot deep, and 15 feet long). Live branch cuttings shall be ½ to 2 inches in diameter and long enough to touch the soil at the back of the rill or gully and extend slightly from the rebuilt slope face. Installation shall start at the bottom with the installation of a 3 to 4 inch layer of live cuttings in a crisscross pattern perpendicular to the slope. The layer of live cutting shall be covered with 6 to 8 inches of fill soil and compacted. This procedure shall be repeated, as required, to fill the rill or gully. See Figure 4.

Brush Mattress (Brush Mat) – Live branches shall be secured together to form an erosion resistant mat. Live branch cuttings shall be ½ to 2 inches in diameter. Live stakes shall be ½ to 1½ inches in diameter 24 to 36 inches long, with side branches removed (see Live Stakes above). Dead stakes shall be made from untreated 2 by 4 lumber, 24 to 36 inches long, cut diagonally to make two stakes from each length.

A horizontal trench, 8 to 12 inches deep, shall be excavated at the toe of the area. Live branch cuttings shall be placed over the area 8 to 12 inches thick slightly crisscrossed with the basal ends in the excavated trench. The live cuttings shall be overlapped and staggered as necessary for even coverage. A mix of live and dead stakes shall be installed in a grid pattern at 3 to 4 foot centers – leaving at least 1 foot of the stake exposed.

The brush mattress shall be secured by tying twine, rope, or wire in a diamond pattern between the live and dead stakes. Once the twine is secure (tied at least 6 inches from the top of the stakes), the live and dead stakes shall be driven further into the ground to compress the mattress tightly against the slope. The toe of the brush mattress shall be secured using a live fascine, rock, or other suitable technique. The brush mattress shall be covered by adding 1 to 2 inch layers of soil and then watered between each soil layer making sure the voids in the brush mattress are filled and the basal ends are covered. See Figure 5.

Root Wad – Trees used for root wads shall be at least 10 feet long with a minimum 12 inch diameter breast height with the root fan attached. The area shall be excavated only as much as necessary for installation, slightly deeper in the back. The root wad shall be placed with the root fan extending just beyond the slope face at a slight angle toward the direction of flow When required a footer log shall be placed at the toe of the excavation for stability and secured with rebar. The root wad shall be backfilled with rock and/or soil and stabilized with an appropriate method. Additional root wads shall be used, as needed. See Figure 6.

Live Cribwall – A live cribwall shall consist of a hollow, box-like interlocking arrangement of untreated log or timber members filled with backfill material and live branch cuttings, installed at the base of a slope to a maximum of 6 feet high. Live cuttings shall be ½ to 2 inches in diameter and long enough to reach the back of the crib structure. Logs or timbers shall be 4 to 6 inches in diameter. Large nails or rebar shall be used to secure the logs or timbers together.

The area shall be excavated 2 to 3 feet below ground level (slightly deeper in the back). The logs or timbers shall be placed at the front and back approximately 4 to 5 feet apart parallel to the slope contour. The next course of logs or timber shall be placed at a right angle on top of the previous course and shall overhang 3 to 6 inches on each end. The logs or timber shall be layered, nailing each course to the previous, until the top of the slope is reached.

Live branch cuttings shall be placed in layers between the logs or timbers perpendicular to the slope, then covered with backfill and compacted. The top of the vegetated cribwall shall be vegetated for erosion control – see practice standard **PERMANENT VEGETATION 880**. See Figure 7.

Vegetated Rock Gabions – Vegetated rock gabions shall consist of rock-filled wire baskets layered with live branch cuttings installed at the toe of a slope to form a low wall. Live branch cuttings shall be ½ to 1 inch diameter and long enough to extend beyond the back of the rock-filled basket into the backfilled soil.

The area shall be excavated 2 to 3 feet below the ground elevation (slightly deeper in the back). Rock gabions shall consist of rectangular containers fabricated from triple-twisted, hexagonal mesh of heavy galvanized steel wire. The empty baskets shall be placed in the bottom of the excavation and filled with rocks. The adjoining baskets shall be wired together. Backfill shall be placed between and around the wire baskets. Live branch cuttings shall be placed on top of the wire baskets perpendicular to the slope extending slightly beyond the wire baskets. Soil shall be placed on top of the branch cuttings and compacted. This procedure shall be repeated as needed until the structure reaches the required height. Branch cuttings may also be placed through the gabion basket as it is filled. The top of the vegetated rock gabion wall shall be vegetated for erosion control – see practice standard **PERMANENT VEGETATION 880**. See Figure 8.

Vegetated Rock Wall – A combination of rock and live branch cuttings shall be used to stabilize and protect the toe of steep slopes (up to five feet high). Live branch cuttings shall be ½ to 1 inch diameter and long enough to extend beyond the rock layer into the undisturbed soil. Rock shall be 8 to 24 inches in diameter with larger boulders used for the base.

The area shall be excavated 2 to 3 feet below the ground surface (slightly deeper in back). The extent of the excavation shall be the minimum amount required. A well-drained base shall be required. A drainage system with an appropriate drainage outlet shall be provided when installed adjacent to an impervious surface. Rocks shall be placed with at least a three-point bearing on the foundation with the center of gravity as low as possible, long axis pointing inward toward the slope.

Live branch cuttings shall be placed between layers of rock and into the openings during and/or after rock placement. Backfill shall be placed around the rock wall and compacted. The top of the vegetated rock wall shall be vegetated for erosion control – see practice standard **PERMANENT VEGETATION 880**. See Figure 9.

Joint Planting (Vegetated Riprap) – Live cuttings of rootable plants shall be installed between the joints or open spaces of riprap. Cuttings shall be ½ to 1½ inch diameter with side branches removed and bark intact long enough to extend into the soil below the riprap. The live branch cuttings shall be tamped into the openings of the riprap during or after construction using a dead blow mallet. Branches shall be installed perpendicular to the slope. See Figure 10.

Bioengineering Technique Variations:

Low Wall/Slope Face Planting – A low retaining wall structure shall be constructed at the toe of the slope allowing a flattened slope suitable for vegetation. See practice standard **RETAINING WALLS 898** for details and specifications for the retaining wall. See Figure 11.

Tiered Wall/Bench Plantings – This shall include the installation of retaining walls in a tiered fashion allowing for additional stabilization and plantings on steeper slopes. Once established, the vegetation will screen the retaining wall structure.

Tiered Cribwall – Cribwalls shall be installed in a tiered fashion to stabilize steep slopes and provide opportunity for plantings to further reinforce the soil bioengineering system.

Timing – Soil bioengineering systems shall be installed during the dormant season (late fall through early spring). Plantings shall be installed concurrent with earth-moving operations.

Plants – Native plants shall be used. Plant species shall be suited for the intended use and adapted to the site's climate and soil conditions.

Construction – Earth excavation shall be in accordance with construction standard **21 EXCAVATION**. Execution of soil bioengineering techniques shall be in accordance with construction standards **750 USE OF DORMANT WOODY PLANTINGS FOR STREAMBANK STABILIZATION** and **751 USE OF GRASSES FOR STREAMBANK STABILIZATION**, as appropriate. When work is required within a stream the stream flow shall be diverted in accordance with practice standard **COFFERDAM 803** or **TEMPORARY STREAM DIVERSION 976**.

The slopes of the soil bioengineering measures shall be properly stabilized, as required. See practice standards **EROSION BLANKET 830** and **EROSION BLANKET: TURF REINFORCEMENT MAT (TRM) 831**.

CONSIDERATIONS

Soil bioengineering should take into account the soil types, slope length, slope angle, erosion potential, urgency, size, and native vegetation to come up with the best solution. When preparing the site, the amount of disturbance should be minimized.

Surface runoff should be temporarily diverted around the work area. See practice standards **DIVERSION DIKE 820** or **TEMPORARY DIVERSION 955**. Earthwork should not be done in saturated soil.

Excavated material should be placed away from trees and outside the drip line. See practice standard **TREE PROTECTION 990**. Care should be taken to minimize the impact on the surrounding area.

Soil bioengineering systems are not appropriate for all sites and situations. In certain cases, conventional vegetative cover may work satisfactorily at less cost. In other cases, the most appropriate solution may be a structural retaining system or a combination of a structural retaining system and soil bioengineering. Review the specific conditions of each project to determine the most appropriate and cost-effective solution. See practice standards **STRUCTURAL STREAMBANK STABILIZATION 940** or **LINED CHANNEL OR OUTLET 872**.

Soil bioengineering systems are most cost effective where comparable construction methods are labor intensive. Since soil bioengineering systems require minimal access for equipment and/or workers, they are ideally suited for environmentally sensitive areas.

PLANS AND SPECIFICATIONS

Plans and specifications for installing a soil bioengineering system shall be in keeping with this standard and shall describe the requirements for applying the practice to achieve its intended purpose. At a minimum include the following items:

1. Location, size and alignment
2. Planting material
3. Soil bioengineering cross section
4. Installation instructions
5. Riprap specification, if used
6. Rock size, if used

All plans shall include the installation, inspection, and maintenance schedules with the responsible party identified.

Standard drawings **IL-695 VEGETATIVE STREAMBANK STABILIZATION** and **IL-696 VEGETATIVE STREAMBANK STABILIZATION – DETAILS** may be used as the plan sheet, as appropriate.

OPERATION AND MAINTENANCE

The establishment period of the soil bioengineering system is usually two years. The soil bioengineering system shall be inspected bi-weekly for the first two months. Immediate action shall be taken, as required (such as supplemental watering).

If the system is growing satisfactorily, inspections shall take place monthly for the next six months. Inspections shall then be extended to every six months for the remainder of the two-year establishment period. Thereafter, the soil bioengineering facility shall be inspected annually, at a minimum.

In addition to regular inspections, the soil bioengineering system shall be inspected during periods of drought or heavy rain. Repairs shall be made as soon as feasible.

Ongoing maintenance shall include annual pruning and removal of undesirable vegetation, as required. Any problem areas shall be repaired as soon as feasible.

REFERENCES

United States Department of Agriculture, Natural Resources Conservation Service, Engineering Field Handbook, Chapter 18 – Soil Bioengineering for Upland Slope Protection and Erosion Reduction.

Washington State Department of Transportation. 740 Soil Bioengineering. Olympia, WA. July 2003.

City of Knoxville, Tennessee. Knoxville BMP Manual. Bank Stabilization and Soil Bioengineering ES-20. May 2003.

Allen, HH and Fishchenich, JC (2000). "Brush Mattresses for Streambank Erosion

Control." Ecosystem Management and Restoration Research Program (EMRRP) Technical Notes Collection (TN EMRRP-SR-23). US Army Engineer Research and Development Center, Vicksburg, MS.

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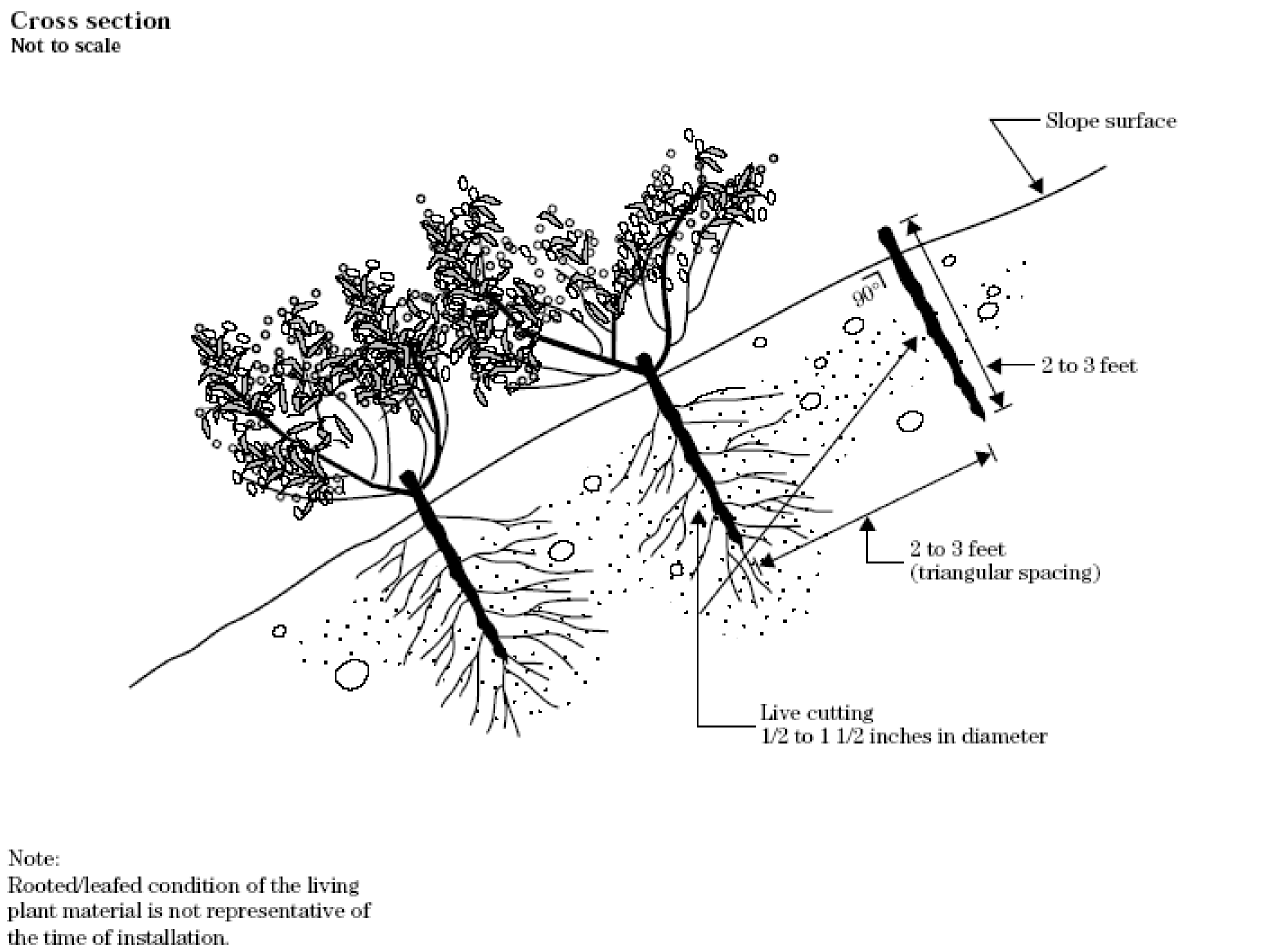


Figure 1 – Live Stake Installation

(NRCS Engineering Field Handbook)

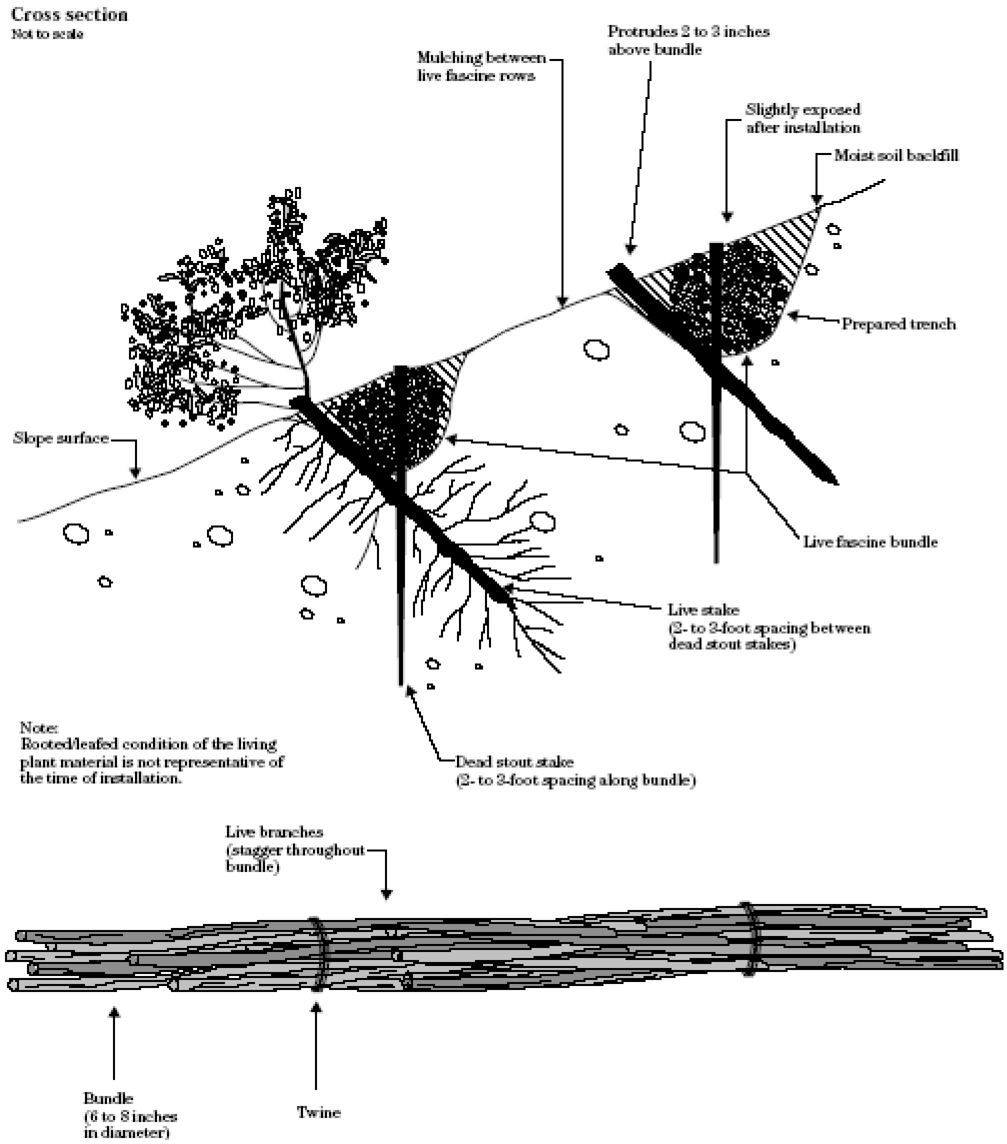


Figure 2 – Live Fascine Details

(NRCS Engineering Field Handbook)

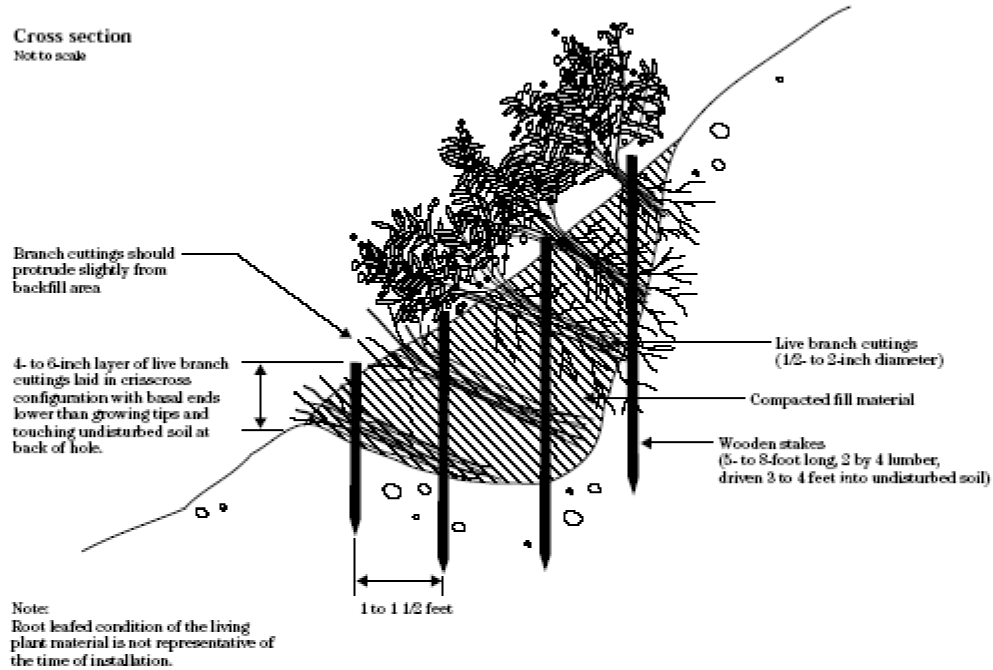


Figure 3 – Branchpacking Details

(NRCS Engineering Field Handbook)

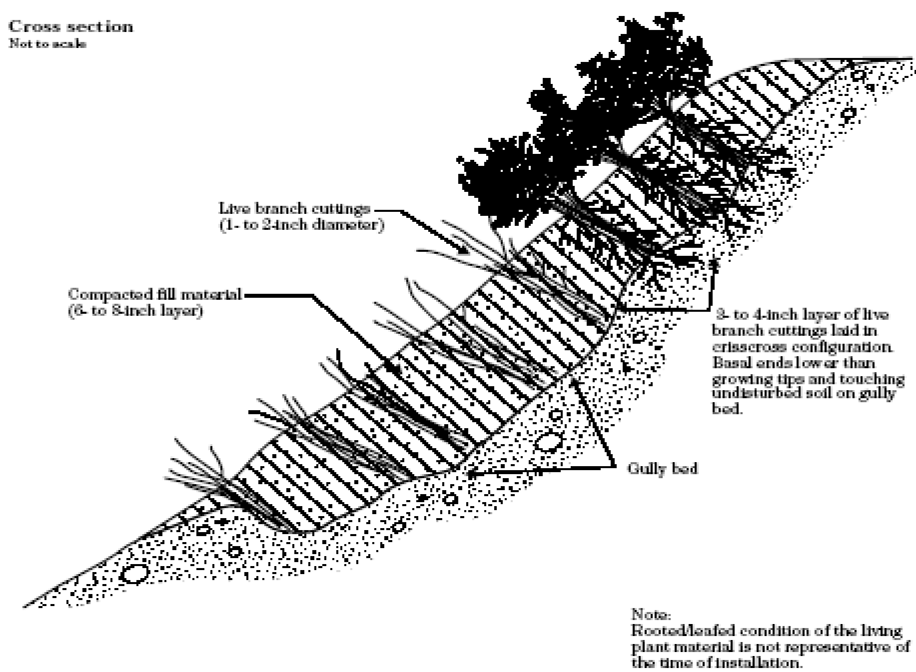
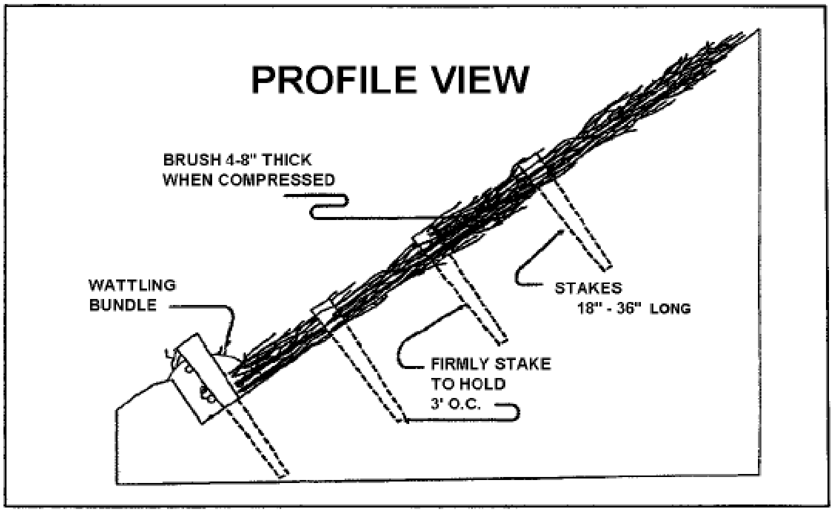
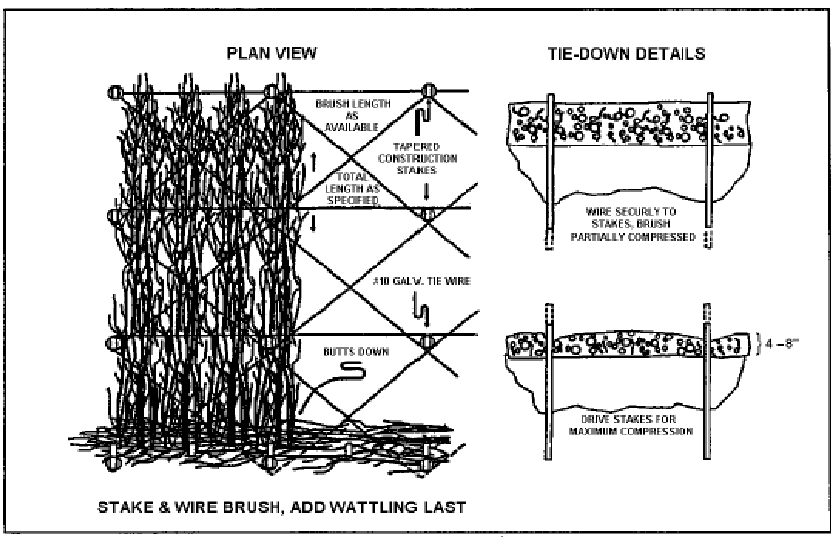


Figure 4 – Live Gully Repair Details

(NRCS Engineering Field Handbook)



a. Profile view



b. Plan view

Figure 5 – Brush Mattress
(EMRRP)

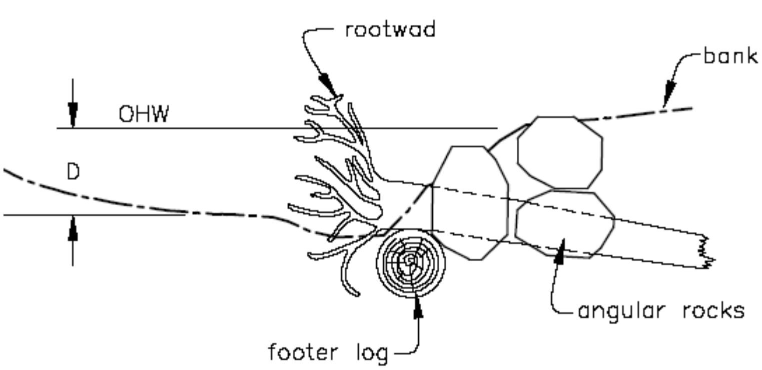


Figure 6 – Root Wad
(NRCS)

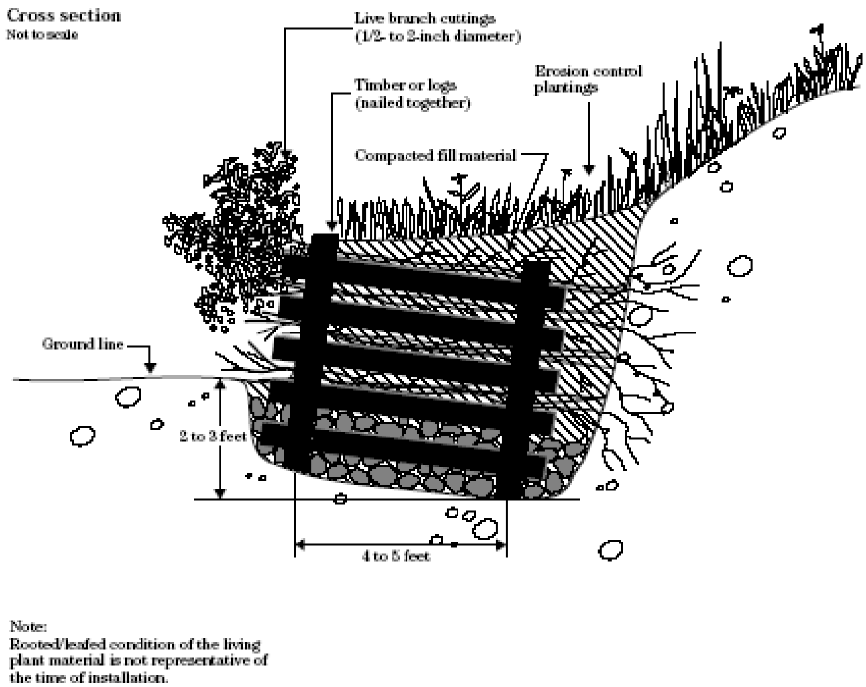


Figure 7 – Live Cribwall Details

(NRCS Engineering Field Handbook)

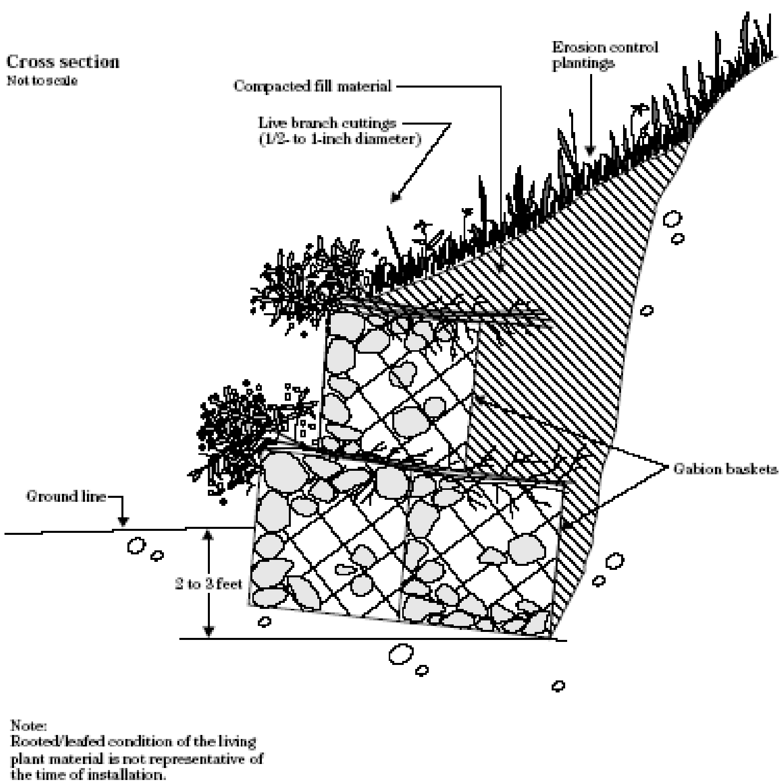


Figure 8 – Vegetated Rock Gabion Details

(NRCS Engineering Field Handbook)

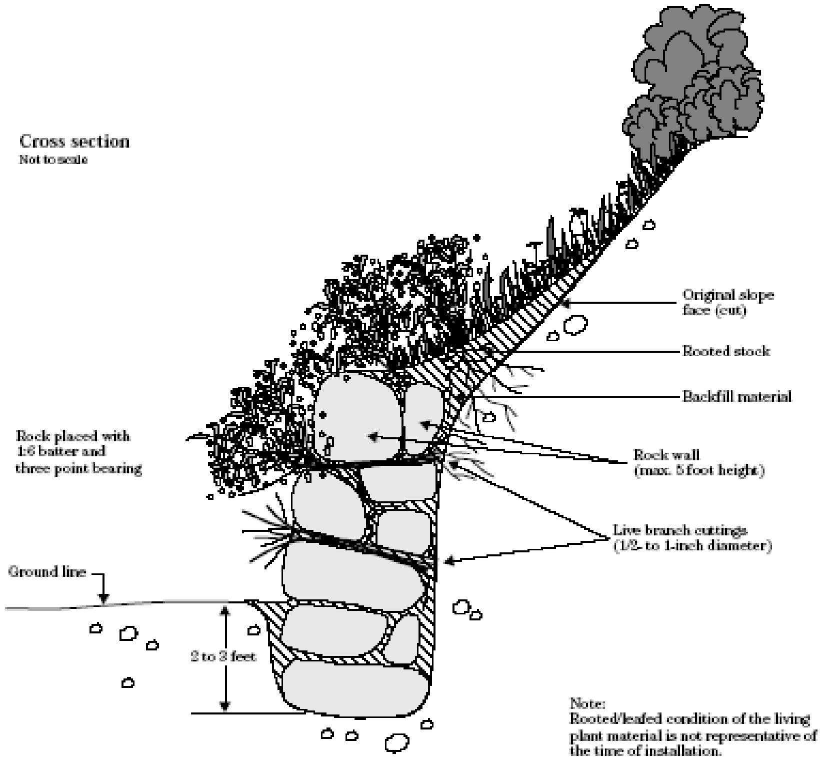


Figure 9 – Vegetated Rock Wall Details
(NRCS Engineering Field Handbook)

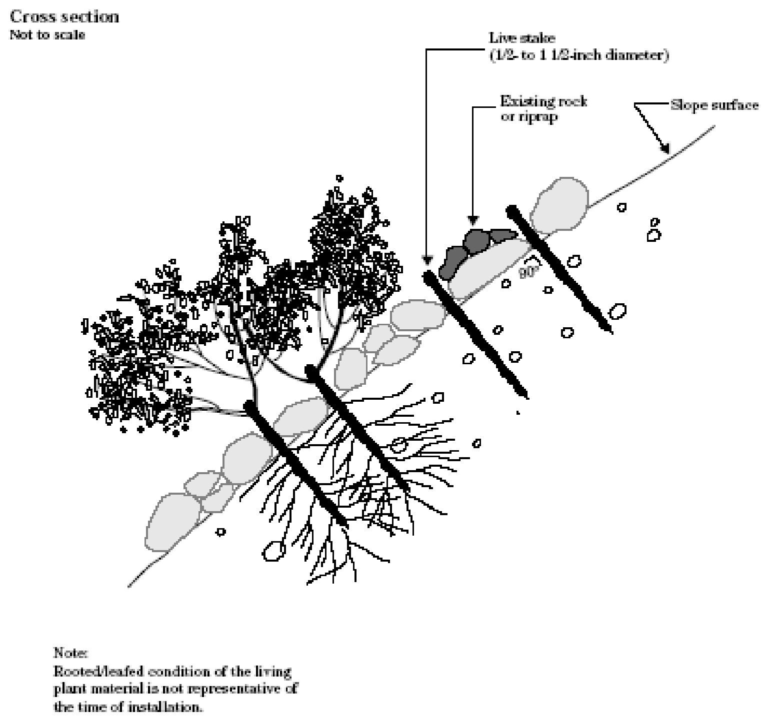


Figure 10 – Joint Planting (Vegetated Riprap) Details
(NRCS Engineering Field Handbook)

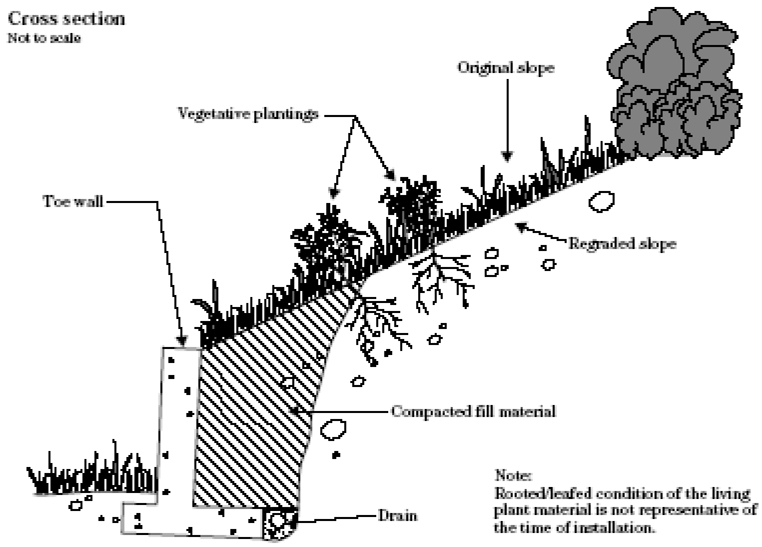


Figure 11 – Low Wall/Slope Face Plantings

(NRCS Engineering Field Handbook)

Additional comments on Code 926 Standard---Wayne Kinney, Midwest Streams, Inc.

1. The figures used are from NRCS Engineering Handbook Chapt. 18 for slope protection. They do not show Soil Bioengineering practices used for Streambank and Shoreline Protection as Chapt. 16 does. Do we want to consider two standards—one for Slope Protection and another for Streambank and Shoreline? My concern is primarily the problem of designing the portion below "bankfull flow" to resist the flow velocities and prevent undermining through toe scour. (the most common reason for failure of soil bioengineering)
2. An alternative would be to expand the standard in order to show the changes in techniques as applicable to slope protection or streambank protection.
3. A reference to the use of a qualified professional to complete the design for streambank applications would also be a consideration.

Explanation for recommended changes—

Conditions where Practice Applies—Added statement about referring to Chapt. 16 for design considerations when working in streams or channels. (Also need to show needed changes in Figures when using Bio-Engineering in streams to provide adequate toe protection.)

Live Stakes ---Use of dead blow mallot –self-explanatory

Branch packing ---Addition of limits on size of soil lifts

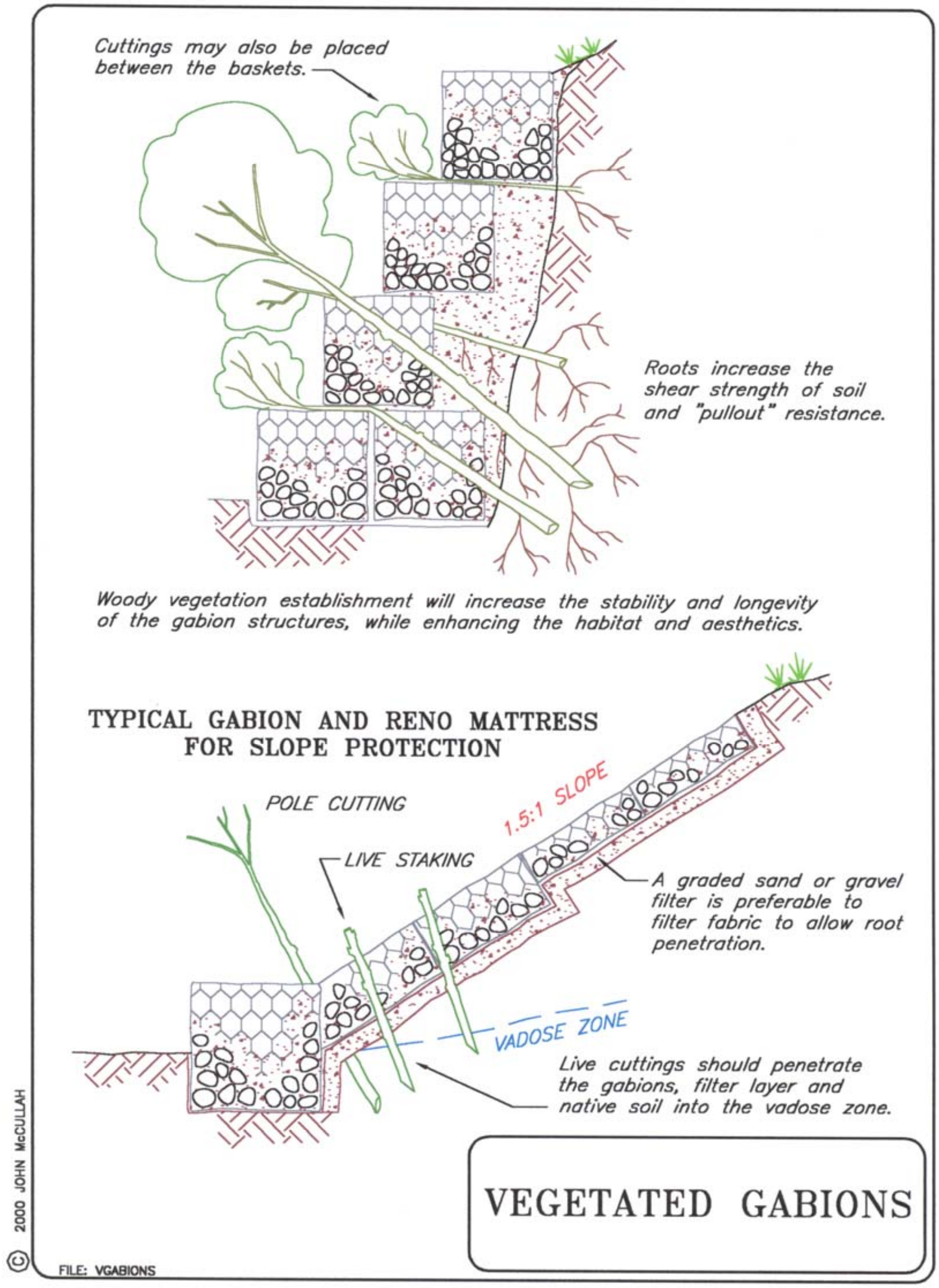
Brushlayer --- two to three foot wide bench should be considered a "minimum" to encourage wider benches and longer branch cuttings to provide more rooting medium to increase survival during dry periods after construction. Some manuals suggest 6 to 8 ft. wide benches.

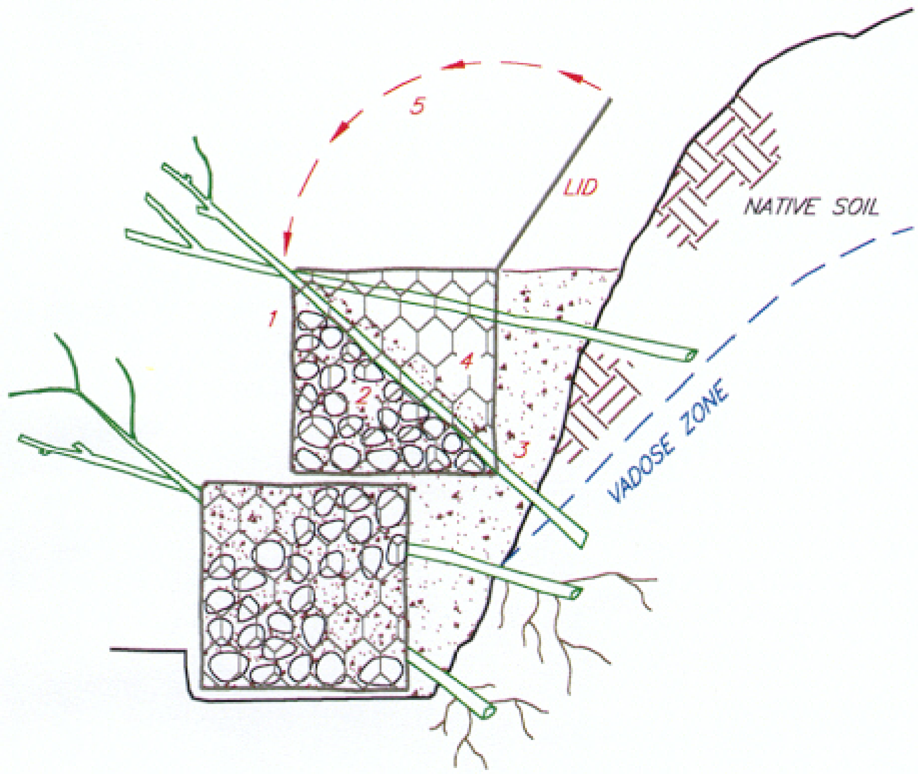
Brush Mattress --- statement of "alternating layers of soil and water" is confusing. How do you add a layer of water?

Root Wad --- Root fan is more effective if angled upstream so that channel flow is better intercepted by the face of the root fan. Some manuals suggest as much a 45 to 60 degrees upstream. Steeper upstream angles may require additional length of tree trunk above the root fan to insure adequate stability.

Live Cribwall --- statement "until ground elevation is reached" is confusing. Same paragraph refers to excavating 2 to 3 feet below ground level (elevation).

Vegetated Rock Gabions—An alternative (or additional) technique is to place branch cuttings through the gabions as they are filled and adding some soil material with the stone. See figure from "Salix Applied Earthcare" ---"Bio-Draw" version 2.0. (John McCullan) I like this approach as it reduces or eliminates the "soil" material between gabions which can wash out leaving voids in the structure.


Cuttings may also be placed between the baskets.
Roots increase the shear strength of soil and "pullout" resistance.
Woody vegetation establishment will increase the stability and longevity of the gabion structures, while enhancing the habitat and aesthetics.
TYPICAL GABION AND RENO MATTRESS FOR SLOPE PROTECTION
POLE CUTTING
1.5:1 SLOPE
LIVE STAKING
A graded sand or gravel filter is preferable to filter fabric to allow root penetration.
VADOSE ZONE
Live cuttings should penetrate the gabions, filter layer and native soil into the vadose zone.
VEGETATED GABIONS
© 2000 JOHN McCULLAH
FILE: VGABIONS



STEPS TO CONSTRUCT:

1. Assemble and place gabion baskets with lid open.
2. Partially fill basket with rock, as shown, keeping the rock toward the front and dipping down.
3. Place willow or cottonwood (poplar sp.) pole cuttings and/or brush layers, dipping down and through the back of the basket into the 'native' soil.
4. Continue to fill the basket with rock, using reasonable care not to damage the cuttings. Some damage is inevitable and acceptable. Use of some soil or 'fines' with the rock will help promote establishment.
5. Close and fasten lid and proceed with next course.

VEGETATED GABIONS DURING CONSTRUCTION

FILE: VEGGABDC