COLORADO EWP
Colorado Emergency Watershed Protection (EWP) Program
Sponsored by the Colorado Water Conservation Board (CWCB)
Administered by the Natural Resources Conservation Service (NRCS)
coloradoewp.com

Revegetation Plans for Stream Restoration Projects

A well-designed revegetation plan is a foundational component of a successful stream restoration project. It helps to ensure the establishment and long-term viability of a healthy riparian corridor, which is critical to stream ecology and stream structure.

This technical guidance document provides information and recommendations on:

- Important elements to consider when developing a revegetation plan for a stream restoration project
- Construction specifications within revegetation plans
- Items to address during and after construction

Contact
EWP Technical Assistance Team
Randy Mandel
Randy_Mandel@golder.com

Considerations When Developing Revegetation Plans

The following are important elements to consider when designing revegetation plans:

Proactive Planning and Integration with Other Design Elements - River design plans should include revegetation considerations at the onset of the project to ensure that their supporting considerations are successfully included within the project plan. Similarly, plant materials costs should be incorporated into budget considerations at the beginning of the project. Vegetation ecologists are a necessary part of the design team from project inception. Usage of the provided CWCB Revegetation Matrix will assist with appropriate species, propagule (seed, cutting, container), and stocking rate choices.

Advanced Plant Material Ordering and Deposit - There is a limited amount plant material available within the marketplace. Once the proper plant species, propagule, and stocking rate choices have been determined, these materials must be ordered in advance from reputable providers. Orders typically require a deposit (usually from 30 to 50% of the total price), and reservation of one year or more in advance of project implementation is strongly recommended.

Timing - Ideally, vegetation is re-established at an appropriate time in relation to season (light and temperature) and hydrology (soil moisture). Seeding is typically best accomplished through dormant fall establishment. Dormant cuttings demonstrate the most success when established during the receding limb of the hydrograph (spring). Containerized plants do best when planted during rainy periods within the active growing season. If the correct timing is not feasible, supplemental measures such as irrigation must be utilized.

Recommended Resources for Revegetation

The Colorado Water Conservation Board (CWCB) recommends the following resources (available at www.ColoradoEWP.com) to support revegetation planning:

Plant Revegetation Matrix

This searchable matrix provides a prioritized list of the major native plant species and their attributes used in the restoration of streambanks, flood terraces, and transitional zones in Colorado, including the Front Range.

***Living Streambanks: A Manual of Bioengineering Treatments for Colorado Streams*.**

This manual provides practitioners with bank stabilization design guidelines to be used during a comprehensive river restoration strategy.

Revegetation Plans for Stream Restoration Projects

Regulatory Compliance - Most riparian areas are, by definition, wetlands, and therefore subject to regulation and permitting by federal, state, and local governments. All wetland permits must be in place prior to project implementation and must be included in planning and design. Additionally, the harvest of plant materials requires collection permitting through responsible land management agencies and these must be in place prior to all collection activities. Planning for these permits must be incorporated into project timelines, budgets, and personnel requirements.

Site Analysis and Comparison to Reference Reaches - Successful project design requires comparison to reference reaches that are of the same approximate elevation, latitude, longitude, hydrology, aspect, biophysical characteristics, and ecological community as the project area. It is strongly recommended that reference reaches are surveyed prior to project design so that their ecological characteristics and functions can be integrated into project design to the greatest degree practical.

Hydrology - Vegetative communities have specific hydrologic considerations that must be met to facilitate successful revegetation. As hydrology changes by year and over the course of a given season, a thorough analysis should be made of the site hydrology prior to project design. If possible, groundwater wells should be established and monitored for several years prior to the project to understand hydrology prior to project design and implementation. Plant materials and bioengineering methods must be of an adequate depth to intersect the lowest annual groundwater level for successful establishment to occur. Site hydrology should be clearly defined and pre-flagged to facilitate revegetation by proper ecological zone, i.e., toe, bank, overbank, transitional, and upland.

Substrate and Amendments - Successful plant establishment requires the presence of a proper planting substrate. This frequently necessitates the use of amendments and addition of adequate organic matter, as well as the establishment of a functioning microbiotic community. Soil should be tested to determine its chemistry. A minimum of 2% organic matter is recommended. Additionally, the relationship between container size and soil depth must be considered to create proper planting conditions (normal minimum average depth is from 6- to 8-inches for 10-cubic inch containers, deeper for 1-quart, 5-gallon, and tall-pots/deep-rooted materials). If soil is imported to the site, extreme care must be taken to ensure that it is free of noxious and/or invasive species. Extremely poor soils may require additional amendments identified by a plant ecologist.

Revegetation Plan Contents

1. Description of plant materials

- Species and quantity (or for seed - species and percentage within the planting mix)
- Required amendment(s) (if any)
- Recommended nurseries/seed providers

2. Implementation plan

- Timing
- Location
- Seeding and planting methodologies
- Crew requirements
- Budget
- Supplemental irrigation requirements
- Monitoring plans
- Operations and maintenance responsibilities

Revegetation Plans for Stream Restoration Projects

Irrigation and Supplemental Water - The importance of timing and proper hydrology for successful revegetation cannot be overstated. If proper timing cannot be met and/or proper hydrologic conditions do not exist, supplemental irrigation through temporary pumps or products such as DriWater may be necessary. Supplemental water is an EWP-eligible construction cost, provided that it is completed within the 220-day construction window. All federal, state, and municipal water regulatory practices must be followed when using supplemental irrigation, and care must be taken not to overwater and cause or exacerbate erosion problems.

Riprap and Armoring Considerations - Minimum soil requirements must be followed for coverage over riprap and armored areas, as successful establishment will not occur in the absence of a proper substrate. Cuttings must be able to penetrate to the minimum annual soil water table height, seed must be able to form adequate roots, and containerized materials must be able to be planted without the occurrence of j-rooting or shortened root length. The Bioengineering Manual outlines several methods for incorporating soil and plants directly into armoring *during construction* in order to improve this critical soil/water connection.

Post-Construction Monitoring - Monitoring for seed emergence, plant and cutting survival, noxious and/or invasive species, predation, and erosion must be included within project design and budgets. Site management plans must be iterative in nature so that adaptive management can be used to address potential problems as they occur and before they become difficult or prohibitively expensive to correct. Erosion issues must be addressed quickly and decisively to prevent site degradation and negative impacts to water quality, including fisheries and aquatic habitat.

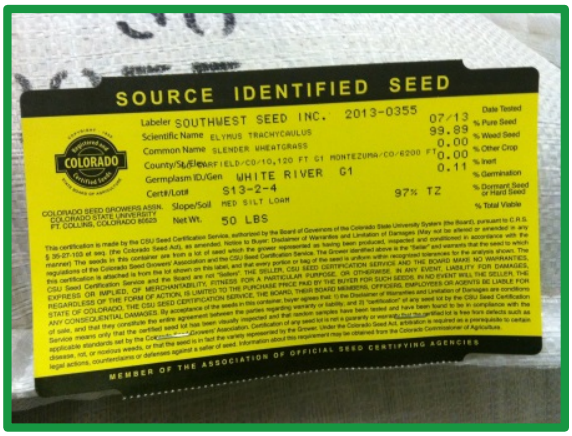
Revegetation Plans and Construction Specifications

Revegetation plans must include plant material implementation methodologies (for seeding, cuttings, and containerized plants) with other site attributes such as soil characteristics, hydrology, bioengineering measures, existing infrastructure, and surrounding ecosystems and human communities. This section lists recommendations and specifications for seeding, cuttings, containerized plants, and bioengineering.

Revegetation Plans for Stream Restoration Projects

Seeding

- Seeding recommendations should be determined on a percentage basis by species to facilitate ecological functionality, to minimize interspecific competition, and to promote proper revegetation.
- Seed mixes should be site-appropriate and, where possible, of an ecotypic (local native) nature. Appropriate mixes are based upon hydrology, elevation, biophysical characteristics, and reference areas, and should be determined using the CWCB revegetation matrix. Distinct mixes are required for each hydrologic zone. Where project sites intersect with USFS land, USFS plant materials requirements will be followed for all species.



- Recommended mixes should be determined on Pure Live Seed (PLS) per square foot basis. Recommended amounts vary by project, but should be in the range of 80 to 150 seeds per square foot for broadcast application, and from 40 to 75 seeds per square foot for drilled applications.
- Recommended mixes should contain graminoids and forbs with woody plants being preferentially established through containers and cuttings.
- Revegetation plans should include recommended seed source (reputable nursery is requisite).
- Proper seed handling is critical. All seed must be transported and stored in a cool, dry environment until the time of planting. If available, the use of site-specific seed that has been tested for purity and germination (PLS) is strongly encouraged.
- All seed must be labeled as 'certified' and should not include the presence of noxious or invasive species prohibited under the Colorado Seed Act (as indicated on the tag by the Colorado Department of Agriculture labeling). Tags must be maintained for documentation.
- Implementation method (broadcast versus drilling) should be specified, though it may vary by accessibility, slope, hydrologic zone, and season.
- Prior to delivery, seed should be processed by the seed provider on a "gravity-table" to remove non-target seed types, such as yellow sweetclover (*Melilotus officinalis*), alfalfa (*Medicago sativa*), wood sorrel (*Oxalis acetosella*), and other potentially aggressive species.
- Engineering estimate of seed cost should be included, with recommendation of alternative species if the included species are unavailable. Substitutions should only be made through consultation with the project vegetation ecologist.
- Once applied, the seed should be raked in, pressed with a weighted water wheel or similar implement to encourage good soil contact, and covered with wood straw at a rate of approximately 3,000 pounds per acre (lb/ac). Alternatively, the seed can be protected via HydraCX2 hydromulch with tackifier at an application rate of 2500 lb/ac within 24 hours of seed application.

Revegetation Plans for Stream Restoration Projects

Dormant Cuttings

- Recommendations for cuttings should be determined on a percentage basis by species to facilitate ecological functionality, to minimize interspecific competition, and to promote proper revegetation.
- Cuttings mixes should site-appropriate and, where possible, of an ecotypic (local native) nature. Appropriate mixes are based upon hydrology, elevation, biophysical characteristics, reference areas, and should be determined using the CWCB revegetation matrix. Distinct mixes are required for each hydrologic zone. Where project sites intersect with USFS land, USFS plant materials requirements will be followed for all species.
- Vegetative cuttings should be harvested as dormant material from pre-identified, site-specific collection locations up to two weeks prior to planting, trimmed as appropriate for the type of bioengineering technique, and then soaked from 5 to 7 days prior to planting.
- All cuttings must be harvested under collection permit from pre-approved harvest areas. No more than 20% of a given stand and 15% of a given shrub should be collected. All cuttings should be clearly labeled as to species, source, and number. If cuttings are purchased through a secondary vendor, then species, source, and number must be labeled on tag and delivery writ.
- Cuttings should be maintained in a shaded, moist, and cool condition from the time of harvest through the time of installation, including during transportation and upon delivery to the site.
- If planting cannot take place prior to spring runoff, then willow and cottonwood material should be collected prior to bud break, placed in water, and kept in cold storage for no more than 6 weeks until planting can occur.
- Project implementation for cuttings should incorporate the recommendations presented in the *Field Guide for Harvesting Willow and Cottonwood Cuttings* (Giordanengo and Mandel 2016) (attached).
- Stakes should be an adequate length to reach 6 inches into the low-season water table, with adequate stem remaining so that no fewer than 3 to 4 live buds remain above the ground.
- All stakes must be placed in proper hydrology, while dormant, preferentially on the receding limb of the hydrograph.
- Stakes should be placed on 3-foot (5,578 plants/ac) or 4-foot centers (3,158 plants/ac).
- Plant materials cost (including collection time, if applicable) and implementation costs should be included in the revegetation plan.
- Means of implementation (planting bar, shovel, auger, etc.) should be clearly outlined and be achievable within a given site's substrate conditions.
- All planting should take place under the supervision of the project vegetation ecologist to ensure that proper techniques are utilized to maximize survival.
- Planting locations should be flagged in advance of planting by the project vegetation ecologist based on hydrologic zone and species-specific requirements for soil type and hydrology.

Revegetation Plans for Stream Restoration Projects

Containerized Plants

- Recommendations for containerized plants should be determined on a percentage basis by species to facilitate ecological functionality, minimize interspecific competition, and promote proper revegetation.
- Plant mixes should site-appropriate and, where possible, of an ecotypic (local native) nature. Appropriate mixes are based upon hydrology, elevation, biophysical characteristics, and reference areas, and should be determined using the CWCB revegetation matrix. Distinct mixes are required for each hydrologic zone. Where project sites intersect with USFS land, USFS plant materials requirements will be followed for all species.
- Plant specifications should include an accurate description by species, container size, and percentage of mix, as well as readiness time and recommended nursery source.
- All plants shall be inspected prior to installation by the project vegetation ecologist to confirm proper species, source, vigor, and readiness.
- Containers should be maintained in a shaded, moist, and cool condition from the time of pick-up from or delivery by the providing nursery through the time of installation, including during transportation and upon delivery to the installation site.
- Planting sites will be pre-flagged by hydrology, ecological zone, and spacing prior to implementation. Two-foot (2-foot) spacing (12,632 plants/ac) is recommended for herbaceous materials, while 3-foot (5,578 plants/ac) or 4-foot centers (3,158 plants/ac) are recommended for shrubs, and 6-foot (1,293 plants/ac) to 8-foot (784 plants/ac) is recommended for trees.
- The recommended size for graminoid (grasses and grasslikes) and forbs is 10 cubic inch plugs, and the recommended size for woody plants is 1-quart materials. Deep-root or tall-pots may be more applicable for woody materials at sites with greater depths to water.
- Plant materials cost (including collection time, if applicable) and implementation costs should be included within the revegetation plan.
- Means of implementation (shovel, auger, etc.) should be clearly outlined and achievable within a given site's substrate conditions.
- Planting holes for containerized stock should be hand dug to allow deep root penetration for maximum stability. Holes should be dug to the depth of the plant root ball.
- Holes should be watered before planting, then filled, tamping down the soil to remove air pockets, and then watered again immediately.
- Wood mulch, or other weed-free biodegradable mulch should be installed around all containerized stock.
- All planting shall take place under the supervision of the project vegetation ecologist to help ensure that appropriate planting methods are used and that plant survival is maximized.
- The need for a supplemental watering/irrigation plan and soil amendments should be determined prior to container planting.
- All permit requirements must be compiled and submitted during the project planning phase.

Revegetation Plans for Stream Restoration Projects

Bioengineering

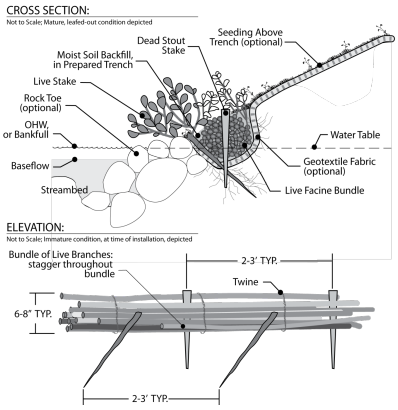
Plant material recommendations should follow the guidelines presented under seeding, cutting, and container planting information. This includes species, percentage, plant materials type, timing, vigor, size, and plant and/or cutting number, source, handling as well as applicable permits, hydrology, etc.

Refer to the Living Streambanks Manual for more information about planting recommendations and plant materials resiliency to bank erosion and scour when used in bioengineering systems.

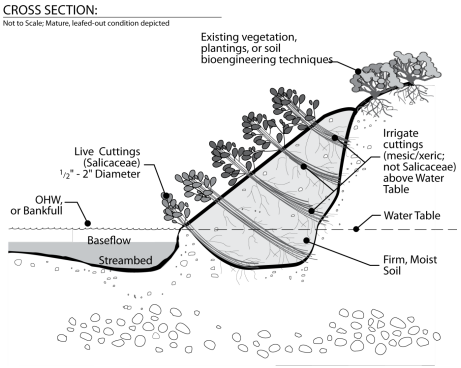
Plant material propagule type (seed, cutting, container, etc.) must be of an appropriate type, timing, and nature to work effectively with the chosen bioengineering technique. Multiple propagule types are often incorporated within the same bioengineering system (e.g., seed and cuttings; seed and plants; seed, plants, and cuttings). The cost of plant materials, including plant materials implementation, must be considered within the budget and true costs for bioengineering systems and project designs. The Revegetation Matrix includes root dimension information useful to understanding the potential contribution made by a specific species, or mix of species, to system performance and resiliency when incorporated into a given bioengineering system.

Examples of Bioengineering Treatments

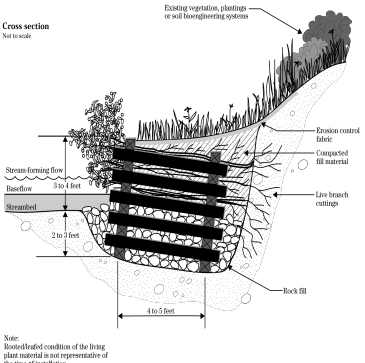
Facine



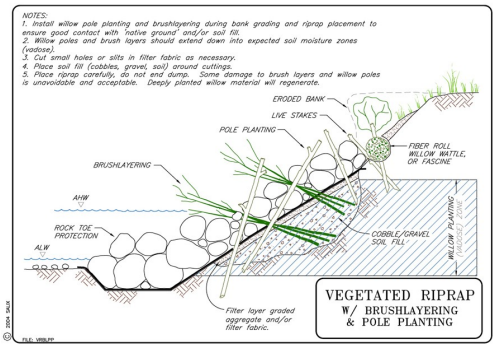
Brush Layer



Cribbing



Vegetated RipRap



Source: *Living Streambanks: A Manual of Bioengineering Treatments for Colorado Streams, CWCB, 2016.*

Revegetation Plans for Stream Restoration Projects

During and After Project Construction

Successful revegetation projects require attention, maintenance, and monitoring during and after construction.

Vegetation Quality and Warranty Information

Warranties are strongly recommended for riparian revegetation plant materials and their implementation. Specific warranties vary between propagule type and whether the plant materials are simply provided to a watershed group or installed by an independent contractor. Plant materials should be warrantied for species correctness, source, labeling, readiness, and potentially, vigor.

For seed, these factors are expressed on the certified seed tag, as required by the Colorado Department of Agriculture through the Colorado Seed Growers Association. The tag should also list noxious weed species present, if any, and state whether the seed has been tested for purity and germinability (as described by PLS).

Although container plants and seed are governed by the Colorado Department of Agriculture, certification information is deficient from most nurseries. However, an examination of plant vigor to determine that it is free of blemishes from insects, disease, and predation and, if container stock, that its root system completely fills the soil profile without being j-rooted, circular, or decadent is strongly encouraged.

If the plant materials are established by an independent contractor, in addition to the attributes described above, some degree of success for cuttings and containerized plants should be warrantied (typically 30 to 50% for cuttings and 85% for plants). However, seed emergence and establishment is rarely if ever warrantied. Warranties typically exclude hydrology, site readiness, predation, soil chemistry, and other factors that are beyond propagule vigor, source, and character.

Irrigation and Supplemental Water

If proper timing for revegetation cannot be met and/or proper hydrologic conditions do not exist, supplemental irrigation may be necessary to promote plant establishment (see page 3).

Operations and Maintenance (O&M)

Operations and Maintenance considerations should be included in the project's O&M plan, with specific attention on predation, insect and weed management, and invasive control. Some urban and developed locations may also require specific vegetation management strategies for woody and herbaceous species. Woody material may require periodic pruning or removal of dead material; herbaceous may require periodic mowing.

Monitoring

Post-construction monitoring for seed emergence; plant and cutting survival; the occurrence of noxious and/or invasive species; the rate of recruitment to the site for native species; predation and/or grazing; and erosion must be included within project design and budget. Monitoring should include determination of general plant cover and vigor as cumulative from seeding, planting, and natural recruitment; the occurrence of invasive or noxious vegetation, predation, or insect or disease damage; and the occurrence of any erosion issues.

ATTACHMENT

Field Guide for Harvesting and Installing Willow and Cottonwood Cuttings

John Giordanengo
Synergy Ecological Restoration
www.synergy3.org

Randy Mandel
Golder Associates
www.golderassociates.com

Support for this field guide and training was provided by the Colorado Water Conservation Board and Synergy Ecological Restoration, and is conducted in partnership with Rocky Mountain Flycasters.

June 06, 2015

Introduction and Purpose

This field guide covers basic techniques for selecting, harvesting, and installing willow and cottonwood cuttings for restoration projects. It also provides a basic understanding of the biology of Salicaceae, the family that includes all willow and cottonwood species. Knowledge of Salicaceae biology can inform plant selection, harvest, and storage methods, and proper techniques can play a key role the success of a diversity of restoration projects, from live staking to advanced bioengineering structures.

Importance of Willows and Cottonwoods in Restoration

In arid regions of the Rocky Mountains, willows and cottonwoods provide important wildlife cover for nesting birds and small mammals, and forage for elk, moose, and other herbivores. Willows and other riparian vegetation provide effective soil stabilization through the large web of underground roots that bind soil particles together. The above-ground biomass of riparian vegetation slows water velocities and therefore aids in reducing shear stress along stream banks, road embankments, and other erosion-prone areas. Willows have a number of characteristics that make them resilient to high-velocity flood waters, burial by sediments, long periods of inundation, high winds, and heavy browsing by wildlife. Cottonwoods provide similar benefits, as well as providing structural diversity (i.e., variety of canopy heights) in a riparian habitat. Furthermore, willows and cottonwoods provide essential shade and organic matter inputs to rivers, both of which are critical to the quality of aquatic habitats. Such riparian vegetation also facilitates nutrient uptake of effluents such as nitrates and phosphates.

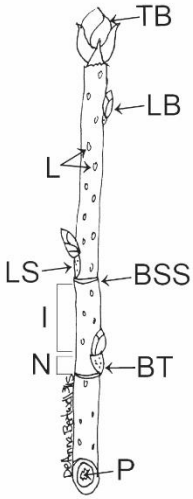
Biology, Beavers, and Benefits

Willows and cottonwoods are deciduous woody plants in the Willow Family (Salicaceae) that typically occur in mesic sites such as riparian areas (i.e., riverside habitats) and other wetland habitats. Willows are classified in the genus Salix, and cottonwoods are in the genus *Populus*. Both willows and cottonwoods have an important feature in their biology that make them excellent candidates for use in ecological restoration.

Willow and cottonwood stems can develop new roots readily from dormant buds and adventitious buds (i.e., buds that develop in an “atypical” place rather than at the branch tip or in leaf axils) when in contact with water or moist soil. This strategy is helpful in habitats where beaver routinely cut and haul willows to construct dams and lodges. Should a stem break loose and flow down river, or become dislodged by a flood, the stems root readily in the muddy riverbanks. And so in the course of riparian restoration we find ourselves following in the footsteps of the beaver. However, incorrect selection of species, as well as improper storage, handling, timing, and installation techniques, can produce widely varying results. This guide provides tips and information to help you improve your chances of success in a riparian restoration project.

Apical Control in Shrubs

All woody plants, including willows and cottonwoods, produce a mix of hormones including auxins, cytokinins, ethylene, and gibberellins. Hormones are substances that are produced in small amounts and influence the growth, development, and differentiation of cells and tissues. The specific ratio and timing of hormone release has strong control over plant growth. One example of this is known as *apical control*, where the top branches of a plant (i.e., apical or terminal buds) have an influence over the lower branches. Apical control occurs widely among willows and cottonwoods, where auxins produced by terminal buds are transported to lateral buds (i.e., buds along the stem below the terminal bud) and adventitious buds to convey a signal to "stay dormant." When the apical bud is removed by a browsing animal or severed by a willow harvester, the hormonal signal from auxin is interrupted, which stimulates the growth of lateral and adventitious buds. In heavily browsed areas, it is the removal of the terminal buds that causes a bushy appearance in both willow and cottonwood stands. Under some conditions, however, and for certain species (e.g., sandbar willow, *Salix exigua*), removal of the terminal bud may not be necessary or desirable to achieve project goals. If a tree-like willow is desired, removing the terminal bud(s) is not recommended.



TB=Terminal Bud; LB=Lateral Bud; BSS=Ring of bud scale scars from previous year's terminal bud; BT=Bundle trace in leaf scar; P=Pith; N=Node; I=Internode; LS=Leaf Scar; L=Lenticels;

Using Live Cuttings for Restoration

Thanks to the nature of willow biology, and especially to the presence of adventitious and dormant buds that form roots when wet, live cuttings (poles, stakes, or whips) can be used in a variety of restoration practices. When installed properly and under the right environmental and moisture conditions, live cuttings can develop roots and above-ground shoots rapidly. Survival of these cuttings through the first growing season can range between 45% and 90% of installed cuttings. However, subsequent survival can be highly variable, and three seasons of monitoring is recommended before claiming success or admitting defeat for any willow restoration project. Lack of adequate soil moisture, poor timing, incorrect species choice, and improper selection of willow stems are important factors associated with poor survivorship of cuttings.

Careful attention to harvesting healthy stems, proper stem diameter and age, groundwater hydrology and hydroperiod, depth of installation, and good soil-to-stem contact all contribute to successful restoration projects.

Roots sprouting from adventitious buds after 13 days of soaking. USDA-NRCS, Aberdeen Plant Materials Center

SELECTING THE RIGHT MATERIALS: GARBAGE IN = GARBAGE OUT

The best willow installation job often fails when the cuttings are not properly selected and stored ahead of time. These simple rules will improve the success of every willow and cottonwood project and help to protect the resource.

Harvest Location: Select a source population as close to your project site as feasible, preferably within the same drainage. Harvest species that occur in the same site conditions (e.g., hydrology, landscape position, elevation) as the conditions of your restoration site. Avoid sourcing plant materials more than 1,000 feet in elevation above or below your restoration site.

Healthy Stems: Always select healthy stems (i.e., "green" wood in cross-section) that are: relatively straight, covered in smooth bark (i.e., not furrowed or damaged), and free of insects, disease, or fungal damage. For most willow and cottonwood species, stems older than 4 years of age produce fewer adventitious buds and are lower in vigor than younger stems. This is especially true for species such as peachleaf willow (*Salix amygdaloides)*, Bebb's willow (*S. Bebbiana*), and many alpine and subalpine species.

HARVEST ETHICALLY -- LEAVE MORE THAN YOU TAKE!

Follow ethical harvest guidelines to conserve health of the donor stand:

- **Know before you go! Obtain approval from land owner (public or private) before harvesting. In some cases a permit may be required.**
- **Remove no more than 20% of the branches from any single willow.**
- **Never remove more than 30% of the overall canopy cover from any willow stand.**
- **Harvest stems evenly through the stand (e.g., not from one side of the plant only).**
- **In Preble's Meadow Jumping Mouse Habitat (<7,400' elevation on the Colorado Front Range), and in other sensitive wildlife habitats, more stringent harvest guidelines should be followed.**

HARVESTING AND PREPARATION

Tools: Lopping shears, hand by-pass pruners, small wood saws or brush cutters, twine, labels, buckets, trash cans.

HARVESTING & STORING

Harvest cuttings during the dormant season (i.e., between fall dormancy/leaf abscission and spring bud break):

Select stems ½ to 1¼ inches (between pinky and thumb width) in diameter for most projects. Some projects may require willow stems up to 3 inches in diameter or cottonwoods up to 6 inches in diameter (e.g., posts) where longer or stronger cuttings are required to reach deep groundwater. In this case, cuttings may need to be installed into the soil via pounding, hammer drills, water stingers, augers, or other means.

Cut stems to length, as determined by specific project needs (e.g., depth to late-summer water table, severity of erosion and flood damage). Cuttings can range from 18 inches to 12 feet long depending on depth to groundwater and height of competing vegetation. Remove the cutting with a clean diagonal cut at the base of the stem. The diagonal surface differentiates the rooting end from the above ground portion, and facilitates installation.

Leave the terminal buds and a few upper branches intact until installation. Remove all but the top few lateral (i.e., side) branches by clipping them as close to the stem as possible. Use caution to avoid damaging the stem while trimming the lateral branches. Removing lateral branches assists in transport and storage, helps maintain an appropriate root-to-shoot ratio, and reduces transpiration losses prior to root establishment. Logistically, a trimmed willow cutting is easier to install down a narrow pilot hole.

Bundle cuttings in groups of 50 or 100 by species. Keep bundles cool, moist, and shaded during transportation and on-site storage.

Prior to planting, **soak cuttings** in water for 7-14 days to increase the rate and degree of adventitious root formation. Cuttings can be soaked in buckets, streams, or ponds with well-oxygenated water. Roughly 50 to 80% of the length of the cutting should be in contact with water while soaking. Plants should be weighted down when soaked in a horizontal position. Research shows significant increase in survival for willows that are pre-soaked prior to planting (Tilley and Hoag 2008).

CAUTION – Dangerous Stowaways!

Avoid soaking cuttings in water bodies that may harbor aquatic nuisance species such as New Zealand mudsnail, Eurasian milfoil, chytrid fungus, and other pests that are exotic and known to negatively impact native species. To be safe, soak your cuttings in buckets of tap water or in water from your restoration site.

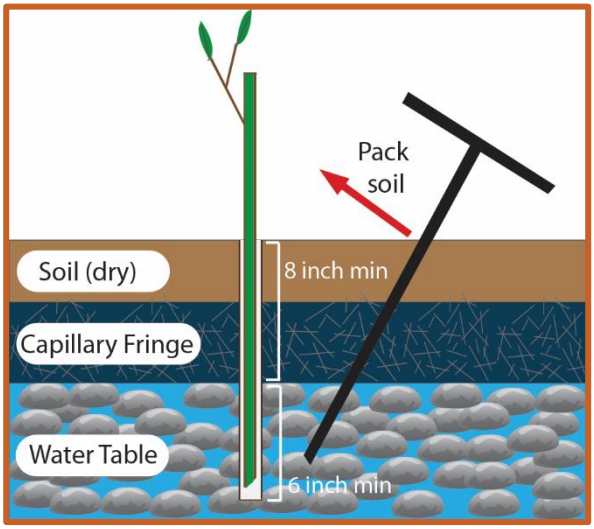
Pre-soaking willow cuttings. (USDA-NRCS, Aberdeen Plant Materials Center)

Tools: planting bars (dibbles), rebar, rubber mallet/mini sledge, post-hole diggers, electric hammer-drills, soil augers, power stingers, shovels, buckets, lopping shears.

Installing Live Cuttings

Location location location. It's as true with willow and cottonwood plantings as it is in real estate: location matters! While a full site analysis and planting location plan is beyond the scope of this field guide, some tips include: (1) previous knowledge of soil moisture, hydrographs, and/or groundwater monitoring well data is extremely helpful; (2) avoid installing cuttings in dense herbaceous wetland communities, as such soils can be anaerobic and difficult for survivorship of fresh adventitious roots; (3) avoid installing cuttings too close to the stream edge, especially in unconsolidated soils, as it is likely the eroding streambank will result in the loss of your planted materials prior to establishment; (4) avoid installing willows too far away from the water, such that the bottom of the cutting and the adjacent buds are not in contact with the low/dry-season groundwater – unless utilizing artificial irrigation.

Optimal time for willow and cottonwood planting varies by region, plant community, and local hydrologic (i.e., stream and groundwater hydrology) regime. Typically, cuttings are installed after spring thaw but before bud break, or in fall after leaves change color and/or drop. If planting in fall, be sure to install cuttings deep enough (i.e., at least 2 feet) to avoid being dislodged from the ground by winter freeze-thaw cycles. In river systems with fairly unaltered flow regimes, planting willows and cottonwoods after peak discharge (i.e, during the receding limb of the hydrograph) is recommended, as long as the timing in that location is prior to bud break. In altered systems, where surface and groundwater elevations are known to drop quickly, early season (i.e., very early spring) planting is recommended.



Pilot holes allow for easier installation without damaging the cuttings. In soft soils, pilot holes may not be necessary. Prepare pilot holes by pounding in rebar or other appropriate tools. Mechanical devices (e.g., stingers or augers) can also be used to prepare deeper holes in difficult soils.

The bottom is of top importance. The bottom 6-8 inches of the cutting should be installed below the expected dry-season water table. **NOTE: Sufficient depth of installation is the most difficult task for any laborer.** Generally, 50-80% of the cutting should is below ground.

TIP: many cuttings are not installed deep enough to reach the low-season groundwater. To adequately address this, ensure that the pilot hole reaches a depth of at least 6 inches into the estimated low-season groundwater.

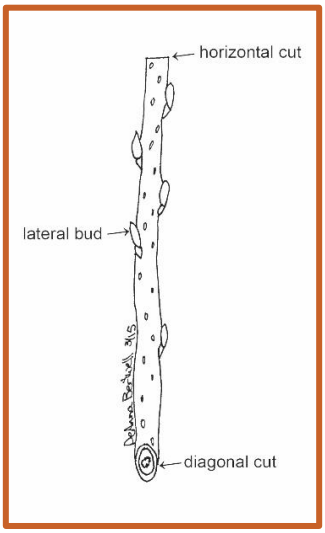
Installing Live Cuttings (continued)

Backfill around cuttings to ensure good soil-to-stem contact (i.e., without air pockets). When installing cottonwood posts or cuttings into pre-augered holes, add a pancake batter-like slurry of soil and water into the hole, allowing sediment to displace any air pockets as water leaches into underlying soil.

NOTE: Willow and cottonwood roots cannot survive in dry air! Tamp your soil around the cuttings to eliminate air pockets.

Important Installation Tips

- Remove the bottom 1 to 2 inches of the cutting with a clean diagonal cut to "freshen up" the conductive xylem cells prior to installation.
- Be sure upward-facing tips of lateral buds point sky-ward and the diagonally cut end, usually the thicker end of the cutting, is inserted into the ground.
- Under normal conditions, the above ground portion should be trimmed to maintain from 2 to three lateral buds. Trimmed top growth is less likely to snag on water-borne debris and maintains more favorable internal water relations. Longer top growth can be beneficial under highly competitive conditions so that competing plants do not overshadow the cutting during the active growing season.
- To help address the challenges of possible debris flows, the average finished height for the placed cuttings should be from 8 to 12 inches above the ground surface. It should be understood that each site will require slight adjustments in placement methodology to account for local conditions.
- Cracked, diseased, or mangled cut ends will increase susceptibility to pest damage, decreasing survival rates. If cuttings are damaged from installation, provide a clean diagonal cut just below the damaged surface.



Cluster Planting

To improve chance of establishment per planting site, install multiple cuttings in a single larger hole (cluster planting, Hoag 2009). Typically, 3 cuttings per hole is sufficient. This is a useful technique in cobble-dominated substrate such as along river banks.

Softwood Cuttings

Softwood cuttings are comprised of the current year's growth. For many non-salicaceae species, softwood cuttings can be used in a nursery setting to propagate container stock. To improve success, follow these tips:

- Perform the snap test to determine if softwood is in an appropriate stage for harvesting.
- Include 6-8 inches of softwood and 6 inches of hardwood with your cutting.
- Place entire cutting in water immediately.
- Remove all but top 3-6 leaves (before harvesting).
- Transport cuttings safely to propagation facility within four hours of harvesting (sooner the better).

GLOSSARY

Adventitious Buds/Roots: buds or roots that develop in an "atypical" place rather than at the branch tip or in leaf axils.

Apical Dominance: The phenomenon whereby the main central stem of a plant grows more strongly and readily than the lateral or side stems.

Bioengineering: Also referred to as "biotechnical slope protection," this is the integration of living woody and herbaceous materials along with organic and inorganic materials to increase the strength and structure of soil.

Buffer: A vegetated area of grass, shrubs, or trees designed to capture and filter runoff from surrounding land uses.

Canopy: The overhead branches and leaves of vegetation.

Capillary Fringe: The distance water is wicked upwards above the water table by capillary action in the soil.

Coir: A woven mat of coconut fibers used for various soil erosion control applications; Biodegrades after a period of a few years.

Fascine: A long bundle of brushwood or cuttings that is typically installed near the toe of the slope, and is used to stabilize stream banks and other slopes.

Leaf Abscission: The process by which a plant sheds some of its parts, such as leaves, spent flowers, secondary twigs, seeds, and ripe fruits.

Live Cuttings: Leafless stem cuttings of woody plant species.

Pilot Hole: A pre-drilled or augered hole in the soil substrate created in advance before installing a live cutting.

Riparian Area: An ecosystem situated between aquatic and upland environments and is characterized by greater soil moisture than adjacent upland areas. Riparian areas are periodically influenced by flooding.

Root-to-Shoot Ratio: The dry weight of root biomass divided by the dry weight of shoot biomass. A plant that has a greater biomass of leaves and stems, compared to the biomass of its roots, would have a low root-to-shoot ratio. A low root-to-shoot ratio is considered an unhealthy condition for many plants.

Stinger: A tool used to create holes to use for planting cuttings from woody species.

Wattle: A sausage-like bundle of plant cuttings used to stabilize stream banks and other slopes.

Xylem: A compound tissue found in vascular plants used to transport water and some nutrients up from its roots to its stem, leaves, and buds.

Recommended Reading and Literature Cited

For advanced techniques and additional detail, refer to the following recommended reading and literature cited.

Auble, G.T., Roelle, J.E., and A. Timberman. 2006. Riparian willow restoration at Arapaho National Wildlife Refuge. The green line online 17:4. http://coloradoriparian.org/GreenLine/V17-4/WillowRest.php.

Bentrup, G. and Hoag, J.C. 1998. The Practical Streambank Bioengineering Guide. USDA-Natural Resources Conservation Service Plant Materials Center. P.O. Box 296. Aberdeen, ID 83210. (208) 397-4133.

Gage, E.A., and D. J. Cooper. 2004. Controls on willow cutting survival in a montane riparian area. Journal of Range Management 57:597-600.

Hoag, J.C. 2007. How to plant willows and cottonwoods for riparian restoration. TN (Technical Note) Plant Materials No. 23. USDA Conservation Services, Boise, Idaho. 22 pp.

Hoag, J.C. 2009. Cluster Plantings: a way to plant live unrooted cuttings in coarse soils, including sands, gravels, and cobbles. Hoag Riparian & Wetland Restoration Guides. No. 27, December, 2009.

Native Plant Revegetation Guide for Colorado: Caring for the Land Series, V. III. 1998. Edited by Jim von Loh, Colorado State Parks, Colorado Natural Areas Program. October 1998.

Natural Resources and Parks, Water and Land Resources Division, King County, WA. 2004. Live stake cutting and planting tips. http://dnr.metrokc.gov/wlr/pi/Cutting.htm.

Schaff, S.D., Pezeshki, S.R., Shields, F.D., Jr. 2002. Effects of pre-planting soaking on growth and survival of black willow cuttings. Restoration Ecology 10:267–274.

Tilley, D., and J.C. Hoag. 2008. Evaluation of fall versus spring planting of dormant hardwood willow cuttings with and without soaking treatment. NRCS Riparian/Wetland Project Information Series No. 25, Fall 2008.

Walter, J., Hughs, D., and D. Moore. 2005. Streambank revegetation and protection: a guide for Alaska (step-by-step fliers). http://www.sf.adfg.state.ak.us/sarr/restoration/techniques/download.cfm.

Zierke, M. 1994. Riparian/ Wetland Project Information Series No. 5: Collection, establishment and evaluation of unrooted woody cuttings to obtain performance tested ecotypes of native willows and cottonwoods. United States Department of Agriculture – Natural Resources Conservation Service, Plant Materials Center, Aberdeen, ID.