ECOSYSTEM RESTORATION

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<u>BIOENGINEERING</u>:

BRUSH MATTRESS

DEFINITION

Also known as live brush mats or brush matting, a brush mattress is a combination of live stakes, live fascines, and branch cuttings installed to cover and stabilize streambanks.

PURPOSE

Brush mattresses are used to form an immediate, protective cover over the streambank. A thick mat of dormant cuttings is placed on the bank and held down with stakes. The goal of a brush mattress is to create structural streambank protection that will eventually root and provide vegetative stabilization. This technique is often used in conjunction with other methods such as live stakes and stone toe protection.

APPLICABILITY

Brush mattresses can restore riparian vegetation and habitat and enhance conditions for colonization of native plants. They reduce soil erosion and intercept sediment flowing down the streambank. After vegetation reaches a height of a few feet, it can improve fish habitat by shading the stream, lowering water temperatures and offering protection from predators. Brush mattresses are also useful on steep, fast-flowing streams.

DESIGN CONSIDERATIONS

- The brush mattress is installed by first grading the streambank to the desired stable angle. Brush mattresses are most successful on slopes not exceeding 2:1.
- A shallow trench is then cut behind the toe protection (coir fiber log, boulder revetment, etc.) and the ends of the branch cutting placed in the trench. This trench is to ensure good soil contact and water for the branches to root.
- The branches are laid down perpendicular to the stream flow until the bank is barely visible through the branches. Stakes are then driven partially into the brush mat on two-foot centers.
- In order to ensure good soil contact, as much loose soil as possible is then agitated into the brush mat. It is important for the growth of the brush mattress that as much brush mat/bank soil contact is made as possible.
- Because brush mattresses use dormant cuttings, they must be installed during the non-growing season; early spring is best.
- This measure should be initiated in conjunction with a revegetation strategy. Brush mattresses make it more difficult to establish supplemental vegetative plantings once the mats become established.

EFFECTIVENESS

The effectiveness of this practice is dependent on the site conditions and material selection. Consult a qualified professional to ensure that the system is designed and installed correctly.

MAINTENANCE

Operation and maintenance requirements vary depending on the characteristics of the stream system including velocity, flood frequency, flood stage, timing and sediment load. Regardless, the system may need repairs until vegetation becomes well-established. Inspection is necessary after each of the first few floods or at least once per year, preferably after the predominant flood season. As the brush mattress becomes established and the live cuttings root, maintenance requirements are significantly reduced.

LIVE FASCINES

DEFINITION

Fascines are dormant branch cuttings bound together into long cylindrical bundles and placed in shallow trenches on slopes to reduce erosion and shallow sliding.

PURPOSE

Live fascines are used to protect banks from washout and seepage, particularly at the edge of a stream, where water levels fluctuate moderately. Fascines are usually willow branches, but other species such as red-osier dogwood or snowberry can be used. Fascines can also be constructed of plant stems not intended for rooting (known as inert fascines).

APPLICABILITY

Live fascines are used from the baseflow elevation and up along the face of an eroded streambank, acting principally to protect the bank toe and bank face. They are also useful over the crown to improve erosion control, infiltration, and other riparian zone functions. The live fascines can also be configured to act as current deflectors and pole drains that collect and transport water, and can provide a living filter to intercept and absorb excess nutrients and pollutants before they reach the water. Fascines should be placed in shallow contour trenches on dry slopes and at an angle on wet slopes to reduce erosion and shallow sliding. They are best suited for moist soil conditions.

EFFECTIVENESS

As fascines grow roots and top cover, they can improve erosion control, infiltration, and other riparian zone functions. Additional benefits resulting from the use of both live and inert fascines include improved fisheries habitat (they provide food and cover when applied close to the edge of the stream), the provision of substrate for an array of aquatic organisms, water quality and aesthetics. However, on steep or long slope lengths, high runoff velocities can undermine live fascines near drainage channels. A significant quantity of plant material is required and it can dry out if not properly installed.

DESIGN CONSIDERATIONS

- The selection of a site for installation of live fascines should include the consideration of substrate and shade requirements for selected vegetation.
- The site should allow the roots to reach the water table during most of the growing season; and where enough soil is available to allow for root penetration.
- This practice should be used in conjunction with other structural BMPs, such as riprap, and vegetative BMPs for the purpose of maximizing soil erosion control.
- Fascines should not be planted below baseflow levels to prevent them from dying from being submerged too long.
- Live fascine construction should occur during the dormancy period, usually late fall or early spring.

MAINTENANCE

Operation and maintenance requirements are dependent on the velocity, flood frequency, flood stage, timing, and future planned use of the stream. Repairs or protective measures, such as enclosures, may be required until the vegetation becomes well established. The fascines should be inspected after each flood initially, at least twice a year the first year, and at least once a year afterwards.

LIVE STAKING/POLE PLANTING

DEFINITION

Live stakes (cuttings) and pole plantings are living plant cuttings from species that root quickly, such as willow and cottonwood.

PURPOSE

Live cuttings from plants can be used to re-establish vegetation on streambanks, providing erosion control and other benefits. Live stakes (cuttings) and pole plantings are living plant cuttings from species that root quickly, such as willow and cottonwood. The plantings grow almost immediately and form a protective layer to help prevent soil erosion. This layer is a living root mat that stabilizes the soil by reinforcing and binding soil particles together and by extracting excess soil moisture. This is a low-cost, highly effective BMP that can be easily installed and maintained on a wide variety of sites.

APPLICABILITY

This practice is applicable on all sizes of streams and for a wide range of bank characteristics. It is most appropriate where erosion is light and washout is unlikely. Live staking is a preventative measure and should be employed before severe erosion problems occur. Because live plant cuttings are more resistant to erosion than traditional seeding techniques, it is beneficial to use them on the lower portions of the bank to moderate flow velocities. They can enhance the performance of surface erosion control materials, create favorable conditions for natural colonization of vegetation from the surrounding plant community, stabilize intervening areas between other soil bioengineering techniques (such as live fascines), and produce streamside habitat.

EFFECTIVENESS

This practice should be used jointly with other restoration techniques, especially on slopes with high erosion rates. Because this is practice employs live vegetation, success is also dependent on the selection of appropriate plants for the site environment (see design considerations).

DESIGN CONSIDERATION

- Installation is best accomplished in late fall at onset of plant dormancy, in the winter as long as the ground is not frozen, or in early spring before budding growth begins.
- Vegetative cuttings are living materials and must be handled properly to avoid drying or exposure to heat. They must be installed in moist soil and adequately covered with mulch. Soil must be tamped to eliminate or minimize air pockets around buried stems.
- The recommended slope is < 3:1. This practice is not applicable for slopes > 2:1.
- Pole plantings are similar to live stakes, but a bit larger (4-10 feet long, whereas stakes may be 1/5-4 feet long), and tend to survive longer (Riley 1998).
- Applicable with other structural methods. Planting should occur on natural bank soil, not fill.
- Plantings may need to be fenced or protected from wildlife (beavers, deer, etc.).

MAINTENANCE

Once the stakes have grown and become established, no maintenance is necessary.

VEGETATED GEOGRIDS

DEFINITION

A vegetated geogrid or geotextile consists of alternating layers of live branch cut tings and compacted soil with geotextiles (natural or synthetic) wrapped around each soil lift. The system is sometimes also referred to as "fabric encapsulated soil" or "live soft gabion." The geogrid traps sediment and reinforces and rebuilds the streambank.

APPLICABILITY

Alternating layers of live branch cuttings and compacted soil with geotextiles wrapped around each soil lift.

Vegetated geogrids can be used to quickly establish riparian vegetation if they are properly designed and installed. They can enhance conditions for colonization of native vegetation. They are applicable on steeper and higher slopes than brush layering, and can tolerate higher initial flow velocities. They can be helpful for restoring outside bends where erosion is a problem.

EFFECTIVENESS

The effectiveness of a geogrid will increase with time, as vegetation becomes permanently established. The use of live woody vegetation provides erosion control, habitat and aesthetic value, while the incorporation of synthetic materials increases stability.

DESIGN CONSIDERATIONS

Systems over 7 feet in height and 20 feet in length should have an engineering analysis for slope stability. This technique requires both heavy equipment and intensive manual labor to install. Used above and below stream-forming flow conditions. Drainage areas should be generally less than 2,000 acres with stable streambeds. The system must be built during low flow condition.

OPERATIONS AND MAINTENANCE

The geogrid should be regularly monitored and repaired as necessary. In particular, it should be inspected for the formation of gullies beneath the mattress prior to the establishment of the root system. Once vegetation is established, maintenance costs are reduced considerably.

WILLOW REVETMENTS

DEFINITION

A tree revetment is constructed from whole trees (except rootwads) that are usually cabled together and anchored by earth anchors, which are buried in the bank. This technique captures sediment and enhances conditions for colonization of vegetation.

APPLICABILITY

- Not appropriate near bridges or other structures where there is high potential for downstream damage if the revetment dislodges during flood events.
- May be damaged in streams where heavy ice flows occur.

PLANNING CRITERIA & EFFECTIVENESS

- Not appropriate near bridges or other structures where there is high potential for downstream damage if the revetment dislodges during flood events.
- May be damaged in streams where heavy ice flows occur.

ADVANTAGES

- Natural appearance.
- Can use recycled material (e.g. discarded Christmas trees).
- Provides habitat value both above and below the water line.
- Protects both the toe of slope and bank from the erosive force of water.
- Has self-repairing abilities following damage after flood events if used in combination with soil bioengineering techniques.

DISADVANTAGES

- Requires periodic maintenance to replace damaged or deteriorating trees.
- May invite colonization of non-native species along with native species.

NATIVE TREE AND SHRUB PLANTING

DEFINITION

Stabilization of mined surfaces to prevent erosion, sedimentation and the degradation of surface and ground water quality.

PURPOSE

To prevent discharge of sediments or other pollutants into stream channels, drainage ways or waters of the state.

APPLICABILITY

Stabilization practices are applicable to surface disturbances resulting from mining activities that are subject to forces of erosion.

ADVANTAGES

- Trees and shrubs can provide superior, low-maintenance, long-term erosion protection. They may be particularly useful where site aesthetics are important.
- Besides their erosion and sediment control values, trees and shrubs also provide natural beauty and wildlife benefits.

DISADVANTAGES/PROBLEMS

- Except for quick-growing species; it may take a number of years for trees to reach full size.
- Trees and shrubs may be expensive to purchase and establish. They may also be more subject to theft than materials used in other practices.

PLANNING CONSIDERATIONS

- There are many different species of plants from which to choose, but care must be taken in their selection. It is essential to select planting material suited to both the intended use and specific site characteristics.
- None of these plants, however, is capable of providing the rapid cover possible by using grass and legumes. Vegetative plans must include close-growing plants or an adequate mulch with all plantings.
- When used for natural beauty and wildlife benefits, trees and shrubs are usually more effective when planted in clumps or blocks.

SPECIES SELECTION

- When erosion or sediment control is not of primary, immediate concern; areas may be stabilized using rugged, fast-growing trees and shrubs that once established have a good record of taking care of themselves. These plants may not be the best ornamentals, but establishment can usually be made with these low-maintenance trees and shrubs.

- In some cases, it may be desirable to use trees and shrubs as screening plants to shield sites such as gravel pits from public view. These plants should be given the best possible attention at planting time, with good soil water, and mulching.
- Contact your local Extension Services for recommendations on shrub and tree species for various soil conditions.

PLANTING

- Trees and shrubs will do best in topsoil. If no topsoil is available, they can be established in subsoil with proper amendment. If trees and shrubs are to be planted in subsoil, particular attention should be paid to amending the soil with generous amounts of organic matter. Mulches should also be used.
- Good quality planting stock should be used. For mass plantings, one or two- year old deciduous seedlings and 3 or 4-year old coniferous transplants should be used. For smaller planting groups or individuals specimen plants, bare rooted, container grown or balled and burlaped stock may be preferred because of their larger size. Stock should be kept cool and moist from time of receipt until planted.
- Competing vegetation, if significant, should be destroyed or suppressed prior to planting by scalping a small area where the plant is to be placed.
- Stock should be planted in the spring by May 15. No fertilizer should be used at the time of planting unless it is a slow-release type formulated for trees and shrubs. Plants should be planted at the approximate depth they were growing in the nursery; the roots should be uncrowded; the soil should be firmly packed against the roots after setting.
- Shrubs should be mulched to a depth of 4 inches or more with woodchips, bark, peat moss or crushed stone. Mulch to the edge of the planting at, but not less than, one foot from the trunk.

MAINTENANCE

- Deciduous plants should be fertilized six months to one year after planting with 1⁄4 pound of a 10-6-8 fertilizer per plant (or 25 lbs. per 1,000 sq. ft. for block plantings) or the equivalent. A slow release fertilizer is preferred. Evergreens should be fertilized half as much.
- The planting should be inspected after the first and second growing seasons. Replanting and repairs, as needed to provide adequate cover, should be scheduled. Fertilizer should be applied to shrubs every 3 to 5 years after planting.

STRUCTURAL PROTECTION

FENCING/CATTLE EXCLUSION FENCING

FENCING - GUIDELINES

Fences are needed in a number of land treatments for water quality management:

1. To exclude livestock, wildlife and federal horses from critical erosion areas, areas of toxic wastes from mining or other industry, and from critical riparian zones.
2. To control access of vehicles and people to critical erosion areas and danger zones.
3. To subdivide grazing lands and regulate grazing use.
4. To protect revegetation planting during the establishment period.

PLANNING CRITERIA

1. Design fence to meet the specific objectives of the project.
2. Where legal fences are needed, they must meet the requirements of State Statues of Nevada and the Federal land manager.
3. Select fencing materials on the basis of availability, cost, soil conditions, and objectives of the fence.
4. Where possible, avoid snowdrift areas, erosive soils, steep slopes and game migration routes.
5. Make maximum use of natural barriers.
6. Avoid creating livestock and wildlife traps; fences should not point in at sharp angles to other fences or natural barriers.
7. Fence lines should be clear of brush and trees.
8. Special provisions should be made where wildlife crossings are needed. Consult game management specialists.

STANDARD GUIDELINE SPECIFICATIONS

1. Space posts a maximum of 20 feet apart (wood posts for suspension fences a maximum of 120 feet).

2. Post sizes - wood posts six feet long with a three inch top diameter (corner posts seven to eight feet long with a five inch top); steel posts 5-1/2 feet long; 1-1/3 pounds per foot and with anchor plate. Wood posts, except juniper, should be butt-treated. Set posts 1-1/2 to two feet deep. Where higher fences are needed, longer posts will be required.

3. Brace post assemblies should be placed:

   (a) 1320 feet apart in a straight line fence on moderate terrain.
   (b) At each gate.
   (c) At each turn of 15 degrees or more.
   (d) At each point of change in the vertical angle of 10 degrees or more.

4. Barbed wire should be heavy duty galvanized, minimum gauge 12-1/2 with a minimum of four wires spaced 12 inches apart, top wire a minimum of 42 inches above the ground and bottom wire a maximum of 12 inches above the ground, except where passage of wildlife under the fence is desired.

5. Woven wire should be heavy duty galvanized with a minimum of one strand of barbed wire on top at a minimum of 42 inches above the ground. Chain-link fencing can also be used. High fences may be needed for certain uses.

6. Staples should be nine gauge or heavier, 1-1/2 inches long (2-1/2 inches for suspension fences.)

7. Use wire stays spaced 10 to 16 feet apart between posts on suspension fences. Special metal clips can be used in lieu of staples on suspension fences.

8. Electric fences can be used where temporary exclusion of livestock is needed, such as in range seedings.

9. Consider the use of solar electric fences when temporary fencing is needed to restrict use in critical riparian zones.

OFFSITE WATER DEVELOPMENT

DEFINITION

Constructing or creating a water source for cattle, away from existing waterbodies, that is beneficial for cattle, wildlife, and riparian health.

PURPOSE

Water development in upland areas that lack water can be a key factor in reducing livestock concentrations in riparian areas. Off-site watering systems that offer clean water increase cattle productivity and weight gain and require frequent and potentially daily monitoring.

CONSIDERATIONS

- Larger pastures where cattle travel a longer distance to water will require a higher capacity watering system as cattle tend to water in larger groups.
- To achieve more uniform pasture utilization in high density grazing systems, the ideal distance to water is about 800 feet. In more extensive rangeland systems, typical advice is that cattle should not have to travel farther than about two miles on flat land and no more than one mile on rugged terrain to water.
- Pasture pipeline systems allow for watering throughout a pasture instead of cattle traveling to a central watering system.
- Both ground and surface water sources can be used for off-site watering systems, but ground water sources are the most reliable as long as they are accessible.
- Electricity is the most reliable power source. If using an alternative power source, it is important to have a backup plan in case there is a malfunction in the off-site watering system.
- Off-site watering systems can be used during the winter, but adaptations to the system and frequent monitoring are necessary to prevent freezing.

BENDWAY WEIR

DEFINITION

The bendway weir is a low level, totally submerged rock structure that is positioned from the outside bankline of the riverbend, angled upstream toward the flow.

PURPOSE

These underwater structures extend directly into the navigation channel underneath passing tows. Their unique position and alignment alter the river's secondary currents in a manner which controls excessive channel deepening and reduces adjacent riverbank erosion on the outside bendway. Because excessive river depths are controlled, the opposite side of the riverbank is widened naturally. This results in a wider and safer navigation channel through the bend without the need for periodic maintenance dredging.

APPLICABILITY

In the un-revetted river bend, currents resulting from the spiraling centrifugal force action of water flowing around the bend circulate outward from the main flow line of the river. This action picks up sediment and deposits it on the inside of the bend, and erodes the outside bankline. This process causes the river to change it's course (meander).

Totally submerged rock weirs are placed on the bottom of the river angled 30 degrees upstream to the river flow. These structures are directly beneath the navigation channel, but at a depth that allows boat traffic to pass over the structures unimpeded even during low water conditions.

With the installation of bendway weirs, the secondary currents are redirected. Sediment is deposited between the bendway weirs beneath the passing tows rather than building up as a point bar on the inside of the bend. The channel remains shallow and wider than if just revetted along the outer bank.

PLANNING CRITERIA

When considering the applicability of bendway weirs for a particular project, a careful assessment of the existing bend condition, geometry, planform, stages and discharges, sediment transport capacity, and stream features must be undertaken. The current directions and velocities entering the area of the proposed weir field must be carefully measured and analyzed. Weirs should be designed for the entire range of flow conditions, but with more emphasis on medium to high flows.

In a typical bend without bendway weirs, surface water currents tend to move toward the outer bank, and highest velocities occur along the outer bank of the bend, at least up to a very high flow condition. With the use of bendway weirs, water flowing over the weir is redirected at an angle perpendicular to the axis of the weir. Thus it is especially important to know the direction of water flow during expected flow regimes. The strong secondary currents in the bend are diminished. With the weirs angled upstream, it is theorized that flow is directed away from the outer bank of the bend, and pointed toward the point bar (inner part of the bend). Flow velocities within the weir field are significantly reduced, even with weir crests well submerged. For certain flow conditions, a set of weirs are designed to act as a system to capture, control, and redirect current directions and velocities through the bend and well into the downstream crossing. Emergent weirs act in the same manner as spur dikes.

GRADE CONTROL MEASURES

DEFINITION

Grade control measures include a variety of rock, wood and earth structures placed across the channel and anchored in the streambanks to provide a "hard point" in the streambed that resists the erosion forces of the degradational zone and maintains a streambed elevation. They either raise the stream invert or maintain the channel invert at its current elevation.

PURPOSE

Culverts, channel straightening and the removal of riparian vegetation can cause undesirable changes in stream channel slope. Usually, this problem will manifest itself as an incised channel (characterized by bed erosion) or an aggrading channel with no pool or riffle sequences and a shallow, wide streambed and silty bottom.

Nearly all stream restoration projects incorporate some form of grade control in the project design. The two main types of grade control utilize logs and rock. Examples of grade control structures include Rock Vortex Weirs, Rock Cross Vanes, Step Pools, Log Drops and V-log Drops. The Stormwater Manager's Resource Center (http://www.stormwatercenter.net) provides information on each of these practices.

APPLICABILITY

If a stable channel bed is essential to the design, grade control should be considered as a first step before any restoration measures are implemented. As with other in-stream work, it is critically important to seek assistance from a qualified river engineer.

DESIGN CRITERIA

- Before instream practices are employed, the stream should be evaluated by a professional.
- The design of grade control structures should be performed by an experienced river engineer.
- These structures have the potential to become low flow migration barriers.
- This practice can be designed to allow fish passage and may help restore fish habitat if properly designed to fit the stream's characteristics.
- The placement of the structures is crucial. One common strategy is to place weirs in upstream "V's" or "U's" to create scour pools below the weir for fish habitat and resting.

EFFECTIVENESS

The effectiveness of instream practices are a function of the appropriateness of their application. Sometimes, these practices can cause unforeseen changes in the channel, as the stream might meander around the structures. The structures may be taken out by constricted stream flows or the structures may catch gravels. If effective, they can help create structural and hydraulic diversity in uniform channels. It should be taken into consideration that log weirs will eventually decompose. Proper design and installation are essential.

MAINTENANCE

These structures should be monitored to ensure that their orientation and geometry do not hinder fish migration. They should also be inspected for deposited sediment, and to bank instabilities or undesirable lateral stream movement.

J-HOOK VANE

DEFINITION

J-hook vanes are flow deflection structures that dissipate energy, deflect stream flow to the center of the channel, reduce streambank erosion, and create pools.

PURPOSE

Where applicable, the j-hook vane is a more ecologically beneficial alternative to traditional bank armor, such as riprap.

PLANNING CRITERIA & IMPLEMENTATION

The j-hook vane is effective for stream reaches which:

- are slightly-to-moderately meandering/sinuous;
- are actively incising;
- would naturally possess a riffle-pool sequence
- have a moderate to high gradient;
- have coarse bed material (small boulders/cobbles to coarse sand), which is mobile enough for scour pool formation; and,
- have few or no regions of stagnant water or backwater.

Use a j-hook vane to halt or prevent bank erosion or lateral migration in situations where it is desirable for the stream cross-section to remain constant at flows less than or equal to the design flood, and to improve pool habitat.

Consider use of the j-hook vane carefully for stream reaches which:

- have no site constraints which require the stream to remain stationary and not naturally migrate across the floodplain;
- are deeply incised or have a low width to depth ratio, as the arm slope may exceed recommended values;
- are experiencing substantial change in their cross-sectional geometry, as additional structural stabilization measures may be required;
- have an opposite bank which is also experiencing or in danger of undesirable erosion, especially in small or narrow streams where flows
- may be deflected directly into the opposite bank, causing higher erosion rates there;
- have high bedload transport, as the longer span of a j-hook vane makes it more susceptible to aggradation than the single-arm vane; or,
- have beds of very fine, mobile material (fine sands and/or silt), which increases the risk of structural failure by undercutting.

MAINTENANCE

The function of most structures can be assessed using repeated visual observations and photographs. Some additional monitoring activities to evaluate j-hook vane function include the following:

- Measure scour pool depth to ensure a pool is forming and the pool depth does not exceed the depth of pilings or footer rock layers;
- Regularly examine the adjacent streambanks for erosion or a lack of vegetation establishment;
- Examine the vane for rock displacement after storm events of a similar magnitude as the design storm, where displacement is defined as complete removal of the rock from its place, rather than minor shifting;
- Regularly examine the vane for bed aggradation or degradation upstream of the structure; and ensure that modified j-hook vanes are not creating tailwater depths greater than upstream structure elevations (i.e. upstream structures are flooded at baseflow).
- If visual assessment of the structure indicates undermining, lateral erosion, or aggradation of the structure, additional assessments, such as cross section and longitudinal surveys, can be conducted to determine what corrective action may be needed.
- Consider requesting help from local conservation or volunteer-based organizations for monitoring work that can be performed by laypeople, if resources for monitoring are unavailable or limited.

REVETMENTS (TREE AND LOG)

DEFINITION

A tree revetment is constructed from whole trees (except rootwads) that are usually cabled together and anchored by earth anchors, which are buried in the bank.

PURPOSE

This technique captures sediment and enhances conditions for colonization of vegetation.

APPLICABILITY

- Not appropriate near bridges or other structures where there is high potential for downstream damage if the revetment dislodges during flood events.
- May be damaged in streams where heavy ice flows occur.

EFFECTIVENESS

- Uses inexpensive, readily available materials to form semi-permanent protection.
- Has a limited life and needs to be replaced periodically, depending on climate and duration of tree species used.

ADVANTAGES

- Natural appearance.
- Can use recycled material (e.g. discarded Christmas trees).
- Provides habitat value both above and below the water line.
- Protects both the toe of slope and bank from the erosive force of water.
- Has self-repairing abilities following damage after flood events if used in combination with soil bioengineering techniques.

DISADVANTAGES

- Requires periodic maintenance to replace damaged or deteriorating trees.
- May invite colonization of non-native species along with native species.

STREAM CHANNEL ARMORING/LINED WATERWAY

DEFINITION

A waterway with an erosion resistant lining of concrete, stone, or other permanent material. The lined section extends up the side slopes to design flow depth. The earth above the permanent lining should be vegetated or otherwise protected.

PURPOSE

To provide for safe disposal of runoff from other conservation structures or from natural concentrations of flow, without damage by erosion or flooding, where unlined or grassed waterways would be inadequate.

APPLICABILITY

This practice applies where channel flow velocities exceed those acceptable for a grass lined waterway and/or conditions are unsuitable for the establishment of grass lined waterways. Specific conditions include:

- Concentrated runoff is of such magnitude that a lining is needed to control erosion.
- Steep grades, wetness, prolonged or continuous base flow, seepage, or piping would cause erosion.
- The location is such that use by people, animals, or vehicles preclude use of vegetated waterways.
- High value property or adjacent facilities warrant the extra cost to contain design runoff in limited space.
- Soils are highly erosive or other soil or climate conditions preclude using vegetation.

PLANNING & DESIGN CONSIDERATIONS

- Linings can consist of: rock riprap; cast-in-place concrete; flagstone mortared in place; or similar permanent linings.
- Riprap liners are considered flexible and are usually preferred to rigid liners.
- Riprap is less costly, adjusts to unstable foundation conditions, is less expensive to repair, and reduces outlet flow velocity.
- Riprap or paved channels can be constructed with grass lined slopes where site conditions warrant.
- Volume, velocity, and duration of flow expected are primary considerations for a lined waterway. Other factors include soil characteristics, safety, aesthetics, availability of land, compatibility with land use and surrounding environment, and maintenance requirements. The type of cross section that is selected depends on these factors.
- Typical cross sections that can be used include parabolic sections, and trapezoidal sections.
- Parabolic sections are suited for higher flows, but require the use of more land because the channels are generally shallow and wide. When velocities exceed the capability of vegetation, rock riprap can be used as a lining. When there is a continuous base flow in

the channel it may be possible to use a combination of rock riprap and vegetation as a lining. The base flow would be carried by the riprap section and the higher flows by the vegetated section; as long as the vegetation is capable of withstanding the velocity.

- A trapezoidal channel is usually used where the flows are relatively large and at higher velocities. Trapezoidal channels usually take up less land than parabolic channels.
- Regardless of the channel shape selected, the outlet should be checked to determine if it is stable. It may be necessary to have some type of energy dissipater to prevent scour to the receiving outlet if there is an overflow or if velocities in the contributing channel are higher than the outlet can withstand.
- The Wetlands Protection Act requires that for any stream crossing or other work conducted in a wetland resource area, or within 100 feet of a wetland resource area, the proponent file a "Determination of Applicability" or a "Notice of Intent" with the local Conservation Commission.
- Capacity: The minimum capacity should be adequate to carry the peak rate of runoff from a 10-year frequency storm.
- Cross Section: The cross section may be triangular, parabolic, or trapezoidal. Monolithic concrete may be rectangular.

VELOCITY

- Rock Riprap Lined Waterways: Rock riprap linings can be designed to withstand high velocities by choosing a stable rock size. Riprap should have a transition material (bedding) placed between the rock and the soil. This transition material can be either a well graded sand-gravel mixture or a geotextile fabric.
- Concrete-Lined Waterways: Velocity is usually not a limiting factor in the design of concrete-lined waterways. Keep in mind however that the flow velocity at the outlet must not exceed the allowable velocity for the receiving outlet.
- Drainage: Is not a factor when considering using a rock riprap waterway since subsurface water will drain through the transition material and the rock. Concrete lined channels may require drainage to reduce uplift pressure and collect seepage water.
- Filters or bedding: Filters or bedding should be used to prevent piping. Filter fabric may be used as the filter. Drains should be used, as required, to reduce uplift pressure and collect water. Weep holes may be used with drains if needed.
- Rock Riprap or Flagstone: Stone used for riprap or flagstone should be dense and hard enough to withstand exposure to air, water, freezing and thawing. Flagstone should be flat for ease of placement, and have the strength to resist exposure and breaking.

CONSTRUCTION RECOMMENDATION

- Outlet must be stable. Stabilize channel inlet points and install needed outlet protection during channel installation.
- Remove all trees, brush, stumps, and other objectionable material from channel and spoil areas and dispose of properly.
- Construct cross section to the lines and grades shown in plans. Install filter fabric or gravel layer as specified in the plan.

COMMON TROUBLE POINTS

- Foundation not excavated deep enough or wide enough: Riprap restricts channel flow, resulting in overflow and erosion.
- Side slopes too steep: Causes instability, stone movement and bank failure.
- Filter omitted or damaged during stone placement: Causes piping and bank instability.
- Riprap poorly graded or stones not placed to form a dense, stable channel lining: Results in stone displacement and erosion of foundation.
- Riprap not extended far enough downstream: Causes undercutting. Outlet must be stable.
- Riprap not blended to ground surface: Results in gullying along edge of riprap.

MAINTENANCE

- Check riprap-lined waterways periodically and after every major storm for scouring below the riprap layer, and to see that the stones have not been dislodged by the flow. Plastic filter cloth, if used, should be completely covered and protected from sunlight.
- If the rocks have been displaced or undermined, the damaged areas should be repaired immediately. Woody vegetation should not be allowed to become established in the rock riprap and if present should be removed. Debris should not be allowed to accumulate in the channel.
- Give special attention to outlets and points where concentrated flow enters channel. Repair eroded areas promptly.
- Concrete-lined waterways should be checked to ensure that there is no undermining of the channel. If scour is occurring at the outlet, appropriate energy dissipation measures should be taken.
- If the waterway is below a high sediment-producing area, sediment should be trapped before it enters.
- Check for sediment accumulation, piping, bank instability, and scour holes. Sediment and debris deposits should be removed before they reduce the capacity of the channel.

WOODY DEBRIS MANAGEMENT

DESCRIPTION

Nevada's rivers and streams contained numerous boulders, large fallen trees, logs and drift jams prior to settlement. In the first decades of colonization, pioneers cleared away debris and obstacles to allow for transportation, logging, mills, and the draining of floodplain forest to create pasture. In recent years, we have come to recognize the importance of large woody debris in river channels and the contribution it makes to channel function and fish habitat. This gives rise to the understanding that there are good log jams and then there are bad log jams.

Differentiating between the two requires knowledge of what instigated the problem from a watershed perspective, typical channel characteristics within the specific reach and the social and biological impacts at the local site level. The risk of severe flooding and erosion or fragmentation of aquatic habitats are concerns that are raised when instream woody debris causes channel obstructions.

Natural accumulations of large woody debris provide a variety of cover habitats for fish, aquatic insects, and wildlife. They also maintain channel stability by trapping sediment and organic matter while redirecting flow that scours pools and exposes larger substrates. The diameter, length, and the degree of being imbedded into the channel will indicate debris stability in the stream and whether it needs to be removed or repositioned. The width of the stream also dictates the typical orientation, with perpendicular logs common in small streams. Larger rivers typically force woody debris into a parallel direction with the current.

Large debris dams caused by changes in adjacent land use practices can have a devastating impact on fish migration, sediment transport, channel stability and increase the threat of flooding. When social values are at risk or some form of serious biological impact is identified, the obstructions should be removed in order to restore channel function and reduce possible harm. Otherwise, natural woody debris should be left alone because it's important to the stream ecosystem. Debris that it is not natural (e.g. shopping carts, trash, etc.) should be removed.

APPLICABILITY

Recognizing the importance, identifying stable forms, and evaluating the function of large woody debris are fundamentals to determining which material should be removed or retained. For the most part, removal of debris obstructions will focus on instream material that has potential to increase ice jamming, flooding and erosion or present impassable barriers to fish migration. Debris removal, as a stream rehabilitation technique, is applied in cases where the watercourse or watershed has been significantly altered in terms of forest removal, catastrophic events, drastic changes in hydrology (increased stormwater runoff volume and frequency) or channelization. It is important to recognize early in the assessment that the actual removal should be the last resort.

Having knowledge of the channel slope, width, entrenchment, sinuosity and substrate combined with the length and diameter of the logs in the obstruction will provide the basis for determining whether the woody debris should be either removed from the floodplain or salvaged for creating log sills, deflectors or cover habitat. Channel width will indicate the size of woody material that can be considered stable in the stream and the manner in which it can be positioned in relation to the flow. Slope, entrenchment, sinuosity and substrate will define the channel forms that accommodate woody structures. In general, those streams and rivers are known for their ability to sustain large woody debris based on the stable nature of the channel and limited sediment supply.

Caution should be exercised in gravel, sand and silt-based streams where bank-placed large wood debris can aggravate erosion on the opposite bank. Generally, high gradient streams have an increased need for wood debris whereas low gradient streams are more likely to benefit from selective removal of woody debris. In addition, small streams might benefit from selected woody debris removal and larger streams benefit from adding wood debris.

Small streams (less than 24 feet wide) can support a larger amount of wood debris with a variety of diameters and lengths. In this case, most logs will orient perpendicularly or downstream to the flow. Those logs will create stable plunge pools, bank-side log jams, deflectors and instream cover when firmly anchored to the bank or bed. Hazardous debris jams are not a common concern in this situation. Larger streams and rivers (over 24 feet wide) typically transport debris smaller than 30 feet long to areas of accumulation such as log jams. Logs and trees greater than 30 feet in length will orient parallel to the high discharge flow and maintain a stable position if firmly anchored to the river bed or bank. Hazardous drift dams are more common in larger streams and rivers.

WOODY DEBRIS REMOVAL GUIDELINES

In most cases, woody debris in a stream is not a concern. In some cases, the flow impediment, sediment accumulation and habitat fragmentation caused by the log jam might prompt the need for action. The guidelines below provide a step-by-step process for developing a removal plan based on consultation, assessment, restoring channel function, and creating cover habitat. Prior to embarking on a debris removal project, there are seven important steps to be followed toward establishing agreement in principle:

1. Ownership: Find out who owns the property at risk and ask (1) if they share a similar concern regarding the obstruction and (2) if they concur with the need for removal.

2. Consultation: Meet with your Conservation District to discuss the proposed removal and related permitting issues. Determine when the least amount of impact is likely to occur as a result of debris removal. Correct timing will help mitigate biological impacts. Ask what is expected in terms of sediment control and removal of woody debris.

3. Agreement: If consensus is reached with the approval agencies and landowner that a serious flooding, erosion or biological impact exists, request their assistance in designing an obstruction removal project.

4. Plan: Once the principle of obstruction removal has been established, you will then develop a

detailed plan of action. As a general rule of thumb, the larger the channel, the more assessment and forethought required. You will need to document existing conditions related to typical channel characteristics and the nature of the obstruction.

5. Draw a plan-view sketch of the reach of stream indicating the location of the debris obstruction, thalweg, pool and riffles, access options. Take photographs.

6. Measure (1) channel widths in 30-foot increments for the reach and determine typical channel width, total length of reach and debris obstruction, (2) the drop in vertical head of the water level from one end of the debris jam to the other using a surveying scope or line level, (3) the average slope of reach with survey scope or line level, and (4) the length and diameter of a representative sample of wood debris.

7. Determine (1) if the debris is consolidated in sediment or not, (2) the nature of the sediment stored upstream of the obstruction (e.g. silt, sand, gravel, organic), (3) if the blockage provides grade control and if removal would accelerate erosion, (4) the predominate substrate for a typical section within the reach limits of the floodplain.

Once the above information has been documented, you will have the knowledge to proceed with developing the removal plan in consultation with the regulatory agencies and landowner. The measurements provide an understanding of the obstruction size and damming effect as well as the characteristics of the channel in a typical section. Determining the nature of accumulated sediment, degree of debris consolidation, typical substrate composition, and extent of floodplain will help you develop answers to questions such as:

- What should the channel look like in the location of the obstruction?
- How is this debris to be removed?
- Is a partial removal sufficient to address the impact?
- Who or what is going to remove it?
- When is it to be removed?
- How long will it take, given the resources available?
- Is there a sufficient volume of stored sediment to warrant a phased removal over several weeks or months?
- What is the closest access?
- Where is the debris to go once removed?
- Is the debris large enough to create instream cover habitat nearby or better suited for floodplain brush piles for wildlife?
- What kind of habitat structures are suitable for this type of channel?

Documented explanations should be carefully thought out because they form the basis of your removal plan. Once you have achieved a level of confidence with these answers, the removal plan should illustrate the proposed channel form through the affected section, the points of access, the location for debris piles outside of the active floodplain, and the location and type of any prescribed sediment controls. You should also include the types and locations of rehabilitation structures such as bankside cabled log jams, sweeps, floating log cover, log sills, or deflectors.

Keep in mind that streams and rivers narrower than 24 feet will accommodate more wood debris than larger channels. In this case, most large wood salvaged from drift dams should be secured to the bed or back of the channel such that it is perpendicular to the flow or oriented downstream. Generally, expect to accommodate 18 to 20 pieces of large woody debris in a 300-foot section. Rivers wider than 24 feet usually deposit the debris in the floodplain or cause it to accumulate on the outside of bends, on top of large anchored logs and boulders. Large logs are anchored at one or both ends in parallel with the flow. In this situation, it is best to construct a log deflector, sweeper or bankside cabled log jam with the salvaged material.

CONSIDERATIONS

In some cases, the buildup of large woody debris can create a hazardous situation that requires immediate attention (e.g. if a large log becomes caught under a bridge, either threatening the stability of the bridge or the safety of the people using it). In a true emergency situation, some of the careful analysis described above will understandably need to be done in a more cursory manner, if at all.

A common motivation for many people to manage and remove large woody debris in streams is to enhance navigability. Paddling clubs and others seeking to keep waterways open for paddling should be educated about the functions and values of live and dead vegetation in and extending into the water. Woody debris that may be a nuisance to paddlers may be important structure for fish, perching birds or basking turtles. People seeking to clear channels for navigation should be encouraged to only clear the minimum amount necessary to enable their boats to squeeze through.

MAINTENANCE

Under most circumstances, the expense of removing debris obstructions is limited to the cost of the crew and hand tools. Costs can escalate where heavy machinery is needed. For larger log jams, the phased approach might be required to reduce the amount of impact from sediment release. It is best to start at the downstream end and work upstream. Frequent monitoring of the area within the first year is needed to ensure that the removal has not aggravated erosion. Sediment scour will reveal buried debris that might require removal as well.

CHECK DAMS

DESCRIPTION

A check dam is a small dam constructed across a drainage ditch, swale, or channel to lower the velocity of flow. Reduced runoff velocity reduces erosion and gullying in the channel and allows sediments to settle out. A check dam may be built from stone, sandbags filled with pea gravel, or logs.

APPLICABILITY

Check dams can be used where temporary channels or permanent channels are not yet vegetated, channel lining is infeasible and velocity checks are required. This practice may be used as a temporary or emergency measure to limit erosion by reducing flow in small open channels. This practice should be used with drainage areas of 2 acres or less. Check dams may be used:

- To reduce flow in small temporary channels that are presently undergoing degradation,
- Where permanent stabilization is impractical due to the temporary nature of the problem,
- To reduce flow in small eroding channels where construction delays or weather conditions prevent timely installation of non-erosive liners.

ADVANTAGES

- Inexpensive and easy to install.
- Reduce velocity and may provide aeration of the water.
- Check dams prevent gully erosion from occurring before vegetation is established, and also cause a high proportion of the sediment load in runoff to settle out.
- In some cases, if carefully located and designed, these check dams can remain as permanent installations with very minor regrading, etc.
- They may be left as either spillways, in which case accumulated sediment would be graded and seeded, or as check dams to capture sediment coming off that site.

DISADVANTAGES

- Because of their temporary nature, many of these measures are unsightly, and they should be removed or converted to permanent check dams before dwelling units are rented or sold.
- Removal may be a significant cost depending on the type of check dam installed.
- Check dams are only suitable for a limited drainage area.
- May kill grass linings in channels if the water level remains high after rainstorms or if there is significant sedimentation.
- Reduce the hydraulic capacity of the channel.
- May create turbulence which erodes the channel banks.
- Clogging by leaves in the fall may be a problem.

PLANNING CONSIDERATIONS

- Check dams are usually made of stone. The center must be lower than the edges.
- The dams should be spaced so that the toe of the upstream dam is at the same elevation as the top of the downstream dam.
- Ensure that overflow areas along the channel are resistant to erosion from out- of-bank flow caused by the check dams.
- Check dams can also be constructed of logs, or pea gravel-filled sandbags. Log check dams may be more economical from the standpoint of material costs, since logs can often be salvaged from clearing operations. However, log check dams require more time and hand labor to install. Stone for check dams must generally be purchased. This cost is offset somewhat by the ease of installation.
- If stone check dams are used in grass-lined channels which will be mowed, care should be taken to remove all the stone from the channel when the dam is removed. This should include any stone which has washed downstream.
- Since log check dams are embedded in the soil, their removal causes more soil disturbance than will removal of stone check dams. Extra care should be taken to stabilize the area when log dams are used in permanent ditches or swales.

DESIGN AND CONSTRUCTION

- Check dams can be constructed of rock, sand bags filled with peagravel, or logs. Provide a sump immediately upstream.
- The maximum spacing between the dams should be such that the toe of the upstream dam is at the same elevation as the top of the downstream dam.
- The rock must be placed by hand or mechanical placement (do not dump rock to form dam) to achieve complete coverage of the ditch or swale and to ensure that the center of the dam is lower than the edges. The rock used must be large enough to stay in place given the expected design flow through the channel.
- Log check dams should be constructed of 4 to 6-inch diameter logs embedded into the soil at least 18 inches.
- In the case of grass-lined ditches and swales, check dams shall be removed when the grass has matured sufficiently to protect the ditch or swale unless the slope of the swale is greater than 4 percent. The area beneath the check dams shall be seeded and mulched immediately after dam removal.
- Stone displaced from face of dam: Stone size too small and/or face too steep.
- Erosion downstream from dam: Provide stone-lined apron.
- Erosion of abutments during high flow: Rock abutment height inadequate.
- Sediment loss through dam: Inadequate layer of aggregate on inside face or aggregate too coarse to restrict flow through dam.

MAINTENANCE

- Inspect after each rainfall event.
- Remove sediment accumulations.
- Check structure and abutments for erosion, piping, or rock displacement. Repair

immediately.

- Remove check dam after the contributing drainage area has been permanently stabilized. Smooth site to blend with surrounding area and stabilize according to vegetation plan.

<u>RIPARIAN RESTORATION</u>

EXCLUSION FENCING

DEFINITION

A constructed barrier to animals or people.

PURPOSE

This practice is used to accomplish the following purpose:

- Provide a means to control the movement of animals, people, and vehicles to accomplish specific conservation objectives.

CONDITIONS WHERE PRACTICE APPLIES

Apply this practice on any area where management of animal or human movement is needed.

CRITERIA

General Criteria Applicable to All Purposes

Plan, design, and construct this practice to comply with all Federal, State, and local regulations. The landowner must obtain all necessary permissions from regulatory agencies or document that no permits are required. The landowner and/or contractor is responsible for locating all buried utilities in the project area, including drainage tile and other structural measures.

Ensure all fencing materials installed are durable and of high quality, and the type and design of the fence installed meets the management objectives and site challenges. Use permanent, portable, or temporary fences based on management objectives.

Position fences to facilitate changes in management strategies, access requirements, or otherwise meet conservation objectives. The fence design and installation must include height, size, spacing, type of materials, and location of features such as gates and cattle guards.

The fence design and materials must have a life expectancy appropriate for the management system and resource objectives. Base the durability of materials in the design and location of fences on topography, environment, purpose, and management objectives. Specialized bracing, designs, and materials may be necessary to cross features such as gullies, canyons, and streams.

Design, locate, and install fences to minimize impacts on local wildlife as appropriate.
Provide for proper disposal of materials when fence construction requires the removal of existing fencing materials to prevent harm to animals, people, or equipment.

CONSIDERATIONS

Consider soil properties, soil moisture conditions, and erosion concerns. Consider livestock management and adaptive grazing strategies, trailing, access to water facilities, and wildlife deterrence or passage. Consider animal and human safety concerns by enhancing visibility of fences through design materials, fence markers, signage or fladry systems (line of rope mounted along the top of a fence, from which are suspended strips of fabric or colored flags that will flap in a breeze). Consider using natural barriers where appropriate and design and locate fences to ease access for construction, maintenance, and landscape aesthetics. Establish cleared rights-of-way to facilitate fence construction and maintenance where applicable. Avoid clearing of vegetation during the nesting and brood rearing seasons for migratory and ground nesting birds.

PLANS AND SPECIFICATIONS

Prepare plans and specifications that describe the requirements for applying the practice according to the requirements of this standard. As a minimum, include:

- Plan view or map showing layout of fence and location of gates.
- Details for fence installation showing post spacing, bracing, and gate installation.
- Material quantities and requirements.

OPERATION AND MAINTENANCE

Regular inspection of permanent, temporary, and portable fences is a part of an ongoing maintenance program that ensures proper function of the fence for the lifespan of the practice. As a minimum, include the following in the operation and maintenance plan:

- Conduct inspections of fences after storms and other disturbance events.
- Repair or replacement of loose or broken material, gates, and other forms of ingress and egress.
- Removal of trees and limbs.
- Repair or replacement of water gaps as necessary.
- Repair of eroded areas as necessary.
- Repair or replacement of markers or other safety and control features as required.
- Maintain fladry or signage as necessary.

WETLAND RESTORATION

SOIL SALVAGE

DEFINITION

Soil salvage is a pre-disturbance technique to conserve a site's topsoil, which is critical for maintaining nutrient cycling, organic matter, soil biota and plant propagules.

PURPOSE

This practice provides the proper means for salvaging and storing topsoil at construction sites. Salvaged topsoil can be reused in revegetating soils later on. Topsoil contains nutrients, seeds, other propagules, microorganisms, and living organisms, which, when salvaged and reused, will improve restoration of vegetative cover.

APPLICABILITY

Topsoil that has been salvaged from a site should be replaced only in close proximity to the location was it was removed. Topsoil stockpiles should be located where they will not be easily disturbed, erode, block drainage structures, or interfere with work on site.

Advantages:

- Minimizes damage to topsoil and its living components at construction sites.
- Increases the likelihood that vegetation restoration efforts will be successful.

Disadvantages:

- Considerable planning and coordination, topsoil analysis, stripping control, and experienced equipment operation are needed.
- Large equipment must be operated carefully and properly to salvage, stockpile, and replace topsoil.

DESIGN CONSIDERATIONS

Conduct topsoil removal, storage, and replacement in a manner that prevents soil erosion and stormwater contamination. Install all temporary and permanent BMPs as needed during both the excavation and replacement phases.

- Ensure that dust control measures are in place to prevent wind erosion of stockpiles.
- Salvage and replace topsoil in areas having the same plant community type.
- Replace topsoil as soon as possible, to prevent leaching of nutrients and loss of micro-organisms.
- Do not salvage topsoil when the ground is frozen.

INSTALLATION CONSIDERATIONS

Topsoil Removal and Salvage:

- Conduct a focused soil survey of the project area, as part of the pre-project site analysis to identify soil properties that indicate value for salvage. Excavation of test pits by backhoe is recommended. Soil properties indicating topsoil suitable for salvage are as follows:
  - Location: Depth of topsoil is usually associated with its position in the landscape. Deeper topsoils can be generally expected in depositional settings, such as draws and valley floors, while ridge tops generally have shallower topsoils.
  - Color: Brownish earth tones indicate the presence of organic matter in mineral soil. The upper portion of soil having these colors should be considered for salvage. The top of the subsoil, indicated by a distinct color and texture change, indicates the appropriate depth limit of salvage.
  - Structure: Topsoil tends to have a more developed structure (blocky, subangular blocky, or granular) than the more-massive subsoil.
  - Texture: Topsoils that contain too much sand or clay may need to be excluded, because they may be too erodible, droughty, or poorly-drained, characteristics not suited to revegetation with many plant types.
  - Root Zone: Depth of extensive rooting of plants is often a good indicator of the limits of the topsoil.
- Establish topsoil salvage limits prior to salvage operations, and document the plant community type with which the topsoil is associated.
- Ensure excavated topsoil is free of coarse debris (vegetation, rocks, and foreign materials).
- Proceed from higher to lower topographical areas when stripping topsoil.
- Remove topsoil as late as possible in the construction sequence.
- After topsoil removal, establish and maintain a clear boundary delineating the area from which soil has been stripped. Apply erosion and sediment control measures to this area until construction ends and/or revegetation is successful.

Topsoil Hauling and Storage

- Store excavated topsoil and any excavated subsoil separately.
- Store salvaged upland topsoil separately from wetland/SEZ topsoil.
- Limit steepness of topsoil piles to 3:1 (run to rise).
- Cover topsoil salvage piles with erosion control matting or geotextiles, not plastic.
- If topsoil will not be used for an extended amount of time, allow a cover of volunteer vegetation to establish. This plant cover enables some of the soil components to remain healthy and alive.

Topsoil Replacement

- When feasible, replace topsoil immediately after grading operations end.
- Till, disc, harrow, or scarify subsoil to a depth of 6 inches prior to placement of topsoil, in order to loosen compacted layers and promote infiltration.
- Spread topsoil uniformly over the designated areas to the specified depth.

- Limit foot access and equipment traffic over top-soiled areas, to prevent compaction of replaced soil.

MAINTENANCE

- Verify that only topsoil is being removed during topsoil salvage operations.
- Verify that all applicable BMPs are in place. Repair/replace perimeter controls and stockpile covers as needed to keep them functioning properly.
- Inspect areas of newly-applied topsoil to gauge success of vegetation establishment. Re-apply topsoil to areas of erosion or settlement to achieve successful revegetation.

DRYLAND RESTORATION

VERTICAL MULCHING

DEFINITION

Vertical mulching is a technique used to assist in alleviating soil compaction within critical root zones of trees.

PURPOSE

Vertical mulching reduces damage from excessive water by allowing necessary aeration during wet periods and sub-soil water penetration during dry periods. The technique also aids greatly in promoting the formation of fine feeder roots.

ADVANTAGES OF VERTICAL MULCHING

The process of vertical mulching can accomplish several simultaneous goals for the roots of a tree:

- It helps to aerate soil right where roots are located.
- It frees up more room in the soil for the two most critically important ingredients for the production of healthy roots: water and oxygen.
- It helps to inject additional organic material directly into the soil in and around the root system. These materials break down in the soil, providing sustenance for micro-organisms that are beneficial to the health of a tree, as well as creating greater root aeration which is important for the nutritional requirements of a tree.
- Promotes of water penetration to the subsoil during dry weather periods.
- Promotes of natural aeration during wet weather periods.
- Minimizes of root damage due to excess water.
- Formation of greater a number of feeder roots.

OPERATION AND MAINTENANCE

It’s recommended to speak with a qualified arborist before proceeding with vertical mulching. Certain trees may have specific requirements, and location is a determinant factor for successful mulching, so it’s important to understand its needs to ensure the best results from the vertical mulching.

SOIL SALVAGE

DEFINITION

Soil salvage is a pre-disturbance technique to conserve a site's topsoil, which is critical for maintaining nutrient cycling, organic matter, soil biota and plant propagules.

PURPOSE

This practice provides the proper means for salvaging and storing topsoil at construction sites. Salvaged topsoil can be reused in revegetating soils later on. Topsoil contains nutrients, seeds, other propagules, microorganisms, and living organisms, which, when salvaged and reused, will improve restoration of vegetative cover.

APPLICABILITY

Topsoil that has been salvaged from a site should be replaced only in close proximity to the location was it was removed. Topsoil stockpiles should be located where they will not be easily disturbed, erode, block drainage structures, or interfere with work on site.

Advantages:

- Minimizes damage to topsoil and its living components at construction sites.
- Increases the likelihood that vegetation restoration efforts will be successful.

Disadvantages:

- Considerable planning and coordination, topsoil analysis, stripping control, and experienced equipment operation are needed.
- Large equipment must be operated carefully and properly to salvage, stockpile, and replace topsoil.

DESIGN CONSIDERATIONS

Conduct topsoil removal, storage, and replacement in a manner that prevents soil erosion and stormwater contamination. Install all temporary and permanent BMPs as needed during both the excavation and replacement phases.

- Ensure that dust control measures are in place to prevent wind erosion of stockpiles.
- Salvage and replace topsoil in areas having the same plant community type.
- Replace topsoil as soon as possible, to prevent leaching of nutrients and loss of micro-organisms.
- Do not salvage topsoil when the ground is frozen.

INSTALLATION CONSIDERATIONS

Topsoil Removal and Salvage:

- Conduct a focused soil survey of the project area, as part of the pre-project site analysis to identify soil properties that indicate value for salvage. Excavation of test pits by backhoe is recommended. Soil properties indicating topsoil suitable for salvage are as follows:
    - Location: Depth of topsoil is usually associated with its position in the landscape. Deeper topsoils can be generally expected in depositional settings, such as draws and valley floors, while ridge tops generally have shallower topsoils.
    - Color: Brownish earth tones indicate the presence of organic matter in mineral soil. The upper portion of soil having these colors should be considered for salvage. The top of the subsoil, indicated by a distinct color and texture change, indicates the appropriate depth limit of salvage.
    - Structure: Topsoil tends to have a more developed structure (blocky, subangular blocky, or granular) than the more-massive subsoil.
    - Texture: Topsoils that contain too much sand or clay may need to be excluded, because they may be too erodible, droughty, or poorly-drained, characteristics not suited to revegetation with many plant types.
    - Root Zone: Depth of extensive rooting of plants is often a good indicator of the limits of the topsoil.
- Establish topsoil salvage limits prior to salvage operations, and document the plant community type with which the topsoil is associated.
- Ensure excavated topsoil is free of coarse debris (vegetation, rocks, and foreign materials).
- Proceed from higher to lower topographical areas when stripping topsoil.
- Remove topsoil as late as possible in the construction sequence.
- After topsoil removal, establish and maintain a clear boundary delineating the area from which soil has been stripped. Apply erosion and sediment control measures to this area until construction ends and/or revegetation is successful.

Topsoil Hauling and Storage

- Store excavated topsoil and any excavated subsoil separately.
- Store salvaged upland topsoil separately from wetland/SEZ topsoil.
- Limit steepness of topsoil piles to 3:1 (run to rise).
- Cover topsoil salvage piles with erosion control matting or geotextiles, not plastic.
- If topsoil will not be used for an extended amount of time, allow a cover of volunteer vegetation to establish. This plant cover enables some of the soil components to remain healthy and alive.

Topsoil Replacement

- When feasible, replace topsoil immediately after grading operations end.
- Till, disc, harrow, or scarify subsoil to a depth of 6 inches prior to placement of topsoil, in order to loosen compacted layers and promote infiltration.
- Spread topsoil uniformly over the designated areas to the specified depth.
- Limit foot access and equipment traffic over top-soiled areas, to prevent compaction of replaced soil.

MAINTENANCE

- Verify that only topsoil is being removed during topsoil salvage operations.
- Verify that all applicable BMPs are in place. Repair/replace perimeter controls and stockpile covers as needed to keep them functioning properly.
- Inspect areas of newly-applied topsoil to gauge success of vegetation establishment. Re-apply topsoil to areas of erosion or settlement to achieve successful revegetation.

SOIL DECOMPACTION

DEFINITION

Soil decompaction is a process where soils that have been compressed over time are mechanically manipulated, creating fissures, gaps and air pockets.

PURPOSE

This allows for greater nutrient uptake greater water movement and importantly allows for invertebrate movement through the soil.

APPLICABILITY & METHODS

Soil decompaction is usually recommended when areas around trees have been historically compacted for a long time, such as parks or street trees.

Winged subsoiler:
This pull-behind implement decompacts soil without inverting the topsoil. It creates large gaps that allow deep penetration of water into the soil, improving both soil moisture and further decompaction through freeze-thaw processes. It should not be used on very wet soils, as it will not break up clods effectively.

Standard mounding:
Soil is scooped and placed in a mound adjacent to the newly created hole. This method is recommended for wet sites, as excavators are better able to access them, and the mounds create raised microsites favorable for plant growth.

Straight ripper shank:
One or two vertically mounted shanks are pulled behind a dozer. This implement is most effective on dry soils with a low clay content and may be used to pre-treat extremely dry, compacted sites prior to using a winged subsoiler. Crossripping is recommended on sites that are severely compacted.

Rough and loose mounding:
Soil is scooped and placed partially within the newly created hole. This approach creates a very heterogeneous soil surface.

MAINTENANCE & CONSIDERATIONS

Decompaction equipment, timing and depths must be carefully planned to avoid damaging soils. The winged subsoiler, for example, will do little to break up soil clods in wet soils, and decompacting very dry soils increases the risk of mixing the topsoil with lower soil layers. Operations on wet, unfrozen soils may also cause additional soil compaction rather than alleviating it. Finally, decompaction must be planned in coordination with vegetation management, – seeding and/or planting, or the exposed microsites and mineral soil will be quickly overtaken by competing vegetation.

INSTREAM BMPs:

TURBIDITY CURTAINS

DEFINITION & PURPOSE

A turbidity curtain, also commonly referred to as a turbidity barrier, silt barrier or a silt curtain, is used to contain turbidity (sediment and silt) that is stirred up by construction activities taking place in or near bodies of water, dredging operations and rainwater runoff.

APPLICABILITY

The skirt is typically long enough to be within one foot of the bottom and can be used to contain various turbidity. Turbidity curtains & silt curtains are usually made in lengths of 25, 50 or 100 ft and those sections are joined to make one continuous containment barrier that encloses a worksite.

TEMPORARY CHANNEL DIVERSION

DEFINITION

A ridge or channel, or a combination ridge and channel, constructed across sloping land; or at the top or bottom of a steep slope used to convey runoff water.

PURPOSE

- To reduce slope lengths, break up concentration of runoff, and move water to stable outlets at a non-erosive velocity.
- To protect work areas from upslope runoff.
- To divert sediment-laden water to an appropriate sediment-trapping facility.

APPLICABILITY

This practice applies to construction areas where runoff can be diverted and disposed of properly to control erosion, sedimentation, or flood damage. Specific locations and conditions include:

- Above disturbed existing slopes, and above cut or fill slopes to prevent runoff over the slope;
- Across unprotected slopes, as slope breaks, to reduce slope length;
- Below slopes to divert excess runoff to stabilized outlets;
- Where needed to divert sediment-laden water to sediment traps;
- At or near the perimeter of the construction area to keep sediment from leaving the site;
- Above disturbed areas before stabilization to prevent erosion and maintain acceptable working conditions.
- Where active construction activities make the use of a permanent diversion unfeasible.

Temporary diversions may also serve as sediment traps when the site has been over excavated on a flat grade. They may also be used in conjunction with a sediment fence.

ADVANTAGES

Diversions are among the most effective and least costly practices for controlling erosion and sedimentation.

PLANNING CONSIDERATIONS

- A temporary diversion is intended to divert overland sheet flow to a stabilized outlet or a sediment trapping facility during establishment of permanent stabilization on a sloping disturbed area. When used at the top of a slope, the structure protects exposed slopes by keeping upland runoff away. When used at the base of a slope, the structure protects adjacent and downstream areas by diverting sediment-laden runoff to a sediment trapping facility.
- If the diversion is going to remain in place for longer than 15 days, it should be stabilized with temporary or permanent vegetation.
- It is important that diversions are properly designed, constructed and maintained since they concentrate water flow and increase erosion potential. Particular care must be taken in planning diversion grades. Too much slope can result in erosion in the diversion channel or at the outlet. A change of slope from steeper grade to flatter may cause deposition to occur. The deposition reduces carrying capacity and may cause overtopping

and failure.

- Frequent inspection and timely maintenance are essential to proper functioning.
- Sufficient area must be available to construct and properly maintain diversions. It is usually less costly to excavate a channel and form a ridge or dike on the downhill side with the spoil than to build diversions by other methods. Where space is limited, it may be necessary to build the ridge by hauling in dike fill material or using a sediment fence to divert the flow. Use gravel to form the diversion dike where vehicles must cross frequently.
- Temporary diversions may be planned to function one year or more, or they may be constructed anew at the end of each days grading operation to protect new fill.
- Temporary diversions may serve as in-place sediment traps if overexcavated 1 to 2 feet and placed on a nearly flat grade. The dike serves to divert water as the stage increases. A combination silt fence and channel in which fill from the channel is used to stabilize the fence can trap sediment and divert runoff simultaneously.
- Wherever feasible, build and stabilize diversions and outlets before initiating other land-disturbing activities.

DESIGN CRITERIA

Temporary diversions must be planned to be stable throughout their useful life and meet criteria given below. Otherwise, they should be designed as permanent diversions.

GRADE

The grade may be variable depending upon the topography and must have a positive grade to the outlet. The maximum channel grade should be limited to 1.0 percent.

SPACING

- Diverted runoff should outlet onto a stabilized area, into a properly designed waterway, grade stabilization structure or sediment trapping facility.
- Diversions that are to serve longer than 30 working days should be seeded and mulched as soon as they are constructed to preserve dike height and reduce maintenance.

MAINTENANCE

- Inspect temporary diversions once a week and after every rainfall.
- Damage caused by construction traffic or other activity should be repaired before the end of each working day.
- Immediately remove sediment from the flow area and repair the diversion ridge.
- Check outlets carefully and make timely repairs as needed.
- When the area protected has been permanently stabilized, remove the ridge and the channel to blend with the natural ground level, and appropriately stabilize it.