Rootwad Composites for Streambank Erosion Control and Fish Habitat Enhancement

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Complexity	Environmental Value	Cost
Low Moderate High	Low Moderate High	Low Moderate High

OVERVIEW

A rootwad composite is a combination of interlocking tree materials where a mass of tree roots, commonly called a rootwad, is utilized with other tree parts and revegetation methods to stabilize streambanks and provide aquatic habitat (Figure 1). Rootwad composites are often a cost-effective bank stabilization and habitat enhancement treatment.

Rootwad composites move the current line away from the streambank so that the bank is less susceptible to erosion through hydraulic forces (Figure 2). This, in effect, reduces the energy environment along the streambank/water interface so that riparian vegetation can provide the necessary bank protection and habitat values. Rootwad composites also generate turbulence that creates streambed scour and provides cover and substrate for aquatic organisms.

Other streambank stabilization measures generally offer less risk, but rootwad composites offer the following advantages: (1) are typically cost-effective because they utilize natural materials that are often found on or near the site; (2) eventually decompose, thus allowing the restored riparian zone to function naturally, (3) create habitat complexity, hydraulic diversity, and substrate sorting (Figure 3), and (4) induce less local sediment deposition than other flow deflection structures.

Figure 1. Rootwad composites after installation along a Montana stream

Figure 2. Project is not complete, but illustrates displacement of the current line away from the streambank (courtesy of Water Consulting, Inc.)

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Rootwad composites, like most bank stabilization treatments, have limitations. Thresholds for allowable shear stress have not been developed, so limits of their applicability have not been well-defined. Field studies suggest that they are susceptible to flanking and that their performance is highly dependent upon their orientation with respect to flow direction. Thus, the use of rootwad composites for erosion control should be limited to conditions where the up- and downstream ends are secured and at least one stable meander sequence exists upstream. However, these requirements do not limit the use of rootwad composites for habitat enhancement or augmenting riparian vegetation restoration.

Rootwad composites require a thorough and immediate revegetation plan for complete and long-term project success, and if not constructed properly, fish habitat enhancement values may be less than desired. Finally, if not orientated correctly with respect to current line and scour depth, and if protective measures for flanking are not accounted for, streambank failure may result.

PLANNING

The first step in the planning process is to determine whether rootwad composites are an appropriate tool to meet project objectives and constraints related to stability and habitat. This determination requires knowledge in many specialty areas including hydrology, hydraulic engineering, fluvial geomorphology, biology, ecology, geology, and landscape architecture.

Questions that must be addressed include the following interrelated items (not exhaustive):

1. Is stabilization necessary, or is the current and projected amount of erosion acceptable?
2. Will a management plan be established that places priority on the health of riparian vegetation after project completion?

Figure 3. Rootwad composites can offer substantial habitat complexity. Prior to installation of rootwad composites, this streambank was raw and eroding

3. Are rootwad composites the appropriate tool, given the magnitude of the erosion problem, e.g. the stream's geomorphic and morphological characteristics?
4. Are rootwad composites the appropriate tool for the desired aquatic habitat and species population dynamics?
5. Will the rootwad composites remain stable and provide the desired habitat for the particular flow regime and vegetative establishment period?
6. Is the level of risk associated with limited knowledge of allowable stress and thresholds acceptable?
7. Have consequences of failure been considered and what are they (e.g., what happens to the site and downstream conditions, if the composite becomes dislodged and moves downstream?)?
8. Are recreationalists subjected to an increased risk relative to other hazards within the stream system?
9. What riparian vegetation should be incorporated; how will the vegetation be planted; are large transplants available and what is the projected success rate based on the transplanting methods, timing, and site conditions?
10. Is there a location outside of the immediate floodplain in which to acquire the rootwad materials?
11. Are costs acceptable?

Rootwad composite projects generally cost less than other habitat enhancement and bank stabilization techniques. The costs in year 2000 dollars generally range from $12.00 to $60.00/lin. ft of streambank treated, with an average cost of about $25.00/lin. ft.

SITE CONSIDERATIONS

Although rootwad composites have the potential to function well on many types of streams, the risk of failure, habitat benefits, complication of design and construction, and overall aesthetics can differ among streams. Project success is often dependent on thorough knowledge of physical stream processes and ecological relations in the project stream, as well as experience in the design and construction of stabilization measures. Considerations when evaluating site viability for rootwad composites include, but are not limited to:

1. *Habitat Requirements*. Streambank stabilization projects where natural materials are sought to produce structural diversity, velocity differentials, scour, undercut banks, and substrate sorting are good candidates.
2. *Sediment Dynamics*. Rootwad composites should not be used where sediment deposition along the bank is desirable.
3. *Stream Size*. Rootwad composites are best suited for streams where the effective rootwad surface spans the distance between base scour elevation and near bank-full elevation (Figure 4).
4. *Planform Stability*. Stable meander geometry must exist at least one meander sequence above and below the project area, e.g. the incoming flow direction must be consistent.
5. *Grade Stability*. Channel incision should be absent or bed elevation must be maintained naturally or by other grade control features. Rootwads do not provide grade control.

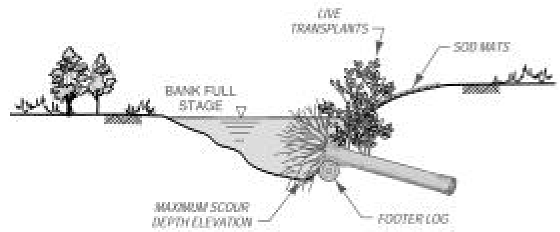

Figure 4. Elevation view. The effective rootwad surface should span the distance between maximum scour depth to near the bank-full elevation.

6. *Bank Soils*. Rootwad composites may have limited success and are considered at high risk of failure on streams where streambed and banks consist of uniform sand (<15 percent silt/clay). (An exception may be very small meandering channels).
7. *Risk*. Rootwad composites should generally be avoided in cases where failure would jeopardize lives or structures. As with many stabilization techniques, the risk of failure is higher on braided streams due to the possibility of flanking and scouring. However, rootwad composites may be more advantageous than other techniques if the cost is less for the same risk.
8. *Life*. Rootwads decompose, so the flow deflection benefits are temporary and vegetation must replace the rootwads to provide long-term stability. Rootwad composites are best where temporary (5-15 yr) stabilization is needed and riparian vegetation will thrive.

HABITAT CONSIDERATIONS

There are several factors to consider when assessing the habitat values of rootwad composites in stream restoration projects. Initially, it is important to consider the geomorphic characteristics of the stream reach. Native macroinvertebrate, algae, and fish species may not be adapted for woody substrates, and unexpected changes in these communities that are counter to the overall project objectives may result.

Limiting factors in the stream reach and overall watershed should also be considered. If woody debris is limited in the stream due to past land use activities, then rootwad composites may provide additional habitat benefits to the system over and above the benefits to bank stabilization. On the other hand, if spawning substrates are limiting, then adding woody debris in the form of rootwad composites may not improve populations because the factor directly limiting the species is not affected.

Common limiting factors that rootwads address more effectively than many other stabilization techniques include: habitat complexity, structural diversity, primary productivity, substrate attachments, velocity differentials, and overwintering habitat.

Life stage requirements and associated habitat limitations of the species of concern are factors that should also be taken into consideration. Rootwads can provide exceptional habitat for both juvenile and mature age groups of many fish species. Due to the increased complexity and diversity of cover that they provide, they are optimal places for juvenile fish to escape predation. In addition, because they create locally diverse habitat under different flows, they can provide important resting and feeding habitats.

MATERIALS

The rootwad composite consists of the following components (Figure 5):

- Rootwad with tree trunk (bole)
- Footer log
- Bank log
- Habitat limbs and tops
- Vegetation

The rootwad fan is the component that deflects the current line from the stream bank and causes the desired scour and habitat elements. Extending from the rootwad fan, the tree trunk (i.e. the "bole") is securely embedded into the stream bank. The footer log is positioned roughly parallel to the stream bank and is also securely embedded. Primarily, the footer log retains a more vertical stream bank and provides support for live transplants in the eddy zone area. It also provides additional lateral and vertical support for the rootwad bole and helps prevent minor settling and lateral adjustments due to scour and soil consolidation. (Figure 7).

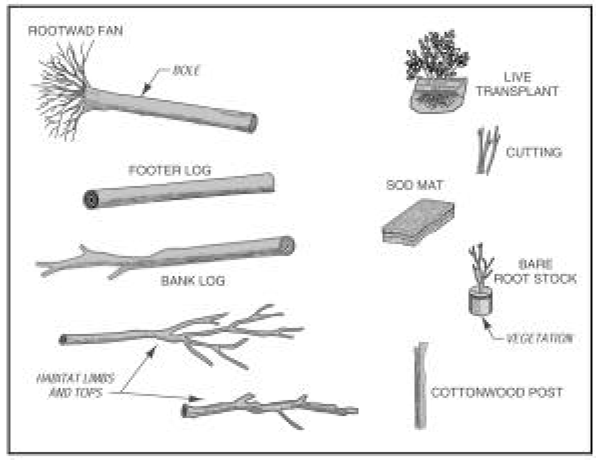

Figure 5. Components of the rootwad composite

Depending on the project design, stream size, and habitat requirements, bank logs can provide scour protection at elevations generally higher than one half bank-full stage. Bank logs also serve as retaining structures for backfill and vegetation and help provide a more vertical bank profile for fish habitat requirements. Depending on channel size, ice, and debris potential, bank logs can also extend into the channel to provide additional habitat complexity. Limbs and tops of trees can provide additional habitat complexity and microcosms for aquatic invertebrates.

Establishing riparian vegetation as part of the design is essential for stream and riparian function. It is also a fundamental requirement for the long-term success of rootwad composites, because the logs themselves are temporary. Life spans of large woody debris (LWD) structures are often underestimated. But reviews of evaluation studies suggest that a realistic life span of LWD structures is 5 to 15 years.
Factors influencing LWD structure life include:

- Tree species used (cypress, cedar, redwood, and oak last longest)
- Climate (dry and cool climates prolong life)
- Position relative to water surface (frequent wetting and drying reduces life;

continuously submerged wood lasts almost indefinitely)
- Soil contact (microbial digestion in soils limits life, but burial in anaerobic soils prolongs life considerably)

DESIGN

Rootwad composites provide streambank stabilization with specific habitat elements. The technique can be used or modified to provide additional habitat in sites that do not need stabilization, or can be used in conjunction with other techniques such as riprap or stone toe armoring to protect upper bank elevations and to provide fish cover at specific elevations. Rootwad composites have also been used successfully with channel control structures such as vanes, weirs, etc. (Figure 6).

Figure 6. Use of rootwad composites with canal check and modified weir design.

The primary design considerations for rootwad composites are a) material dimensions, configuration, and spacing,
b) habitat requirements, c) revegetation, and d) failure mechanisms.

Dimensions, Configuration, and Spacing

Dimensions

Material sizes primarily depend on stream size. The effective rootwad fan width should be sized to span from the maximum scour depth to near the bank-full elevation. If one rootwad is not sufficient, two or more can be combined, provided that backfill and structural integrity are not jeopardized.

The rootwad bole should be firmly attached to the rootwad fan. If the desired tree is standing, deep-rooted species and certain ground conditions often require careful excavation around the base of the tree before it is pushed over. If excessive pressure is applied to the tree without destabilizing the roots, a break in the bole can occur.

The necessary embedment length dictates the length of the bole and footer log. The embedment length should be sufficient to maintain the position of the rootwad structure both vertically and laterally throughout its design life. As a general rule, after the projected scour behind the rootwad, three-quarters of the length should remain securely embedded. For streams with widths less than 15 ft, bole length can be as short as 10 ft, where larger streams may require an embedment length of 20 ft or more.

Generally, specific diameter sizes are not necessary because diameter typically relates to the rootwad fan size, which is the overriding criterion. The diameter of the footer log should be at least three-quarters the diameter of the rootwad bole to provide the necessary support.

Bank logs, habitat limbs, and tops must be sized to provide the necessary function, but not hinder the strength and backfill of the structure.

Configuration

Proper configuration of the rootwad fan in relation to flow and channel elevation can not be overstated. The face of the rootwad fan must intersect the incoming velocity vectors at a 90-deg angle, but can be rotated as much as 15 deg toward the stream channel (away from the stream- bank). The rootwad fan should not be rotated towards the streambank or extend straight out into the channel or excessive bank erosion and failure may result
(Figure 7).

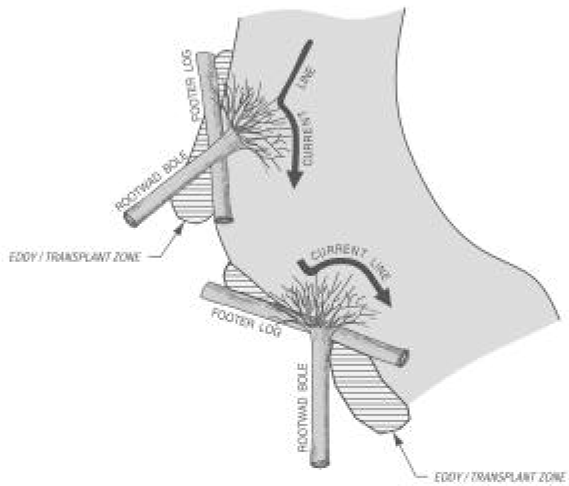

Figure 7. Orientation of the rootwad fan to velocity vectors. Rootwad bole and footer log configuration

Because the lower third of the channel receives the highest shear stress (toe zone), it is important to position the rootwad so that the root material effectively protects this zone (Figure 4). Maximum scour depths can be calculated, but such computations should be confirmed by measuring the maximum scour depth in a channel of similar size under similar energy conditions.

The angle between the footer log and rootwad bole is roughly parallel with the stream bank, but can deviate provided that function is maintained. One footer log can be utilized for two rootwads if the footer is long enough and rootwad spacing and configuration is correct (Figure 7). The rootwad is placed on the streamside of the footer log and the bole rests upon the footer log. The footer log will extend beyond the rootwad fan for a length sufficient to support the vegetation revetment (i.e. sod mats or transplants) in the eddy zone. Vertically, the footer log will be slightly higher than the maximum scour depth with the rootwad fan extended to the scour depth.

Where more conservatism is warranted, the footer log can be placed at maximum scour depth and the rootwad fan placed below maximum scour depth. On very small streams, and other situations where revetment does not need support, footer logs may not be necessary.

If a vertical bank profile is desired to maximize overhanging cover for fish, bank logs offer support for backfill and vegetation as new vegetation increases rooting strength. Bank logs are secured behind the rootwad fan or well embedded in the streambank and are generally oriented parallel to the streambank. They can also protect the upper banks from scour at high flows if the bank does not have vegetation for protection and can extend into the channel to provide additional habitat.

Tree limbs and tops can be placed between the footer log and the rootwad bole and extend downward into the stream along the streambank on the downstream side of the rootwad fan (Figure 8). These structures should extend beyond the rootwad fan only if they will not affect rootwad performance or sediment deposition, or they do not obstruct debris and ice flows.

Figure 8. Tree limbs and tops provide exceptional fish habitat. Bank logs can provide retaining support. Photo taken without stream flow

Spacing

Each composite creates a "shadow effect" downstream. The size of this region of lower velocity is dependent on the size of the rootwad and the channel planform. Spacing between rootwads is designed so that the primary velocity current is deflected away from the streambank for the distance between rootwads.

As a general rule, a spacing of 3 to 4 times the projected length of the rootwad is adequate. Figure 9 displays the maximum allowable spacing and distance of current line deflection for Rc/W (radius of curvature to top width ratios) greater than 3.0. As the radius of the bendway decreases, so should the rootwad spacing. For Rc/W less than about 2.5, the rootwads no longer deflect the flow and must effectively overlap to armor the bank. More conservative approaches can be employed as warranted, but rootwad composites are not generally recommended for such situations and their design exceeds the scope of this technical note.

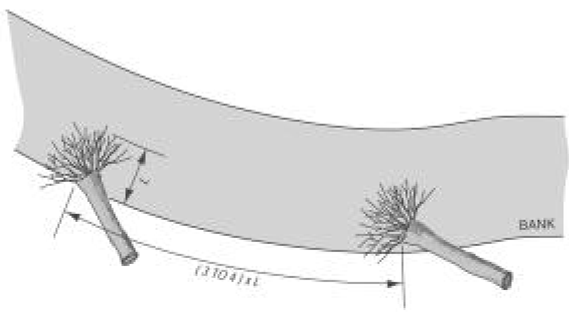

Figure 9. Rootwad spacing

Habitat Requirements

The effectiveness of rootwad composites in providing habitat benefits is dependent upon the physical characteristics of the composite structure and the associated streambed and bank. Rootwad composites are most effective in providing habitat benefits when their fans are within a few feet of the bed and bank. This allows for consistent water circulation on all sides of the structure, and provides important habitat niches along all surfaces of the structure, as well as increasing the scour and textural diversity of the corresponding bed and bank.

This spacing also allows for increased velocity diversity, which is important as flows change and alter the resting and feeding needs of fish species. In short, rootwad composites are generally more effective in providing habitat for fish species when they mimic natural conditions in terms of being less orderly and more complex.

Revegetation

An aggressive revegetation plan should be incorporated into most rootwad composite projects. Ideally, numerous live transplants are incorporated with other revegetation methods such as sod mat placements, bare root plant stock, cuttings, cottonwood posts, etc. Revegetation guidelines will be presented in other technical notes in this series, but site conditions and project objectives will dictate the best methods.

Keeping in mind that some scour is desirable for habitat complexity, vegetation is especially important in the area between the rootwad and the streambank called the "eddy zone." This zone extends slightly upstream and downstream of the rootwad and varies depending on the rootwad size and configuration. As the rootwad deflects primary velocity vectors away from the streambank, secondary velocity currents are created, and although velocities are much lower in the eddy zone, constant flow and wave action can cause bank scour if the bank is unprotected.

Transplanting large woody vegetation such as willows, dogwood, alder, etc., not only expedites revegetation and habitat, but also significantly decreases scouring within the eddy zone. Transplanting sod mats in the eddy zone is another technique that offers immediate protection.

Failure Mechanisms

Failure of rootwad composites, as well as other stabilization methods, can be attributed to several mechanisms, notably flanking, and undercutting.

Flanking occurs when the stream migrates around the structure and usually occurs when there is instability in the upstream or downstream meander geometry. This can be prevented by avoiding unstable situations, by extending the protection limits, or by keying the rootwad composites into natural or constructed control devices such as bedrock outcrops, rock or log sills, etc.

Undercutting occurs when the rootwad is placed too high in the channel and flows scour the underlying soils. The rootwad should be placed near the maximum projected or measured scour depth. Undercutting failures typically result from setting the rootwad at an improper elevation, but can occur from inadequate embedment length - minor scouring can eventually cause structure adjustments, which can eventually lead to failure.

Stone is commonly incorporated with rootwad composites, and graded stone backfill is recommended in cases where bank drainage must be maintained. When used for this purpose, some settling topsoil overburden can be expected. The practice of placing large boulders on the footer log is recommended only when it is necessary to provide additional support to the transplants and when additional bank protection in the eddy zone is warranted. In many circumstances the boulders do not improve structure stability and can add unnecessary cost to the project, especially when an aggressive revegetation plan is incorporated.

Impacts of ice flows are largely unknown, but observations of hundreds of structures suggest that correctly designed and installed rootwad composites have minimal impacts from and upon ice under normal events. But impacts could occur depending on the stream size, the magnitude of the ice event, and the nature of freeze and breakup.

CONSTRUCTION

The primary considerations concerning construction are diversion, trenching, backfill, equipment selection, and revegetation. If possible, stream flow should be diverted from the construction area, or the composites should be installed under dry or low-flow channel conditions (Figure 10).

Figure 10. Temporary water diversion through point bar

Terrace heights and location and soil conditions dictate trench heights and construction techniques. Normally, a trench is excavated for both the rootwad bole and footer log, working from the streambank (Figure 11). On streams less than 30 ft in width and where soils are unstable, it may be more desirable to eliminate individual trenches, excavate a large hole, place the materials, then backfill.

Figure 11. Trenches for rootwad bole and footer log

Where terraces are encountered, a "bench" in front of the terrace should be constructed where possible (Figure 12). This technique reduces stream bank stress on the rootwad stabilization and places vegetation at a better location in relation to the water table.

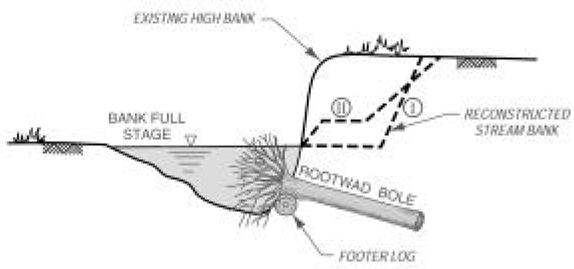

Figure 12. Bench construction at base of terrace minimizes trenching depths, reduces risk of streambank failure, and places vegetation closer to the water table

If soils have the potential to liquefy, equipment should be staged from the streambed, or construction undertaken during winter when water tables are lower or the ground surface is frozen and can support equipment. However, if the frost layer becomes too thick, backfilling and transplanting become difficult and costs can increase.

Sharpening the end of the rootwad bole and footer log with the intention of driving the ends into the bank to avoid trenching has limited success and is not recommended. Under this method, the rootwad can be destroyed, quality control for elevation and orientation is very difficult, and adequate penetration is often not possible.

Once the trenches are excavated to the proper elevations, the footer log is placed into position and the rootwad bole and fan are placed on top of the footer log according to the desired configurations. Static water level can complicate placement and often requires creativity. The excavator can place a track on one end of the footer log to hold it in place while placing the rootwad bole on top. Large boulders can sometimes hold the material in place, and then can be removed or incorporated into the backfill. It is good practice to have a person in the channel measuring elevations and checking for proper placement.

Backfilling with good materials and obtaining appropriate soil densities at specific locations is very important. There are two "zones" of backfill. The first zone is the area directly behind the rootwad called the eddy zone, which is composed of transplanted soil, roots, and vegetation, sod mats, or other revegetation media capable of protecting the bank. The second zone is the trench backfill, which is conserved from the initial excavation. Typically backfill is compacted through stringent compaction with the excavation bucket. The method of compaction should correspond with the acceptable failure risk as it relates to stream size and possible failure mechanisms.

An additional concern regarding backfill and possible failure mechanisms is the alteration of ground seepage flow patterns. Backfill material should be relatively free-draining. It should not be placed in a manner that blinds seepage horizons and creates high pore water pressures that could fail the fill.

Live transplants should be incorporated around the rootwad fan whenever possible. A divot should be dug to the desired elevation and dimensions for optimum transplant success and as much root and soil as possible should be retrieved with the transplant. For most transplants, positioning the roots in a desirable location relative to the water table is paramount and often this may mean that the base of the transplant may be buried by backfill. Transplants should be moved quickly or kept in a location and condition where the roots remain moist.

An excavator with a thumb is best suited for the majority of the work. End loaders are effective in digging and transporting sod mats and transplants. An excavator is better for digging the divot for the transplant and in compacting around the transplant. Other equipment (such as dozers) is useful for earthwork such as sloping banks and channel shaping.

APPLICABILITY AND LIMITATIONS

Techniques described in this technical note are applicable where primary objectives are to provide temporary (5 - 15 yr) stabilization and habitat enhancement while a streambank and riparian system recover from instability. Rootwad composites offer habitat diversity, erosion control, and aesthetic enhancements.

Thresholds and allowable stress for rootwad composites have not been established, and their use is in a developmental stage. Limits are somewhat dependent on scale. Caution should be exercised in large stream systems, unstable stream systems, and where a revegetation plan may have limited success. Consideration should be given to safety issues in areas where recreationalists float and swim.

Consequences of failure should be considered if the rootwad composites are washed downstream. Is failure likely to create hazards that otherwise would not occur (e.g., trapping debris and causing undesired local scour, current deflection, and flooding)?

OPERATION AND MAINTENANCE

Operation and maintenance requirements of any treatment will vary depending on the stream system and its associated parameters, such as velocity, flood frequency, flood stage, and timing. With proper placement, an aggressive vegetation plan, and consideration of precautionary measures, operation and maintenance should be minimal.

In any case, one should be prepared, at least early in the project life, to repair the system until plants can become established. Minimally, inspection should occur after each of the first few floods or at least once a year, preferably after the predominant flood season.

Undercutting and flanking of the treatment and any other substantial scour evidence should be observed. Plants should be examined for adequate survival and growth and absence of disease, insect, or other animal damage (e.g., grazing, digging, and cutting). Successful plants will grow vigorously and spread their roots throughout the surrounding substrate.

If animal damage is evident, such as plants being removed or eaten by waterfowl or ungulates, preventative measures, such as use of exclosures, may be required. Such exclosures may only need to be temporary until plants are well-established.

Assuming the rootwad composites remain in place and plants root and become established, maintenance will become much less intensive.

Fish and aquatic invertebrate sampling is always recommended both before and after installation to determine habitat improvement effectiveness.

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