Pend Oreille County

Shoreline Bank Stabilization Guide

Box Canyon Reservoir and other water bodies in Pend Oreille County

April 2016

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Box Canyon Dam (Looking Downstream)
Source: Jan Fries 2008 (see http://www.wunderground.com/wximage/JanFries/14)

1 Shoreline Bank Stabilization Guide Overview

Overview

This guide provides guidance for shoreline stabilization projects along water bodies in Pend Oreille County, focusing on the Box Canyon Reservoir. The 54-mile-long Box Canyon Reservoir begins at Box Canyon Dam, just downstream of the Town of Ione, and extends upstream (south) to the City of Newport. The shorelines along the Box Canyon Reservoir have experienced increased land development and high rates of riverbank erosion in recent years, including implementation of a large number of bank stabilization projects (Mainstream 2007).

Pend Oreille County (County) adopted a Shoreline Master Program (SMP) update in 2012 with a limited SMP amendment in 2015 (Pend Oreille County 2015). The SMP includes the provision for no net loss of ecological function of shorelines and encourages softer methods for shoreline stabilization. Per SMP XX.34.060.K, "Biotechnical bank protection measures, which may include vegetation enhancement, upland drainage controls, or planting anchor trees, are preferred. 'Hard' solutions such as the placement of riprap may only be permitted upon a finding that no other less environmentally intrusive option is feasible."

This Shoreline Bank Stabilization Guide was developed to help shoreline property owners and consultants select the best method of shoreline stabilization, including appropriate alternatives to "hard" stabilization solutions, and streamline the voluminous guidance documents available on shoreline stabilization approaches. This guide also incorporates the provisions for shoreline stabilization measures included in the County's SMP update (2015).

Using This Guide

This guide includes tables, illustrations, and design graphics to help landowners identify the most environmentally appropriate design options for addressing riverbank erosion along their shoreline properties. It also provides the information necessary to adhere to new SMP regulations.

This guide should be used along with shoreline regulations included in the County's updated SMP. The following additional guidance documents should be referred to, as appropriate:

- *Box Canyon Riverbank Stabilization Guidelines* (Mainstream 2007)
- *Integrated Stream Bank Protection Guidelines* (ISPG; WDFW 2003)
- *Stream Corridor Restoration: Principles, Processes, and Practices* (FISRWG 2001), adopted as Part 653 of the National Engineering Handbook
- Natural Resources Conservation Service (NRCS) Guidance for Stream Restoration:
  - U.S. Department of Agriculture's NRCS *National Engineering Handbook Part 650: Chapter 16 Streambank and Shoreline Protection* (NRCS 1996)
- U.S. Army Corps of Engineers (USACE) Regional General Permit #7: *Maintenance, Modification, and Construction of Overwater Structures and Bank Stabilization in the Pend Oreille River, in the State of Washington*

Pend Oreille River, near river mile 80
Source: Washington State Department of Ecology

2 Natural Shoreline Functions

The Box Canyon Dam is a run-of-the river hydroelectric facility owned and operated by the Pend Oreille County Public Utility District No. 1 (PUD). The river water surface can be raised or lowered by controlling the release of water at the dam. A naturally occurring narrowing in Box Canyon (about 150 to 200 feet wide), located about 0.5 mile upstream (south) from the dam, affects the upstream water surface elevation of the reservoir, all the way to Newport, at higher discharges.

Some areas experience pool fluctuations of up to 4 feet (downstream in the northern part of the County), and others experience river fluctuations up to 12 feet (upstream in the southern part of the County). The Box Canyon Dam and a narrow segment of the reservoir upstream affect the water surface of the reservoir. The water level in the reservoir changes relative to river flows and location within the reservoir. The mean annual fluctuations in water surface within the reservoir vary from 3 feet at Ione to 10 feet near Newport. During dry and wet years, the fluctuations can change dramatically, with dry years experiencing up to 5 feet of fluctuation and wet years experiencing up to 14 feet of fluctuation (Mainstream 2007).

The following sections generally discuss natural shoreline processes within the Box Canyon Reservoir.

Peak Flows

A peak flow (or recurrence interval flow) is a flow estimate based on the probability of the given flow to be equaled or exceeded in any given year. Statistical techniques are applied to historical flow data to estimate the probability of the flow events. For example, some recurrence intervals that are typically calculated are 2-, 10-, 25-, 50-, and 100-year recurrence intervals. The specific year of each recurrence interval is simply the statistical percentage of the event occurring in a given year. For example, a 100-year flow defines a flow event that statistically has a 1/100 or 1% chance of occurring in a given year. This is why two 100-year flow events can be seen in the same year (USGS 2015).

At Box Canyon Dam near Ione, Washington, flows of 142,500 cubic feet per second (cfs) and 84,900 cfs are the 100-year flood and 2-year flows, respectively (see Table 1).

TABLE 1

Recurrence Interval Flows for the Pend Oreille River at Newport and Ione, Washington

Station No.	Station Name	Period of Record	2-year Flow (cfs)	10-year Flow (cfs)	25-year Flow (cfs)	50-year Flow (cfs)	100-year Flow (cfs)
12395500	Pend Oreille River at Newport, Washington	1953 to 2015	81,000	118,200	130,500	137,600	143,400
12396500	Pend Oreille River at Ione, Washington	1953 to 2015	84,900	121,000	131,900	137,900	142,500

Notes:

cfs = cubic feet per second

Peak flows for analysis provided from U.S. Geological Survey gage data at the two gage sites. Recurrence interval analysis completed using Log Pearson Type III Distribution. Flow values are rounded to the nearest 100.

Riparian Conditions

The riparian zone is the vegetated area on both sides of a stream or river and generally consists of trees, shrubs, and grasses. Vegetation is a critical component of streambank stability. Riparian vegetation helps to dissipate stream flow and energy, protecting the surface from erosion. Vegetation protects streambanks in several ways (NRCS 1996):

- Root systems help hold the soil particles together, increasing bank stability.
- Vegetation may increase the hydraulic resistance to flow and reduce local velocities in small channels.
- Vegetation acts as a buffer against hydraulic forces and abrasive effects of transported materials.
- Dense vegetation on streambanks can induce sediment deposition.
- Vegetation can redirect flow away from the bank.

When shoreline vegetation is removed or altered, streambank instability often occurs. Natural shoreline functions also affect streambank stability, such as toe erosion, scour, bank seepage, and mass failures (see Erosion section for additional descriptions of these functions).

Riparian vegetation conditions along the Box Canyon Reservoir and other water bodies within the County vary depending on the level of existing development, bank heights and slopes, and water-level fluctuation along different segments of the reservoir. High rates of riverbank erosion have led to the implementation of a large number of bank stabilization projects in recent years. Following are some representative photographs documenting bank conditions along the Pend Oreille River through the Box Canyon Reservoir.

Development Along a Shallow Bank Area

Figure 1 illustrates an example of development along a shallow bank area. On the left side of the photograph, shoreline development has occurred, with landowners using differing techniques to access and protect their shorelines. Moving to the right side of the photograph, the shoreline appears to be in pre-development, with trees and other vegetation extending all the way to the water's surface.

Figure 1: Shoreline Example of Development Along Shallow Bank
Source: Bing Maps birds-eye aerials

Development Along a Steep Bank Area

Figure 2 illustrates an example of development along a steep bank area. On the left side of the photograph, shoreline development has occurred, with landowners removing vegetation for access and views. House structures rest on the top of the bank, looking over the Pend Oreille River. Moving to the right side, the shoreline appears to be in pre development, with trees extending to the top of the bank and shorter, smaller vegetation extending all the way to the water's surface.

Depending on the location along the river, the disturbance of the natural riparian conditions can leave shorelines more vulnerable to the natural process of a river channel and exacerbate erosion.

Figure 2: Shoreline Example of Development Along a Steep Bank
Source: Bing Maps birds-eye aerials

Erosion

Bank erosion is a common, natural process that occurs in rivers; however, land-use changes or natural disturbances can cause the frequency and magnitude of water forces to increase. Direct human activities, such as channel confinement or realignment, and damage to, or removal of, vegetation, are major factors in streambank erosion that typically accelerate the processes of erosion, transport, and sedimentation along a river corridor (NRCS 1996).

The practice of using rock riprap to stabilize eroding banks for the protection of property has been a popular approach in the past and continues to be implemented today. However, riprap fixes a river in place, allowing no bank deformability and subsequently limiting habitat-forming processes, which includes the recruitment of sediment and large woody debris. Because riprap is relatively permanent, it leads to long-term restraint on stream movement and habitat generation. As habitat is lost, the velocities within the channel can increase and lead to accelerated erosion to adjoining lands. This effect of hardening a river's bankline can continue and migrate downstream, affecting other property owners along the river.

Alternately, vegetative techniques to stabilize shorelines may take time to develop but can last a lifetime. The secondary effect of enriching the ecological habitat along property can also provide additional benefits to landowners by dissipating noise, reducing maintenance time and related costs, providing privacy screening, and enhancing scenic views (TVA 2015). Woody material, such as trees that have fallen along a shoreline, can serve to reduce the effect of wave action. Fallen trees also trap dislodged sediments so grasses and sedges can become established. Willow and sedges growing along the riverbank can absorb the force of waves, preventing bank erosion.

Natural Erosion Processes

There are various identifiable physical processes, also known as mechanisms of failure, which lead to erosion along the Box Canyon Reservoir and other water bodies within the County. It is important to note that erosion processes, such as toe erosion, scour bank seepage, and mass failure are natural dynamic processes that are essential for ecological health of an aquatic system. A stream's most productive and diverse habitat exists along the shoreline, where the streambank and water intersect. The interaction of water, sediment, wood, and vegetation from erosion processes helps create channel and shoreline structure, and contributes to ecosystem complexity, diversity, change, and connectivity (WDFW 2003).

Evidence of erosion occurring on a site does not necessarily mean action to stabilize conditions is necessary. Stabilization needs may vary depending on site conditions such as the severity of erosion or potential threat to existing structures. Stabilization techniques are discussed in Section 4, Design Guidance.

The natural erosion processes that occur along the Box Canyon Reservoir and other water bodies within the County are described as follows:

Figure 3: Toe Erosion with Mass Failure Along Box Canyon Reservoir
Pend Oreille River 2015

Toe erosion

Toe erosion occurs when water flow removes particles from the streambank and streambed and undermines the bank toe. This physical process can cause failure of overlying bank layers. Toe erosion occurs intermittently throughout Box Canyon Reservoir (see Figure 3). Vertical to near-vertical riverbanks, ranging in height from a few feet to more than 40 feet, have formed along the river because of toe erosion and subsequent gravity collapse of the banks. Such bank failure typically occurs when cohesive silty or clayey soils are undercut. This failure process acts to temporarily reduce and normalize these over-steepened conditions. Subsequent removal of materials from the base of these slopes regenerates them as vertical slopes. The erosion process continues as the bank retreats, and banks begin to collapse again (Mainstream 2007).

Scour

Scour is localized bed erosion greater than erosion found at other nearby locations of the streambed and bank. Water surface slope in the river is small (fewer than 6 inches per mile), and water depth during high flows can be significant (40 to 50 feet). Nonetheless, the forces of scour, even at extreme flows in the river, are small, and local scour along the banks of the Pend Oreille River within the reservoir can be considered relatively insignificant (Mainstream 2007).

Figure 4: Erosion from Bank Seepage Along Box Canyon Reservoir
Pend Oreille River 2015

Bank seepage

Water seeping through a riverbank can entrain soil particles through a process called piping. This process occurs when subsurface flow loosens soil particles until small tunnels develop. Changes in water level and groundwater seepage (caused by natural subsurface flow or human-related landscaping and irrigation activities) are common causes of piping. Excessive irrigation of residential lawns and agricultural fields can also cause ground seepage. Bank erosion from piping is evidenced as localized small failures and undermining where areas of saturated soils liquefy and fail due to the positive pore pressure from groundwater (see Figure 4; Mainstream 2007).

Mass failure

Mass failure is the downward movement of large, intact masses of soil and rock. The majority of mass failures are triggered by water saturating a slide-prone slope. Mass failures often exhibit as slumps and earthflows in near-saturated circumstances and as soil materials liquefy. Shorelines within the Box Canyon Reservoir exhibit slump and earthflow failures in two forms—relatively small bank failures (more common) and larger, more deep-seated failures (more rare). Slumps are evident as masses of soil that have slid down a slope, often with intact collections of trees and shrubs (see Figure 5). Slumps with trees are recognizable because the trees lean at an angle; large slumps with numerous trees are often seen with trees leaning in different directions (Mainstream 2007).

Figure 5: Mass Failure Erosion Along Box Canyon Reservoir
Pend Oreille River 2015

Site-specific Erosion Processes

There are also various site-based causes that can lead to these natural erosion processes described in the Natural Erosion Processes section. These causes include vegetation disturbance and removal, rapid drawdown of the reservoir water levels, wave action from wind and motorized boating activities, and freeze-thaw cycles on the reservoir surface (see the Box Canyon Riverbank Stabilization Guidelines for further discussion on these processes; Mainstream 2007).

Although all of these processes are present along the Box Canyon Reservoir, vegetation removal has been identified as the major cause of riverbank failure along the margins of the reservoir (Mainstream 2007), where vegetation on the streambanks has been removed or heavily altered to build structures, create open areas, provide views of the river, gain shoreline access (via steps and docks), and clean up the riverbank.

3 Site Assessment

A site assessment is the first step to identifying the most environmentally appropriate bank stabilization technique for addressing riverbank erosion along shoreline properties. Stabilization techniques are discussed in Section 4, Design Guidance; however, prior to selecting a technique, it is important to understand the physical conditions that are occurring on the property and identify the causes of erosion.

A Site Assessment Checklist is provided in Appendix A. In addition, the following considerations should be taken when completing the site assessment to help with developing, evaluating, and selecting the appropriate stabilization technique (HDFCD 2015):

- Physical conditions of the streambank:
  - Where does the streambank of interest fall within the stream's pattern (e.g., outside of a bend or in the middle of a straight section)?
  - How far does the streambank erosion extend upstream and downstream?
  - Where on the streambank does the erosion occur (i.e., toe of slope or upper banks)?
  - How tall is the streambank?
  - How steep is the streambank?
- Whether the streambank has been physically altered in some way:
  - Has vegetation been removed along the shoreline?
  - Has the streambank previously been stabilized with retaining walls, riprap, concrete, or sheetpiles?
  - Has the shape of the streambank been changed through excavation?
- Additional considerations include the following:
  - Is the erosion new, or has it been ongoing?
  - If erosion has been an ongoing issue, has it gotten worse in recent years?
  - Has there been recent flooding?
  - Are neighbors also having problems, or is the problem occurring only on a particular property?

In addition to completing the Site Assessment Checklist (Appendix A), a reach assessment is also recommended in locations where upstream and downstream processes may have an effect on the site. For additional detail on best practices for site and reach assessments, see Chapters 2 and 3 of the Washington Department of Fish and Wildlife (WDFW) ISPG (WDFW 2003).

Pend Oreille River, river mile 75
Source: Washington State Department of Ecology

4 Design Guidance

Bank Stabilization Techniques

This section provides a brief overview of some of the techniques to consider for stabilizing bank conditions. The County's SMP update requires that bank stabilization projects not result in a net loss of shoreline ecological function. New bulkheads and the use of gabions are prohibited under the SMP, and biotechnical bank protection measures are encouraged over hard solutions such as riprap (see Appendix B for the County's SMP Shoreline Stabilization provisions). Projects that include, vegetation enhancement, upland drainage controls and planting anchor trees are preferred. Projects should also identify proposed measures to avoid, minimize, and/or mitigate adverse environmental effects.

The techniques included in this section range in extent of engineered solutions based on the level of site risk. Table 2 provides a summary overview of the following five stabilization techniques described in this section:

- Technique 1: Monitoring with:
  - 1a: No Action
  - 1b: Site Best Management Practices (BMPs)
- Technique 2: Vegetation Establishment
- Technique 3: Bank Shaping
- Technique 4: Bioengineered Bank Treatments
- Technique 5: Toe Armor Without Bank Sloping

Additional figures and applicability guidance are provided for Techniques 2 through 5 in Appendix C – Shoreline Bank Stabilization Techniques. Appendix C also includes multiple design options for each technique.

TABLE 2

Bank Stabilization Techniques Matrix

	Applicability[1]	Description	Materials	Design Options (See Appendix C)
Technique 1: Monitor with No Action or Site BMPs	Low risk	1a – No Action: Assess existing conditions and evaluate changes over time; monitoring may lead to site BMPs. 1b – Site BMPs: Monitoring and site BMPs or the selection of additional bank treatment.	Surveying equipment, photographic documentation, plants, and mulch	N/A
Technique 2: Vegetation Establishment	Moderate risk	Remove invasive vegetation or bank hardening materials; plant native species and provide temporary erosion control and regular maintenance during plant establishment.	Plants, mulch, and temporary erosion control materials	2A: Coconut fiber roll 2B: Dormant post plantings 2C: Live stakes
Technique 3: Bank Shaping	Moderate to high risk	Excavate a low bench and slope the bank back above the bench; plant the bench with native species and provide temporary erosion control and regular maintenance during plant establishment.	Excavation and haul, plants, mulch, and temporary erosion control materials	3A: Bank shaping and planting 3B: Live fascines
Technique 4: Bioengineered Bank Treatments	Moderate to high risk	Re-slope the bank or work with existing conditions; overlay slope with geotextile system or construct a log crib, plant with native species, and provide regular maintenance during plant establishment.	Geotextiles, plants, excavation and fill, and temporary erosion control materials	4A: Branch packing 4B: Brush mattresses 4C: Tree revetments 4D: Vegetated geogrids 4E: Live cribs
Technique 5: Toe Armor Without Bank Sloping	High risk	Place rock armor at toe; slope bank back from toe, seed bank, and provide temporary erosion control.	Rock, excavation and haul, seeding, and temporary erosion control materials	5A: Joint plantings 5B: Log, rootwad, and boulder revetments 5C: Stone toe protection 5D: Riprap[2]
General Notes: • Often, a successful project may include one or more of these techniques. In all situations, it is important to monitor the site over time. • Associated cost and mitigation requirements generally increase with higher numbered techniques, which typically require more clearing and grading, and materials.				

BMP = best management practices

1 = Assessing site risk is a highly subjective yet critical process in selecting a stabilization technique. The Site Assessment Checklist (Appendix A) will help assess site risks. Lower-risk situations are generally when the probability of occurrence and outcome is less severe. Higher-risk situations are when the probability and/or the consequence of failure is high. The County will assist in assessing applicability of techniques.

2 = Per SMP XX.34.060.K, "'Hard' solutions such as the placement of riprap may only be permitted upon a finding that no other less environmentally intrusive option is feasible."

It’s also important to consider SMP provisions when selecting a shoreline stabilization technique, such as (see Appendix B for a complete list provisions included in SMP XX.34.060.K):

- SMP XX.34.060.K.1: Biotechnical bank protection measures, which may include vegetation enhancement, upland drainage controls, or planting anchor trees, are preferred. “Hard” solutions, such as the placement of rip rap, may only be permitted upon a finding that no other less environmentally intrusive option is feasible.
  a. New bulkheads are prohibited.
  b. The use of gabions is prohibited.
- SMP XX.34.060.K.3: New bank stabilization measures and the enlargement of existing structures should be designed and constructed to avoid the net loss of ecological function. Applications for bank stabilization projects should highlight proposed measures to avoid, minimize, and/or mitigate measures that may have an adverse environmental impact or an adverse effect on ecological functions.
- SMP XX.34.060.K.3.a: The County may require that the Project Sponsor prepare, at no cost to the County, a geotechnical report to address the necessity for shoreline stabilization by estimating time frames and rates of erosion and to report on the urgency associated with the specific situation.
- SMP XX.34.060.K.3.b: The size of proposed stabilization measures shall be limited to the minimum necessary.
- SMP XX.34.060.K.5 includes provisions for the replacement of existing shoreline stabilization structures.

Technique 1: Monitor with No Actions or Site BMPs

Overview
If the site is tending toward a stable condition, then landowners should monitor the site and consider whether the best course of action might be to take no action (Technique 1a) or apply site BMPs (Technique 1b) to minimize site erosion. Generally, sites that have minimal evidence of erosion and limited structural risk can benefit from this technique.

Description
The following steps apply to Technique 1a:

1. Document the riverbank in question by taking photographs and making notes about the site conditions using the direction described in Section 3, Site Assessment.
2. Monitor the site periodically and continue to document site conditions, noting any changes in the riverbank’s condition.

The following steps apply to Technique 1b:

3. Apply site BMPs described in Table 3, as needed to manage minor erosion on site.
4. If site conditions begin to develop into more serious problems, reassess the site and determine a suitable approach based on Techniques 2 through 5, described subsequently.

TABLE 3

Technique 1b: Monitor Site and Apply Site BMPs

No.	Site BMP	Erosion Process			
		Toe Erosion	Bank Seepage	Mass Failure	Scour
1	Minimize water use on lawns to reduce soil saturation.		•	•	
2	Water deeply, but infrequently to avoid shallow watering, which leads to shallow rooting and disease.		•	•	
3	Manage upland drainage such as downspouts to prevent saturation during rainfall events and reduce surface water flow down the banks.		•	•	
4	Avoid removal of native vegetation.	•	•	•	•
5	Consider alternatives to lawns, such as ground covers and native vegetation planting (see Appendix D), to reduce watering and maintenance needs.	•	•	•	•
6	Establish vegetation to address minor areas of erosion.[1]	•	•	•	•

Note:

1 = Native vegetation such as willow (Salix spp.) and red-osier dogwood (Cornus stolonifera) has wide-spreading root systems and will provide fast-growing vegetative cover. Plant selection should be informed by plant sun/shade tolerance, soil preference, and water requirements. See Table 4 and Appendix D for additional guidance on plant selections.

Table 4 provides additional guidance on what plants might be effective in improving slope stability and habitat functions.

TABLE 4

Recommended Planting Guide[1]

Common Name	Scientific Name	Size[2]	Spacing	Notes
Trees				
Black Cottonwood	*Populus balsamifera*	Pole	6-ft O.C.	100-150-ft height, rapid growth rate. Plant during dormant season (mid-Oct to mid-Mar).
Gray Alder	*Alnus incana*	1 gallon	15-ft O.C.	50-65-ft height, rapid growth rate.
Shrubs				
Black Hawthorne	*Craetagus douglasii*	1 gallon	6-ft O.C.	20-25-ft height, moderate growth rate.
Blue Elderberry	*Sambucus cerulea*	1 gallon	6-ft O.C.	6 to 18-ft height, moderate growth rate.
Common snowberry	*Symphoricarpos albus*	1 gallon	6-ft O.C.	4-ft height, plant in areas to maintain views and allow for periodic shoreline access.
Coyote willow	*Salix exigua*	Livestake	2-ft O.C.	6 to 12-ft height, moderate growth rate. Plant during dormant season (mid-Oct to mid-Mar).
Low Oregon grape	*Mahonia nervosa*	1 gallon	6-ft O.C.	2-ft height, plant in areas to maintain views and allow for periodic shoreline access. Prefers partial to full shade.
Oceanspray	*Holodiscus discolor*	1 gallon	6-ft O.C.	10-15-ft height, moderate growth rate.
Scouler's willow	*Salix scouleriana*	Livestake	2-ft O.C.	30 to 35-ft height, rapid growth rate. Plant during dormant season (mid-Oct to mid-Mar).

Note:

O.C. = On Center

1 = Please see Appendix D - Pend Oreille County Native Plants List, for additional planting options. Plants identified in this table and Appendix D may not be appropriate for all sites. Select plants consistent with surrounding vegetation and appropriate for the site. Also consider contacting the County for additional guidance.

2 = Smaller or larger sized plants may be used but would have different spacing requirements.

Materials for Technique 1 may include:

- Survey equipment (optional) for locating and tracking areas of concern (e.g., a GPS locator, total station, rod, data collector, and lath)
- Camera or other device for documenting riverbank conditions with photography
- Note-taking devices for keeping notes about site conditions
- Measurement devices for measuring bank heights, bank slopes, and other various parameters of the site
- Plants and mulch

Technique 2: Vegetation Establishment

Overview
Vegetation establishment is an option for improving bank stability in moderate risk locations. Generally, Technique 2 can be effectively applied to reaches of degraded streambank characterized by minor superficial erosion, small earth slumps, marginal vegetative cover, and a relatively wide, shallow channel cross section (WDFW 2003).

Description
Vegetative systems provide many benefits to fish and wildlife populations, as well as increasing the streambank's resistance to erosive forces. Vegetation near the channel provides shade to help maintain suitable water temperature for fish, provides habitat for wildlife and protection from predators, and contributes to aesthetic quality (NRCS 1996).

Materials for Technique 2 may include:

- Minor excavation and site preparation equipment (e.g., rakes, shovels, and buckets)
- Live stakes (see NRCS NEH Part 650.1601(d)(2)(i and ii) for material specifications)
- Coir fabric or erosion-control fabric
- Wooden stakes for holding down fabric and live fascines
- Dead-blow hammer and metal rod for pilot holes (optional)
- Native plants and seeds

Considerations when using vegetation as the primary stabilization mechanism include the following:

- Plantings require establishment time, and bank protection is not immediate.
- Maintenance may be needed to replace dead plants, control disease, or otherwise ensure materials become established and self-sustaining.
- Establishing plants to prevent undercutting and bank sloughing in a section of bank below baseflow is often difficult.
- Establishing plants in coarse, gravely material may be difficult.
- Protection and maintenance requirements are often high during plant establishment.

Example: One example is live staking, a vegetative treatment technique that involves the insertion and tamping of live, rootable vegetative cuttings into the ground with the objective for them to root and grow (NRCS 1996). Figure 6 illustrates a typical live staking design. Figure 7 shows an example of vegetation establishment in progress prior to installation of live staking.

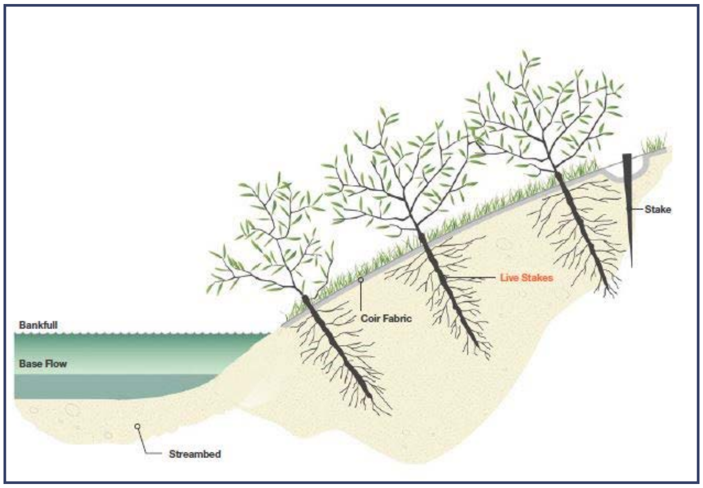


Figure 6: Typical Live Staking Design
Source: HCFCD 2015

Figure 7: Example Vegetative Planting Construction in Progress
Source: Anchor QEA, LLC, 2014. Nine Mile Creek, WA
(coir fabric with live staking to be installed)

Technique 3: Bank Shaping

Overview
Bank shaping is an option for improving bank stability in moderate- to high-risk locations. Generally, Technique 3 is commonly applied along steep or eroding streambanks undercut and failing in cohesive masses due to either toe erosion or mass failure (WDFW 2003).

Description
This technique includes reshaping of the bank to create a protective vegetative barrier of grasses and willows on a low bench to reduce the bank's susceptibility to failure. This can be achieved using seed, willow cuttings, willow fascines, and coir erosion-control fabric (see Figure 8).

Materials for Technique 3 may include the following:

- Excavators or equivalent pieces of heavy machinery for earthwork
- Loaders, dozers, or dump trucks (if necessary for excavation removal)
- Compacted fill material (topsoil)
- Granular filter material (optional)
- Erosion-control fabric (optional)
- Native seed, willow fascines, or live stakes (optional)

Considerations when using vegetation as the primary stabilization mechanism include the following:

- Plantings require establishment time, and bank protection is not immediate.
- Maintenance may be needed to replace dead plants, control disease, or otherwise ensure materials become established and self-sustaining.
- Establishing plants to prevent undercutting and bank sloughing in a section of bank below baseflow is often difficult.
- Establishing plants in coarse, gravely material may be difficult.
- Protection and maintenance requirements are often high during plant establishment.

Example: Designing live fascines is one example of bank shaping that involves long bundles of branch cuttings bound together in cylindrical structures. They are placed in shallow contour trenches on dry slopes and at an angle on wet slopes to reduce erosion and shallow sliding. Figure 8 illustrates a typical live fascine design.

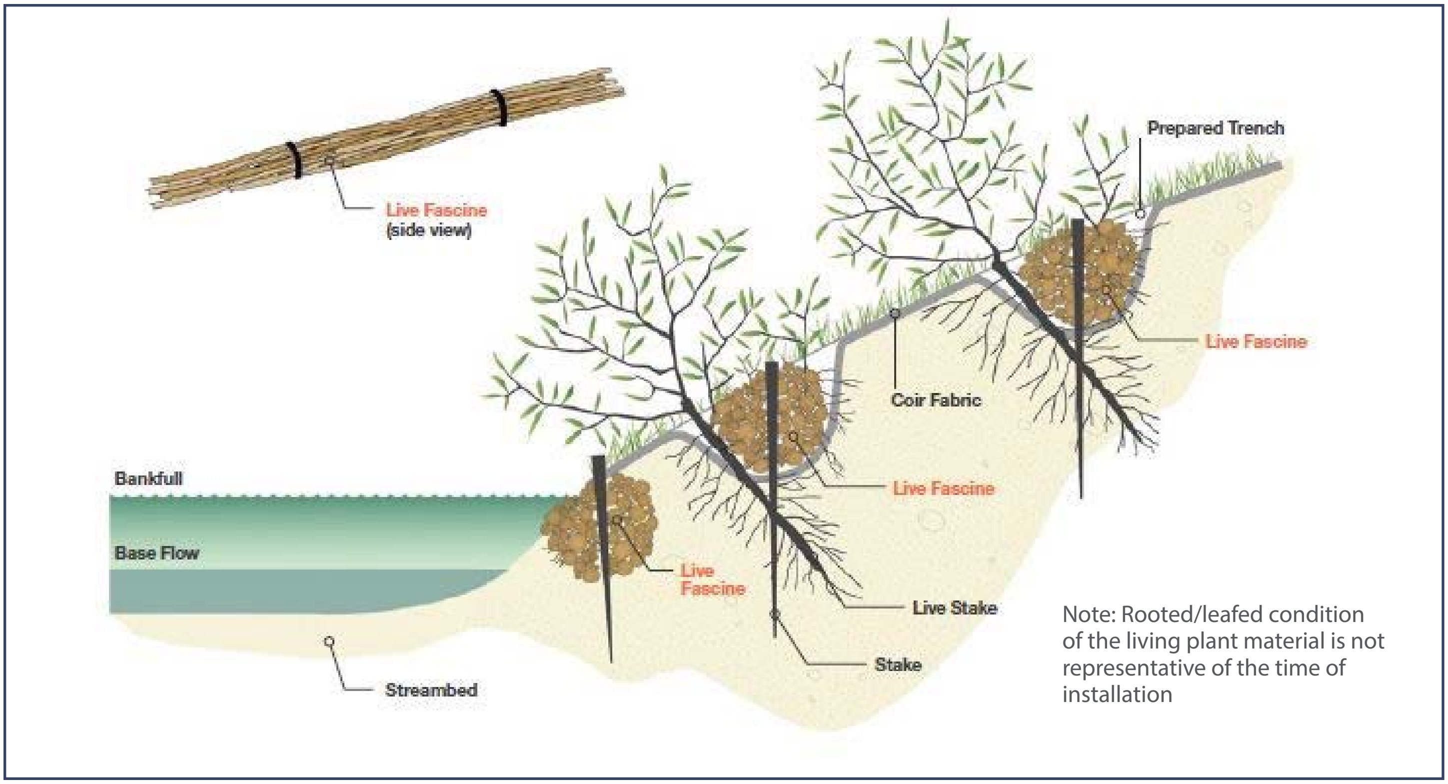


Figure 8: Typical Live Fascine Design
Source: HCFCD 2015

Design tips for Technique 3:

- Native plant species should be used (see Appendix D for a native plants list).
- Native perennial grasses should be used rather than annual grasses.
- Woody vegetation, which is seeded or planted as rooted stock, is used most successfully above maximum pool level fluctuation, on properly sloped banks, and on the floodplain adjacent to the banks.

Technique 4: Bioengineered Bank Stabilization

Overview
Bioengineering is an option for improving bank stability in moderate- to high-risk locations. Generally, Technique 4 is commonly applied along streambanks with moderate to steep slopes, significant toe erosion, or those that may require near-vertical structures to protect an eroding channel bank (WDFW 2003).

Description
Bioengineered techniques use vegetation and wood to reproduce the natural system and provide structural and surface erosion protection. Bioengineered techniques consist of entirely biodegradable components (i.e. natural material such as erosion-control fabrics, willow cuttings, and large woody debris). A major benefit of bioengineered techniques is that they are self-sustaining. Vegetation continues to grow and large, woody material continues to be contributed as it falls into the stream. In a healthy and ecologically diverse river system, the channel and channel banks contain many pieces of large woody debris, and the vegetation will be densely distributed along the banks (WDFW 2003).

Materials for Technique 4 may include the following:

- Excavation and site preparation equipment
- Natural geotextile material
- Logs that are 6 to 18 inches in diameter for live cribs
- Polyethylene or polyester thin-walled geocells
- Live branch cuttings (4 to 6 feet long)
- Coir fabric or erosion-control fabric (or filter fabric)
- Backfill soil
- Native plants and seed
- Rocks at toe (2 to 3 inches in diameter; optional)

Example: A vegetated geogrid is one example of a bioengineered stabilization technique that includes a system of soil layers or lifts reinforced with a combination of natural fabric and vegetation. The lifts are oriented along the face of a bank in a series of stepped terraces (Mainstream 2007). Geogrids are widely used to provide internal stability to slopes and embankments. Figure 9 illustrates a typical design of a vegetated geogrid.

Design tips for vegetated geogrid systems include the following:

- The system should be limited to a maximum height of 8 feet.
- The final installation should not exceed the existing bank slope.

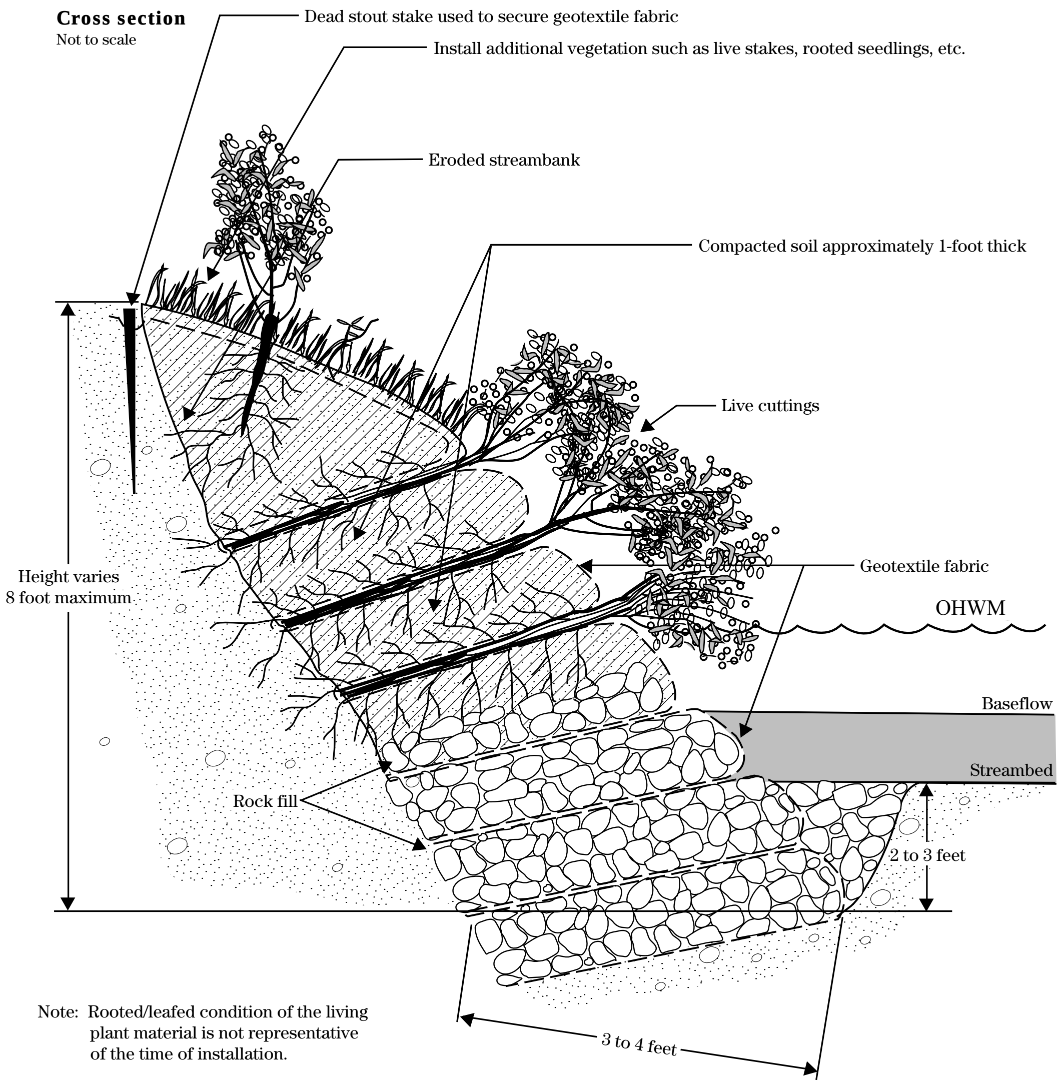


Figure 9: Typical Design of Vegetated Geogrid System
Source: NRCS 1996

Technique 5: Toe Armoring Without Bank Slope Reduction

Overview
Toe armoring without bank slope reduction is an option for improving bank stability in high-risk locations. Generally, Technique 5 is effective when used near infrastructure where toe erosion is unacceptable and there is insufficient space between the top of the bank and adjacent infrastructure to accommodate Techniques 2 through 4 (WDFW 2003).

Description
Toe armoring includes structural features such as rock that prevent erosion at the toe of a streambank. The toe is where a streambank is most vulnerable because that is where the erosional forces are greatest. However, rock toes generally provide little habitat complexity or cover. It is also not advisable to use a non-deformable rock toe within a channel migration zone because it will interrupt the natural, riverine channel migration process and likely cause future erosion problems upstream and downstream (WDFW 2003). Technique 5 should only be applied when other less environmentally intrusive options are not feasible.

Materials for Technique 5 may include the following:

- Minor excavation and site preparation equipment
- Angular rock or stone
- Live stakes, logs, or rootwads
- Filter material (i.e., gravel or fabric)
- Compacted fill material
- Large woody debris (encouraged)

Example: Riprap is an example of toe armoring that includes a blanket of stone extending from the toe of a slope. Figure 10 illustrates a typical rock toe armoring design without bank sloping.

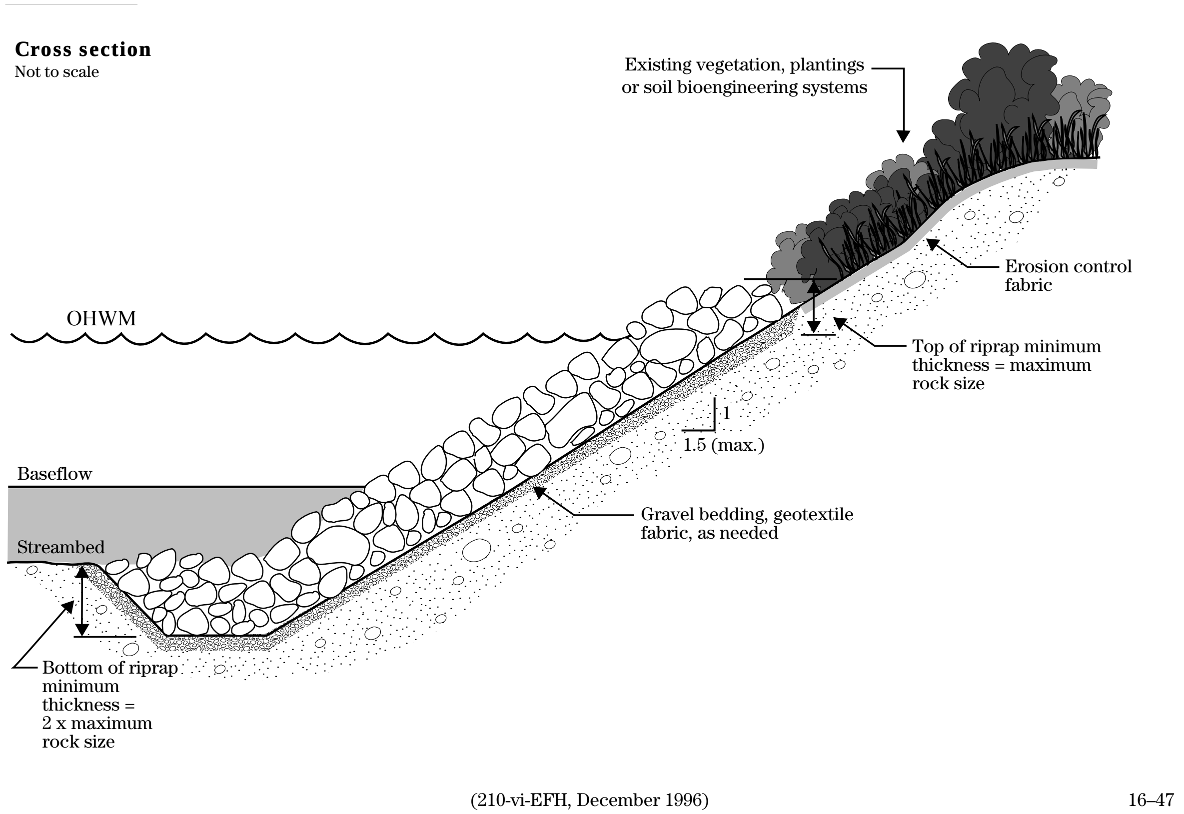


Figure 10: Typical Design of Vegetated Geogrid System
Source: NRCS 1996

Design tips for riprap armoring:

- Upper bank slopes at a ratio of 2:1 or flatter are recommended by most riprap design references, although a ratio of 1.5:1 is allowable in some cases.
- The use of large woody debris is encouraged for incorporation into rock toe armoring as a habitat feature and to provide additional roughness.
- Rock toe armoring should be extended from the maximum predicted depth of scour to the lower limit of vegetation.
- Rock toe armoring can be employed as a complementary toe treatment for bioengineered streambank protection and reshaped banks.
- As increasing rock sizes are used, more attention should be paid to proper bedding and granular-filter design

Materials

Plants

It is recommended that selection of species and planting intensity be made with consideration given to project-specific objectives and risk tolerance. Table 5 includes a preliminary list of vegetation goals and provides basic guidance for when and where certain types of plants are recommended and at what density (see Appendix D for a native plants list).

TABLE 5

Planting Plan Selection Matrix

No.	Vegetation Goal	Site Risks	
		Low	**High**
1	Woody vegetation establishment	Invasive clearing and underplanting with native conifers	Invasive clearing and underplanting with native deciduous
2	Mixed vegetation goal	Mix of 1 and 3	Mix of 1 and 3
3	Clear bank (grass slope)	Invasive clearing and seeding or plug planting	Benched surface grading, seeding, and temporary erosion control fabric installation

Fabric

It is recommended that selection of geotextile fabric and other erosion-control products be made with consideration given to project-specific objectives and risk tolerance. Table 6 includes a preliminary list of vegetation goals and provides basic guidance for when and where certain categories of geotextiles and other erosion-control products are recommended (see Chapters 6-99 and 6-119 of the WDFW ISPG for a more detailed and thorough explanation of erosion techniques).

TABLE 6

Geotextile and Erosion-control Product Selection Matrix

No.	Vegetation Goal	Site Risks	
		Low	**High**
1	Woody vegetation establishment	Natural fiber	Bio/UV-degradable synthetic fiber
2	Mixed vegetation goal	Natural fiber in woody areas and degradable synthetic fiber in clear areas	Degradable synthetic fiber in woody areas and permanent fiber in open areas
3	Clear bank (grass slope)	Bio/UV-degradable synthetic fiber	Permanent UV-resistant, non-biodegradable fiber

Rock

It is recommended that selection of rock for use in bank treatments be made with consideration given to project-specific objectives and risk tolerances. Table 7 includes a preliminary list of bank conditions and provides basic guidance for when and where certain types and gradations of rock are recommended.

TABLE 7

Rock Type and Size Selection Matrix

Bank Condition	Site Risks	
	Low	**High**
Bank slope reduced	Rounded cobbles and gravel	Rounded boulders and cobbles with a gravel filter layer
Steep bank maintained	Rounded boulders and cobbles with a gravel filter layer	Angular boulders (riprap) with a gravel or geo-synthetic filter layer

Pend Oreille River, near Lake Newport State Park
Source: Washington State Department of Ecology

5 Plans and Permits

Developing a Good Plan

After conducting a site assessment and selecting an environmentally appropriate bank stabilization technique, the next step is to develop a design plan in sufficient detail to assist in streamlined review with regulatory agencies (see the Permits section for agencies that may require permits).

Good plans will provide sufficient detail and information to fully illustrate what is being proposed. Plans should accomplish the following:

- Clearly identify project purpose and need
- Describe size, scale, and scope of project
- Describe measures to protect fish and ensure no net loss of shoreline ecological function, including the following details:
  - Erosion and sediment control measures
  - In-water work and methods
  - Riparian vegetation that will be removed, replaced, or established
- Describe proposed work waterward of ordinary high water mark (OHWM), including work windows, construction methods and equipment, and work sequencing
- Include plan and profile view drawings showing proposed work and include the following details:
  - Project location, river mile, and vicinity map
  - Dimensions including project location in relation to OHWM

Permits

It is the responsibility of the landowner to acquire all necessary permits for work along the river prior to starting work on any project. See Table 8 for summary of local, state, and federal permits and review that may be required for work in, over, under, or adjacent to water.

TABLE 8

Permit Matrix

Permit/Approval	Agency	Trigger	Approximate Agency Review Timeframe	Notes[1]
Federal Jurisdiction: Permits				
CWA Section 404 (Section 404 Permit)	USACE	Triggered by a discharge of dredged or fill material into Waters of the United States, including adjacent wetlands. Projects that trigger 404 may have compensatory mitigation requirements.	Total time: 3 months to 1 year	Bank stabilization projects that meet certain criteria may qualify for approval by USACE under RGP 7, which is a streamlined permit that provides joint authorization for Section 404 and Section 10. RGP 7 is effective through July 26, 2016. A subsequent RGP issued for the Pend Oreille River may include different criteria. Projects not eligible for RGP may be eligible for streamlined Nationwide Permits or may require Individual Permit authorization.
Rivers and Harbors Act Section 10 (Section 10 Permit)	USACE	Triggered by any proposed work in, over, or under navigable Waters of the United States that affects navigable capacity	Total time: 3 months to 1 year	
Federal Jurisdiction: Associated Approvals				
ESA Section 7 Consultation	NOAA Fisheries and USFWS	All projects with federal nexus are subject to Section 7 of the ESA, which requires federal agencies to ensure that projects they authorize, permit, or fund do not jeopardize the continued existence of any threatened or endangered species or destroy or adversely modify critical habitat	Total time: approximately 6 months to 1 year	USACE may determine additional or separate consultation for ESA may apply for projects that deviate from or are not eligible under RGP 7.
National Historic Preservation Act Section 106 Consultation	USACE in coordination with DAHP	Projects with a federal nexus are subject to Section 106 of the National Historic Preservation Act, which evaluates actions that have the potential to affect cultural, archaeological, or historical properties	Total time: 2 months to more than 1 year	USACE may determine additional or separate consultation for Section 106 may apply for projects that deviate from or are not eligible under RGP 7.

Permit/Approval	Agency	Trigger	Approximate Agency Review Timeframe	Notes[1]
State Jurisdiction: Permits				
CWA Section 401 Water Quality Certification	Ecology[2]	Applying for a federal permit or license to conduct any activity that might result in or create discharge or runoff into surface water or non-isolated wetlands, or excavation in water or non-isolated wetlands	Total time: 3 months to 1 year	Typically processed concurrent with USACE regional or nationwide permit; RGPs may require individual Section 401 Certification. USACE Individual Permits require Individual 401 Certification
CWA Section 402 NPDES Construction Stormwater General Permit	Ecology	Required for all soil-disturbing activities where one or more acres will be disturbed and have a discharge of stormwater to a receiving water or storm drains that discharge into a receiving water (i.e., wetland, creek, river, marine water, ditch, or estuary)	Total time: 2 months or more	
Hydraulic Project Approval	WDFW	Triggered by a proposed activity that uses, diverts, obstructs, or changes the natural flow or bed of any of the salt- or freshwaters of the state	Total time: 2 months or more	WDFW has 45 calendar days to issue Hydraulic Project Approval after application is deemed administratively and technically complete by WDFW Biologist
Aquatic Lands Use Authorization	WDNR	Triggered by proposed actions that take place on state-owned aquatic lands	Total time: 6 months to more than 1 year	Copies of other approved aquatic resources permits and compliance documentation must be provided to DNR prior to issuance of authorization
State Jurisdiction: Associated Approvals				
SEPA Compliance	Pend Oreille County	Any proposal that requires a state or local agency decision to license, fund, or undertake a project, or the proposed adoption of a policy, plan, or program can trigger environmental review under SEPA	Total Time: 3 to 6 months	SEPA compliance timeframes vary based on size and complexity of the project.

Permit/Approval	Agency	Trigger	Approximate Agency Review Timeframe	Notes[1]
Local Jurisdiction				
Shoreline Permit	Pend Oreille County	Triggered by proposed activities occurring within the Shoreline Management Act Jurisdiction (generally within 200 feet of mean higher high water)	Total time: 1 month to more than 6 months	See Table 9 for shoreline permit requirements for bank stabilization projects in Pend Oreille County.
Other Local Permits and Approvals (e.g., Building, Fill/Grade, Land Use, and Noise)	Pend Oreille County	Required for proposed activities within city or county jurisdiction	Varies by permit or approval	Generally recommended to contact the local permitting agency prior to application submittal to determine required permits and approvals.

Notes:

1 = Mitigation requirements will likely increase with the application of more intense (higher numbered) stabilization techniques.

2 = This is a federal approval through the U.S. Environmental Protection Agency administered by Ecology.

CWA = Clean Water Act

DAHP = Washington Department of Archaeology and Historic Preservation

Ecology = Washington State Department of Ecology

NOAA National Oceanographic and Atmospheric Agency

NPDES = National Pollutant Discharge Elimination System

RGP = Regional General Permit

SEPA = State Environmental Protection Agency

USACE = U.S. Army Corps of Engineers

USFWS = U.S. Fish and Wildlife Service

WDFW = Washington Department of Fish and Wildlife

WDNR = Washington Department of Natural Resources

Shoreline Permit

Bank stabilization measures exceeding $6,416 require a shoreline permit under the County's SMP (see Table 9).

TABLE 9

Shoreline Master Program Permit Requirements for Bank Stabilization Measures

<table>
<tr><th colspan="2">Environment Designation</th><th>Bank Stabilization Measures</th><th>Notes[1]</th></tr>
<tr><td rowspan="2">Conservancy</td><td>Rural</td><td rowspan="6">SSDP</td><td rowspan="8">• Bank stabilization measures that do not meet the thresholds for an SSDP (total cost or fair market value does not exceed $6,416) may be permitted through an SA.
• Structural bank stabilization measures should only be permitted to protect a legally existing structure or use that is in danger of loss or substantial damage and no other alternatives are available. New developments in these shoreline designations should be designed and located to preclude the need for such work.
• Biotechnical erosion-control measures may be permitted in the Natural Shoreline Environment.</td></tr>
<tr><td>Urban</td></tr>
<tr><td rowspan="2">Residential</td><td>Rural</td></tr>
<tr><td>Urban</td></tr>
<tr><td rowspan="2">Higher Intensity</td><td>Rural</td></tr>
<tr><td>Urban</td></tr>
<tr><td colspan="2">Natural</td><td rowspan="2">SCUP</td></tr>
<tr><td colspan="2">Aquatic</td></tr>
</table>

Notes:

SA = Shoreline Authorization required for development activity or use where SSDP is not required

SCUP = Shoreline Conditional Use Permit

SSDP = Shoreline Substantial Development Permit

1 = Per SMP XX.34.050.B.4, Table of Permitted Uses, footnotes.

Joint Aquatic Resources Permit Application

It is the goal of the County to integrate the processing of required permits or approvals for development activities or uses proposed for jurisdictional shorelines with other permits and approvals that may be required. In order to streamline this process, the County has adopted the Joint Aquatic Resources Permit Application (JARPA) form for shoreline projects within the County.

The County's planning staff can provide application materials and assist with the process. In addition to the County application, other state and federal applications may be required (see the County's Shoreline Activities Information website for access to JARPA forms: http://pendoreilleco.org/your-government/community-development/shoreline-activities-information-and-permits/).

Additional specific information may be required depending on the nature of the proposal and the presence of sensitive ecological features or issues related to compliance with other County requirements and the provisions of the SMP.

Funding

The County PUD has established a fund for erosion-control projects on privately owned lands where the PUD may contribute up to $5,000 for qualified applicants, as an incentive to landowners (see additional application requirements and materials at the PUD's website: http://popud.org/projects/erosion-control).

6 References

FISRWG (Federal Interagency Stream Restoration Working Group), 2001. *Stream Corridor Restoration: Principles, Processes, and Practices*. Published October 1998. Revised August 2001. Adopted as Part 653 of the National Engineering Handbook.

HCFCD (Harris County Flood Control District), 2015. *Streambank Stabilization Handbook – A Guide for Harris County Landowners*. 2015 Version 2.0.

Mainstream (Mainstream Restoration Inc.), 2007. *Pend Oreille River in Box Canyon Reservoir – Riverbank Stabilization Guidelines Final*. Prepared for WDFW.

NRCS (Natural Resources Conservation Service), 1996. *National Engineering Handbook Part 650: Chapter 16 Streambank and Shoreline Protection*. U.S. Department of Agriculture, NRCS, Colorado. December 1996.

Pend Oreille County, 2015. *Updated Shoreline Master Program*. Available from: http://pendoreilleco.org/wp-content/uploads/2015/11/Adopted-SMP_10-30-2015COPY.pdf.

TVA (Tennessee Valley Authority), 2015. *Benefits of Riparian Zones That Use Native Plants*. Cited: December 17, 2015. Available from: http://pendoreilleco.org/wp-content/uploads/2015/07/Benefits-of-Native-Plants.pdf.

USGS (U.S. Geological Survey), 2015. *Floods: Recurrence intervals and 100-year floods.* Cited: December 17, 2015. Available from: http://water.usgs.gov/edu/100yearflood.html.

WDFW (Washington Department of Fish and Wildlife), 2003. Washington State Aquatic Habitat Guidelines Program – Integrated Streambank Protection Guidelines (ISPG).

A Site Assessment Checklist

No.	Characteristic/ Activity	Description				Check
1	Location	Address:				☐
		River Mile:				☐
2	Riparian Vegetation	Describe existing bank vegetation:				☐
3	Clear bank (grass slope)	Bank slope (H:V): Circle one	Steep: 1:1 or steeper	Moderate: 1:1 to 4:1	Gentle: 4:1 and gentler	☐
		Bank Height (feet):				☐
4	Adjacent Property Bank Conditions	Upstream:				☐
		Downstream:				☐
5	Water Level Fluctuation	Determine range based on River Mile:				☐
6	Wave Action	Circle all that apply:	Minor	Moderate	Major	☐
			Wind	Motor-boats		
7	Mechanism of Erosion	Describe mechanism(s) of erosion occurring on the bank (e.g., toe erosion, bank seepage, or small or large mass failure):				☐
8	Structural Risks	Describe any structures that may be at risk due to shoreline conditions:				☐

Notes: H:V = horizontal-to-vertical ratio

Site Assessment Guidance:

This guidance is provided for the Site Assessment Checklist. In general, a site assessment should include the following components:

1. Location and river mile (RM):
   - Locate the segment of riverbank under investigation. Estimate RM location.
2. Riparian vegetation:
   - Describe existing riparian vegetation conditions, including the general location in relation to erosion areas and bank slopes.
   - Identify the types of existing vegetation (e.g., trees, shrubs, grasses, or invasive species).
   - Identify areas where riparian vegetation has been removed.
3. Bank configuration (slopes and topographic relief):
   - Determine if the riverbank is relatively steep or gentle (see Table 1).
   - Additional considerations to note about bank slopes include:
   - Any predominant changes in slope and where they are located in reference to the typical water level.
   - Riverbank conditions upstream and downstream from the proposed project.
   - Consideration for how the proposed bank stabilization measures will transition into the adjacent riverbank. In some cases, a comprehensive stabilization project is typically more successful than those constrained by property boundaries.

TABLE 1
Bank Slopes

Bank Slope	Typical Horizontal-to-vertical Ratio
Steep	1:1 or steeper
Moderate	1:1 to 4:1
Gentle	4:1 and gentler

4. Adjacent property bank conditions:
   - Identify conditions on adjacent properties, such as level of existing vegetation, slopes, evidence of erosion, and existing improvements or stabilization projections.
5. Water level fluctuation:
   - Determine the range of river water levels that can be expected at the project site. Site-specific analysis should be conducted. Table 2 summarizes water level fluctuations at select RMs and accounts for dry and wet years.
   - Determine the elevation of these ranges, using the established ground elevation at the benchmark.
   - Set stakes in the ground for the upper level of these extremes to represent seasonal high water levels. Set reference stakes within the area of the proposed project, as well as stakes corresponding to these elevations outside the project, so these reference stakes will not be disturbed during construction (Mainstream 2007).

TABLE 2

Water Level Fluctuations

Location	River Mile (RM)	Water Level Fluctuation (feet)1
Ione	RM 38	3
Tiger Slough Outlet	RM 45	5
Blueslide	RM 52	6.5
River Bend	RM 60	9.5
Cusick	RM 70	10
Dalkena	RM 77	11
Marshall Creek	RM 84	12
Newport	RM 88	13

Notes:

1 = Water level fluctuation is determined using Pend Oreille County Public Utility District No. 1 (PUD's) relationship of river flow to river water surface elevation presented in Mainstream 2007. Flows analyzed ranged from 10,000 cubic feet per second (cfs) to 80,000 cfs. The difference between maximum and minimum pool elevation, over the range of flows, was considered the water level fluctuation.

6. Wave action:

- Waves in Box Canyon Reservoir cause toe erosion by dislodging soil particles and undermining riverbanks. Where motorized recreation is popular in the reservoir, boat-caused waves can be common (Mainstream 2007).

7. Erosion:

- Toe erosion:
  - Toe erosion occurs intermittently throughout Box Canyon Reservoir when water flow removes particles from the streambank and streambed and undermines the bank toe, causing failure of overlying bank layers.
- Mass failure:
  - Shorelines within the Box Canyon Reservoir exhibit slump and earthflow failure in two forms—relatively small bank failures (the more common form) and larger, more deep-seated failures (which are relatively rare along the reservoir). Slumps are evident as masses of soil that slid down the slope, often with intact collections of trees and shrubs.
- Bank seepage:
  - Look at the riverbank to determine if there is, or has been, seepage from within the riverbank.
  - Seepage is commonly evidenced as bare areas from which small quantities of groundwater have flowed. These are often associated with small, localized collapse failures.

8. Structural risks:

- Describe any structures that may be at risk due to shoreline conditions.

B SMP Shoreline Stabilization Provisions

To guide applicants in applying for a Shoreline Stabilization project, the following is the most recent code revision for Pend Oreille County. The code can be found in the Pend Oreille County Development Regulations under XX.34.060.K.

Shoreline Stabilization Measures. Proposed development activities or uses intended to stabilize banks and prevent erosion and/or protect recreation sites may only be permitted by the County based on a finding that the proposal will not result in a net loss of ecological function, provided that:

1. Biotechnical bank protection measures, which may include vegetation enhancement, upland drainage controls, or planting anchor trees, are preferred. "Hard" solutions such as the placement of rip rap may only be permitted upon a finding that no other less environmentally intrusive option is feasible.
    a. New bulkheads are prohibited.
    b. The use of gabions is prohibited.
2. Project Sponsors are encouraged to design bank stabilization measures proposed for the Pend Oreille River in compliance with the standards of the Regional General Permit issued to the U.S. Army Corps of Engineers in effect at the time that the bank stabilization application has been submitted and deemed by the County to be complete. Bank stabilization measures that do not meet these standards may be permitted only if an individual or nationwide permit has been obtained from the U.S. Army Corps of Engineers which may include the preparation of a biological assessment and an individual consultation in accordance with the requirements of the Endangered Species Act.
    a. Project Sponsors are also encouraged to consult the publication of the Washington State Department of Fish and Wildlife, prepared in consultation with several natural resource agencies, Integrated Stream Bank Protection Guidelines.
3. New bank stabilization measures and the enlargement of existing structures should be designed and constructed to avoid the net loss of ecological function. Applications for bank stabilization projects should highlight proposed measures to avoid, minimize, and/or mitigate measures that may have an adverse environmental impact or an adverse effect on ecological functions. The County may require revisions that have less impact and/or require on- or off-site mitigation.
    a. The County may require that the Project Sponsor prepare, at no cost to the County, a geotechnical report to address the necessity for shoreline stabilization by estimating time frames and rates of erosion and to report on the urgency associated with the specific situation.
    b. The size of proposed stabilization measures shall be limited to the minimum necessary.

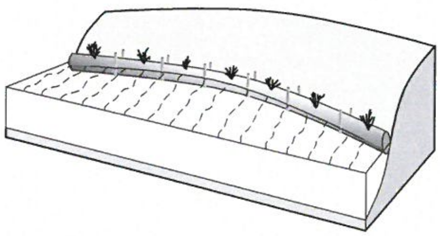
   c. Publicly financed or subsidized shoreline erosion control measures should not restrict public access to the shoreline except where such access is determined to be infeasible because of incompatible uses, safety, security, or harm to ecological functions.
   d. Adverse impacts to sediment conveyance systems should be avoided or if that is not possible, avoided.
4. New development that would require shoreline stabilization which would cause significant impacts to adjacent or down-current properties and shoreline areas should not be approved.
5. An existing shoreline stabilization structure may be replaced with a similar structure provided that:
   a. There is a demonstrated need to protect the principal use or structure from erosion;
   b. The replacement structure is designed, located, sized, and constructed to assure no net loss of ecological functions; and
   c. The replacement wall or bulkhead shall not encroach waterward of the ordinary high water mark or existing structure unless the residence was occupied prior to January 1, 1992 and there are overriding safety or environmental concerns. In such cases, the replacement structure shall abut the existing shoreline stabilization structure.

C Shoreline Bank Stabilization Techniques

Source: FISRWG 2001 (Appendix A)

Technique #2: Vegetation Establishment

2A Coconut Fiber Roll

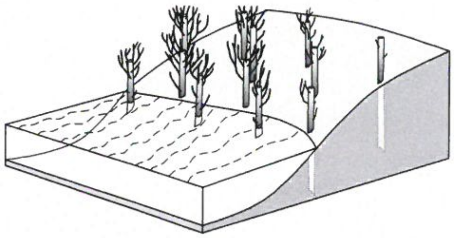


Cylindrical structures composed of coconut husk fibers bound together with twine woven from coconut material to protect slopes from erosion while trapping sediment which encourages plant growth within the fiber roll.

Applications and Effectiveness

- Most commonly available in 12 inch diameter by 20 foot lengths.
- Typically staked near the toe of the streambank with dormant cuttings and rooted plants inserted into slits cut into the rolls.
- Appropriate where moderate toe stabilization is required in conjunction with restoration of the streambank and the sensitivity of the site allows for only minor disturbance.
- Provide an excellent medium for promoting plant growth at the water's edge.
- Not appropriate for sites with high velocity flows or large ice build up.
- Flexibility for molding to the existing curvature of the streambank.
- Requires little site disturbance.
- The rolls are buoyant and require secure anchoring.
- Can be expensive.
- An effective life of 6 to 10 years.
- Should, where appropriate, be used with soil bioengineering systems and vegetative plantings to stabilize the upper bank and ensure a regenerative source of streamside vegetation.
- Enhances conditions for colonization of native vegetation.

2B Dormant Post Plantings



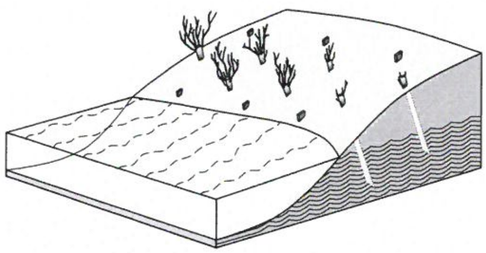
Plantings of cottonwood, willow, poplar, or other species embedded vertically into streambanks to increase channel roughness, reduce flow velocities near the slope face, and trap sediment.

Applications and Effectiveness

- Can be used as live piling to stabilize rotational failures on streambanks where minor bank sloughing is occurring.
- Useful for quickly establishing riparian vegetation, especially in arid regions where water tables are deep.
- Will reduce near bank stream velocities and cause sediment deposition in treated areas.
- Reduce streambank erosion by decreasing the near-bank flow velocities.
- Generally self-repairing and will restem if attacked by beaver or livestock; however, provisions should be made to exclude such herbivores where possible.
- Best suited to non-gravely streams where ice damage is not a problem.
- Will enhance conditions for colonization of native species.
- Are less likely to be removed by erosion than live stakes or smaller cuttings.
- Should, where appropriate, be used with soil bioengineering systems and vegetative plantings to stabilize the upper bank and ensure a regenerative source of streamside vegetation.
- Unlike smaller cuttings, post harvesting can be very destructive to the donor stand, therefore, they should be gathered as 'salvage' from sites designated for clearing, or thinned from dense stands.

2C

Live Stakes



Live, woody cuttings which are tamped into the soil to root, grow and create a living root mat that stabilizes the soil by reinforcing and binding soil particles together, and by extracting excess soil moisture.

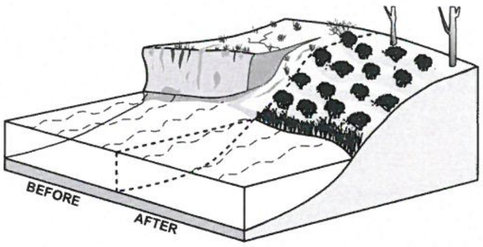
Applications and Effectiveness

- Effective where site conditions are uncomplicated, construction time is limited, and an inexpensive method is needed.
- Appropriate for repair of small earth slips and slumps that are frequently wet.
- Can be used to stake down surface erosion control materials.
- Stabilize intervening areas between other soil bioengineering techniques.
- Rapidly restores riparian vegetation and streamside habitat.
- Should, where appropriate, be used with other soil bioengineering systems and vegetative plantings.
- Enhance conditions for colonization of vegetation from the surrounding plant community.
- Requires toe protection where toe scour is anticipated.

Technique #3: Bank Shaping

3A

Bank Shaping and Planting



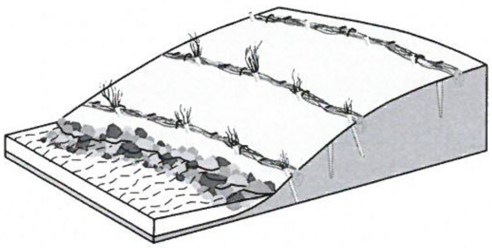
Regrading streambanks to a stable slope, placing topsoil and other materials needed for sustaining plant growth, and selecting, installing and establishing appropriate plant species.

Applications and Effectiveness

- Most successful on streambanks where moderate erosion and channel migration are anticipated.
- Reinforcement at the toe of the embankment is often needed.
- Enhances conditions for colonization of native species.
- Used in conjunction with other protective practices where flow velocities exceed the tolerance range for available plants, and where erosion occurs below base flows.
- Streambank soil materials, probable groundwater fluctuation, and bank loading conditions are factors for determining appropriate slope conditions.
- Slope stability analyses are recommended.

3B

Live Fascines



Dormant branch cuttings bound together into long sausage-like, cylindrical bundles and placed in shallow trenches on slopes to reduce erosion and shallow sliding.

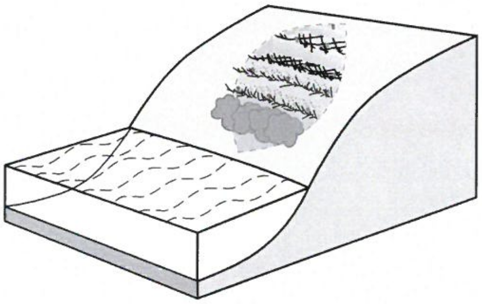
Applications and Effectiveness

- Can trap and hold soil on streambank by creating small dam-like structures and reducing the slope length into a series of shorter slopes.
- Facilitate drainage when installed at an angle on the slope.
- Enhance conditions for colonization of native vegetation.
- Should, where appropriate, be used with other soil bioengineering systems and vegetative plantings.
- Requires toe protection where toe scour is anticipated.
- Effective stabilization technique for streambanks, requiring a minimum amount of site disturbance.
- Not appropriate for treatment of slopes undergoing mass movement.

Technique #4: Bioengineered Bank Treatments

4A

Branch Packing



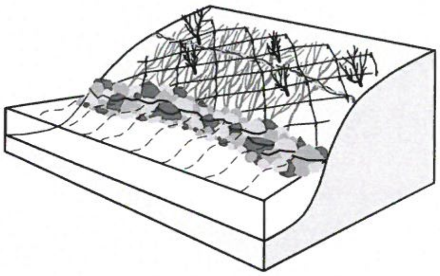
Alternate layers of live branches and compacted backfill which stabilize and revegetate slumps and holes in streambanks.

Applications and Effectiveness

- Commonly used where patches of streambank have been scoured out or have slumped leaving a void.
- Appropriate after stresses causing the slump have been removed.
- Less commonly used on eroded slopes where excavation is required to install the branches.
- Produces a filter barrier that prevents erosion and scouring from streambank or overbank flows.
- Rapidly establishes a vegetated streambank.
- Enhances conditions for colonization of native species.
- Provides immediate soil reinforcement.
- Live branches serve as tensile inclusions for reinforcement once installed.
- Typically not effective in slump areas greater than four feet deep or four feet wide.

4B

Brush Mattresses



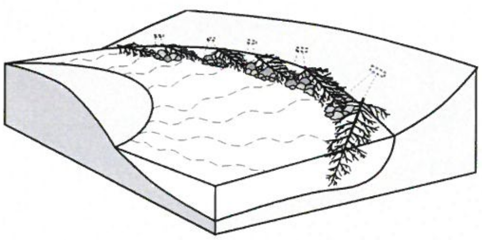
Combination of live stakes, live facines, and branch cuttings installed to cover and physically protect streambanks; eventually to sprout and establish numerous individual plants.

Applications and Effectiveness

- Form an immediate protective cover over the streambank.
- Capture sediment during flood flows.
- Provide opportunities for rooting of the cuttings over the streambank.
- Rapidly restores riparian vegetation and streamside habitat.
- Enhance conditions for colonization of native vegetation.
- Limited to the slope above base flow levels.
- Toe protection is required where toe scour is anticipated.
- Appropriate where exposed streambanks are threatened by high flows prior to vegetation establishment.
- Should not be used on slopes which are experiencing mass movement or other slope instability.

4C

Tree Revetments

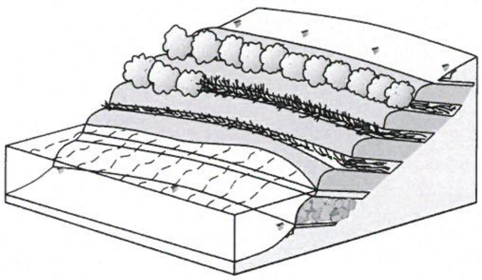


A row of interconnected trees attached to the toe of the streambank or to deadmen in the streambank to reduce flow velocities along eroding streambanks, trap sediment, and provide a substrate for plant establishment and erosion control.

Applications and Effectiveness

- Design of adequate anchoring systems is necessary.
- Wire anchoring systems can present safety hazards.
- Work best on streams with streambank heights under 12 feet and bankfull velocities under 6 feet per second.
- Use inexpensive, readily available materials.
- Capture sediment and enhances conditions for colonization of native species particularly on streams with high bed material loads.
- Limited life and must be replaced periodically.
- Might be severely damaged by ice flows.
- Not appropriate for installation directly upstream of bridges and other channel constrictions because of the potential for downstream damages should the revetment dislodge.
- Should not be used if they occupy more than 15 percent of the channel's cross sectional area at bankfull level.
- Not recommended if debris jams on downstream bridges might cause subsequent problems.
- Species that are resistant to decay are best because they extend the establishment period for planted or volunteer species that succeed them.
- Requires toe protection where toe scour is anticipated.
- Should, where appropriate, be used with soil bioengineering systems and vegetative plantings to stabilize the upper bank and ensure a regenerated source of streamside vegetation.

4D Vegetated Geogrids

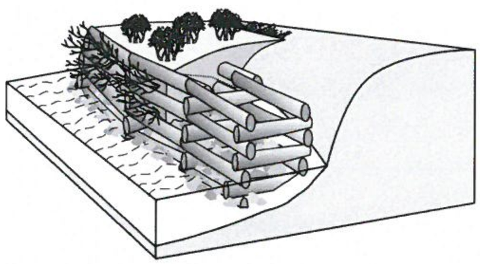


Alternating layers of live branch cuttings and compacted soil with natural or synthetic geotextile materials wrapped around each soil lift to rebuild and vegetate eroded streambanks.

Applications and Effectiveness

- Quickly establish riparian vegetation if properly designed and installed.
- Can be installed on a steeper and higher slope and has a higher initial tolerance of flow velocity than brush layering.
- Can be complex and expensive.
- Produce a newly constructed, well-reinforced streambank.
- Useful in restoring outside bends where erosion is a problem.
- Capture sediment and enhances conditions for colonization of native species.
- Slope stability analyses are recommended.
- Can be expensive.
- Require a stable foundation.

4E Live Cribs



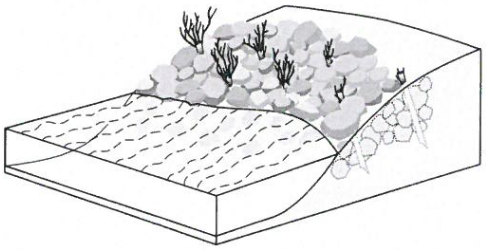
Hollow, box-like interlocking arrangements of untreated log or timber members filled above baseflow with alternate layers of soil material and live branch cuttings that root and gradually take over the structural functions of the wood members.

Applications and Effectiveness

- Provide protection to the streambank in areas with near vertical banks where bank sloping options are limited.
- Afford a natural appearance, immediate protection and accelerate the establishment of woody species.
- Effective on outside of bends of streams where high velocities are present.
- Appropriate at the base of a slope where a low wall might be required to stabilize the toe and reduce slope steepness.
- Appropriate above and below water level where stable streambeds exist.
- Don't adjust to toe scour.
- Can be complex and expensive.
- Should, where appropriate, be used with soil bioengineering systems and vegetative plantings to stabilize the upper bank and ensure a regenerative source of streambank vegetation.

Technique #5: Toe Armor with Bank Sloping

5A Joint Plantings

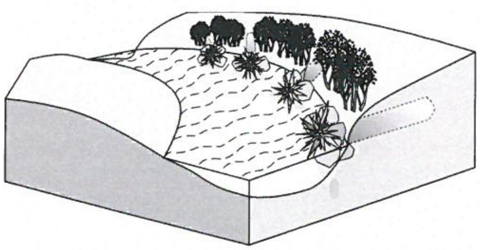


Live stakes tamped into joints or openings between rock which have previously been installed on a slope or while rock is being placed on the slope face.

Applications and Effectiveness

- Appropriate where there is a lack of desired vegetative cover on the face of existing or required rock riprap.
- Root systems provide a mat upon which the rock riprap rests and prevents loss of fines from the underlying soil base.
- Root systems also improve drainage in the soil base.
- Will quickly establish riparian vegetation.
- Should, where appropriate, be used with other soil bioengineering systems and vegetative plantings to stabilize the upper bank and ensure a regenerative source of streambank vegetation.
- Have few limitations and can be installed from base flow levels to top of slope, if live stakes are installed to reach ground water.
- Survival rates can be low due to damage to the cambium or lack of soil/stake interface.
- Thick rock riprap layers may require special tools for establishing pilot holes.

5B Log, Rootwad, and Boulder Revetments

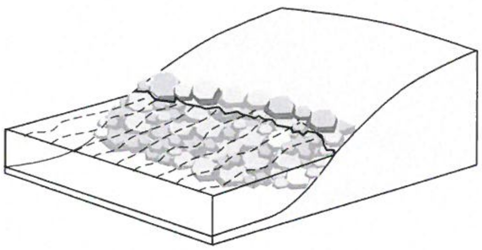


Boulders and logs with root masses attached placed in and on streambanks to provide streambank erosion, trap sediment, and improve habitat diversity.

Applications and Effectiveness

- Will tolerate high boundary shear stress if logs and rootwads are well anchored.
- Suited to streams where fish habitat deficiencies exist.
- Should, where appropriate, be used with soil bioengineering systems and vegetative plantings to stabilize the upper bank and ensure a regenerative source of streambank vegetation.
- Will enhance diversity in riparian areas when used with soil bioengineering systems.
- Will have limited life depending on climate and tree species used. Some species, such as cottonwood or willow, often sprout and accelerate colonization.
- Might need eventual replacement if colonization does not take place or soil bioengineering systems are not used.
- Use of native materials can sequester sediment and woody debris, restore streambanks in high velocity streams, and improve fish rearing and spawning habitat.
- Site must be accessible to heavy equipment.
- Materials might not be readily available at some locations.
- Can create local scour and erosion.
- Can be expensive.

5C Stone Toe Protection

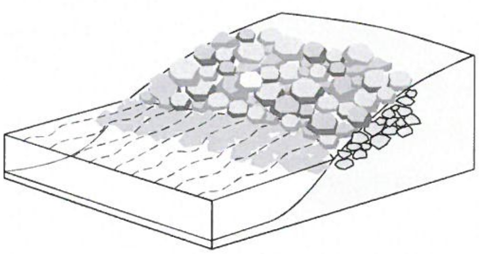


A ridge of quarried rock or stream cobble placed at the toe of the streambank as an armor to deflect flow from the bank, stabilize the slope and promote sediment deposition.

Applications and Effectiveness

- Should be used on streams where banks are being undermined by toe scour, and where vegetation cannot be used.
- Stone prevents removal of the failed streambank material that collects at the toe, allows revegetation and stabilizes the streambank.
- Should, where appropriate, be used with soil bioengineering systems and vegetative plantings to stabilize the upper bank and ensure a regenerated source of streamside vegetation.
- Can be placed with minimal disturbance to existing slope, habitat, and vegetation.

5D Riprap



A blanket of appropriately sized stones extending from the toe of slope to a height needed for long term durability.

Applications and Effectiveness

- Can be vegetated (see joint plantings).
- Appropriate where long term durability is needed, design discharge are high, there is a significant threat to life or high value property, or there is no practical way to otherwise incorporate vegetation into the design.
- Should, where appropriate, be used with soil bioengineering systems and vegetative plantings to stabilize the upper bank and ensure a regenerative source of streambank vegetation.
- Flexible and not impaired by slight movement from settlement or other adjustments.
- Should not be placed to an elevation above which vegetative or soil bioengineering systems are an appropriate alternative.
- Commonly used form of bank protection.
- Can be expensive if materials are not locally available.

D Pend Oreille County Native Plants List

All listed plants have wildlife habitat value (i.e. food, cover, nesting site or shelter). Plants may have more than one common name; list provides both common and scientific name for each species to help with identification. Planting site will dictate species selection. List is not inclusive.

Soil: Saturated Wet ≈ (including seasonal inundation) Moist Well-drained Dry

Light: Full Sun Partial Sun Shade

Willow *(Salix spp.)* ≈ Max. Ht. 9'- 45' Med. to Fast Growing ~ Wide Spread Root System

Black hawthorn *(Crataegus douglasiz)* ≈ Max Ht. 20' Thicket Fonning - Deep Root System

Black cottonwood *(Populus trichocarpa)* ≈ Max. Ht. 120' Fast Growing - Fibrous Roots

Red-osier dogwood *(Cornus stolonifera)* ≈ Max. Ht. 20' Fast Growing - Spreading

Douglas spirea *(Spiraea douglasii)* ≈ Max. Ht. 7' Thicket Fonning - Rhizome

Dwarf birch *(Betula glandulosa) (a.k.a. bog birch)* ≈ Usually less than 10' Small shrub/tree

Bulrush species *(Scirpus spp.)* ≈ Max. Ht. 2'-5' Perennial Rhizome - Spreading

Sedge species *(Carex spp.)* ≈ Max. Ht. 1 '-4' Spreading

Rush species *(Juncus spp.)* ≈ Max. Ht. 1'-4' Spreading

Spike-rushes *(Eleocharis spp.)* ≈ Max. Ht. 3' Spreading

Common snowberry *(Symphoricarpos alb us)* Max. Ht. 4' Rhizome

Beaked hazelnut *(Corylus corn uta)* Max. Ht. 15' Suckering - Native Nut

Alder species *(Alnus spp.)* ≈ Max. Ht. 10'-40' Nitrogen Fixing Root Nodules

Serviceberry *(Amelanchier alnifolia)* Max. Ht. 20' Spreading and Deep Roots - Berries

Chokecherry *(Prunus virginiana)* Max. Ht. 20' Fast Growing - Berries

Russet buffaloberry *(Shepherdia canadensis)* Max. Ht. 7' Nitrogen Fixing - Berries

Nootka rose *(Rosa nutkana)* ≈ Max. Ht. 7' Soil Binding Characteristics - Edible flowers - Hips

Cascara *(Rhamnus purshiana)* ≈ ◆ ● ☼ ☾ Max. Ht. 30' Fonns Groves - Wildlife Berries

Highbush cranberry *(Viburnum opulus L. var. americanum, V. edule)* ◆ ● ☼ ☾ Color - Berries

Mockorange *(Philadelphus lewisii)* ◆ ● ☼ ☾ Max Ht. 15' Fibrous Root System - Fragrant

Oceanspray *(Holodiscus discolor)* ● ■ ☼ ☾ Max. Ht. 13' Spreading Root System - Dry Slopes

Black twin berry *(Lonicera involucrata)* ≈ ◆ ● Max. Ht. 10' Spreading Root System

Blue elderberry *(Sambucus cerulea)* ◆ ● ■ ☼ ☾ Max. Ht. Strong Fibrous Root System - Berries

Thimbleberry *(Rubus parvijlorus)* ≈ ◆ ☼ ☾ Max. Ht. 10' Thicket Fonning - Berries

Douglas maple *(Acer glabrum var. douglasii)* ◆ ● ■ ☼ ☾ Max. Ht. 30' Hardy - Fall Color

Oregon grape species *(Mahonia spp.)* ◆ ● ■ ☼ ☾ ● Max. Ht. 1'-7' Evergreen Rhizome - Berries

Kinnikinnick *(Arctostaphylos uva-ursi)* ◆ ● ■ ☼ ☾ Max. Ht. 8" Evergreen Groundcover - Berries

Western red cedar *(Thuja plicata)* ≈ ◆ ☾ Max. Ht. 180'

Ponderosa pine *(Pinus ponderosa)* ◆ ● ■ ☼ Max. Ht. 140'

Quaking aspen *(Populus tremuloides)* ◆ ☼ Max. Ht. 85' Extensive Clone System

Western larch *(Larix occidentalis)* ◆ ● ■ ☼ Max. Ht. 200'

Pinegrass *(Calamagrostis rubescens)* ◆ ● ■ ☼ ☾ Rhizome - Perennial Bunchgrass

Idaho fescue *(Festuca idahoensis)* ◆ ● ■ ☼ Rhizome - Perennial Bunchgrass

Junegrass *(Koeleria macrantha)* ■ ☼ Tufted Perennial

Yarrow *(Achillea millejolium)* ◆ ■ ☼ ☾ Max. Ht. 4"-39" Perennial Wildflower - Rhizome

Goldenrod *(Solidago canadensis)* ◆ ■ ☼ Max. Ht. 2'-4' Perennial Wildflower - Rhizome

Pearly everlasting *(Anaphalis margaritacea)* ◆ ● ■ ☼ Max. Ht. 2' Perennial Wildflower

Silky lupine *(Lupinus sericeus)* ◆ ■ ☼ ☾ Max. Ht. 1'-2' Perennial Wildflower

Shrubby penstemon *(Penstemonfruticosus)* ● ☼ ☾ Max. Ht. 1 '-2' Perennial Wildflower

Marsh cinquefoil *(Potentilla palustris)* 💧 ≈ ☼ ☾ Perennial Wildflower - Reddish-purple-Rhizome