MEMORANDUM

Date: October 23, 2020
To: Andrea McNamara-Doyle, Office of Chehalis Basin
From: Merri Martz, Tracy Drury, and Andy Brew, Anchor QEA, LLC
Cc: Chrissy Bailey, Office of Chehalis Basin; Jim Kramer and Ken Ghalambor, Office of Chehalis Basin consulting staff; Bob Montgomery and Heather Page, Anchor QEA, LLC; Larry Karpack, Watershed Science and Engineering
Re: Local Actions Program Near-term Technical Analyses for Office of Chehalis Basin: Summary and Evaluation of Potential Bank Protection Strategies

Overview

This memorandum is intended to provide options for bank protection strategies in the Chehalis Basin for potential inclusion in a Local Actions Program. These options may be modified based on input from the Technical Advisory Group at the direction of the Office of Chehalis Basin (OCB) prior to consideration by the Chehalis Basin Board.

The Chehalis Basin Board has agreed upon several outcome measures for a Local Actions Program, with the following being the most directly relevant to bank protection:

- The number of locations where migrating river channels and bank erosion pose a high risk of near-term damage to valuable structures or loss of economically productive land uses would be reduced by an average of X per year over up to 30 years, while protecting ecological processes (Outcome 4A: Farmland and Rural Structures Protected). The Board anticipates they will define the percentage reduction when they have an understanding of the programmatic requirements needed to achieve a specific result.
- No new structures would have been developed that are vulnerable to channel erosion or mainstem or tributary flooding from 2080 predicted 100-year flood levels, because all basin local governments have adopted model floodplain management ordinances that exceed the State and National Flood Insurance Programs' minimum requirements; all local government construction and building code standards support flood damage risk reduction through measures such as subdivision set-asides, filling restrictions, freeboard height of new buildings, critical facility placement and protection, and non-conversion agreements; and incentives direct future development out of harm's way (Outcome 8: Prevent New At-Risk Development).

This memorandum provides a summary of existing codes, plans, and manuals that address bank protection strategies, with a focus on bioengineering techniques, used at the local, state, and national level that could be appropriately used in the Chehalis Basin. This memorandum also summarizes the pros and cons of different bank protection techniques and applicability in the basin, identifies new and emerging approaches within Washington State and the Pacific Northwest, and provides options and considerations of how to facilitate the use of bioengineered bank protection techniques within a Local Actions Program. The use of bioengineered bank protection techniques could also provide more certainty of compatibility with other elements of the Chehalis Basin Strategy, such as the Aquatic Species Restoration Plan (ASRP).

This memorandum is organized as follows:

- Previous goals developed related to bank protection for the Chehalis Basin Strategy
- Available resources and guidelines for bioengineered bank protection techniques that are applicable to the Chehalis Basin
- Range of bank protection techniques that could be included in the Local Actions Program
- Hypothetical examples of erosion issues and potential solutions
- Options for how to incorporate and promote use of bioengineered bank protection techniques into a Local Actions Program

Summary of Options

Near-term Options

The majority of state and local codes and regulations related to bank protection encourage the use of bioengineering techniques unless it can be demonstrated that only a harder solution is suitable. There is significant uncertainty on the part of private landowners on what they can do to protect against erosion damage. It can be costly to analyze and design bioengineered solutions that are likely to be effective based on the site geomorphic and hydraulic conditions. Without this analysis, it can be difficult for landowners to obtain permits. Landowners may sometimes elect to not address bank erosion issues until it becomes an emergency. For emergency situations, it can be easier to justify the need for hard solutions. This does not benefit either the environment or landowners as typically more private property damage has occurred and then rock is placed in the rivers. There is significant uncertainty on the part of private landowners on what they can do to protect against erosion damage. It will be important to provide education and technical assistance to landowners. There also appears to be instances of illegal bank stabilization and enforcement will be an important element of a future program.

Thus, options to facilitate the use of bioengineering techniques with landowners could be an important element of a Local Actions Program. There may also be circumstances where there is high risk to critical infrastructure or other structures that cannot be moved or protected with bioengineering techniques and harder types of bank protection may be necessary. Combining harder bank protection with bioengineering techniques is another option to reduce negative impacts to the river ecosystem and lower life-cycle costs in the long term.

For the near-term analyses, the Board could consider the following:

1. Develop goals for a Bank Protection Strategy (BPS) to be incorporated into a Local Actions Program, including which types of techniques would be promoted (such as in Table 1).
2. In consideration with the memorandum titled *Local Actions Program Near-term Technical Analyses for Office of Chehalis Basin: Potential Options for Delineating Erosion Hazards* (Anchor QEA 2020), identify one or more pilot subbasins to develop a pilot technical assistance plan for landowners.

Long-term Options

A future step to developing a bank protection approach for the Local Actions Program would be to identify high priority bank protection areas to understand what issues are of most importance and develop potential options for stabilization on a reach- or subbasin-specific basis.

To implement bioengineering in the Chehalis Basin per goals developed by the Board, a technical assistance program will likely be needed and will also help foster coordination of funding resources between the parts of the Chehalis Basin Strategy (e.g., ASRP, Community Flood Assistance and Resilience [CFAR]). In addition, streamlining permitting will be important to provide more certainty for landowners. Longer term options could include the following:

- Develop technical assistance position(s) at OCB or local governments to support landowners in identifying the key issues and potential solutions, such as identified for the hypothetical examples.
- Develop or modify existing standard details for the range of bioengineering techniques that landowners can use for permit submittals and to solicit contractors for the work.
- Develop streamlined bioengineered bank protection permitting process at local and state level so landowners have more certainty around obtaining permits.
- Provide technical training for local governments, maintenance crews, and local contractors, as feasible, on the installation of bioengineered techniques.
- Provide better enforcement of existing codes and regulations to reduce illegal bank protection actions.
- Monitor bioengineered bank protection techniques and report out on their effectiveness.

Questions for Technical Advisory Group Members

Specific questions for the Technical Advisory Group to consider:

1. Are there additional emerging bioengineering techniques not identified in this memorandum that should be considered for use in the Chehalis Basin?
2. Under what circumstances can bank protection be provided and not have a significant impact on natural processes and functions? In what circumstances may it be necessary to provide bank protection that can negatively impact natural processes and functions?

3. What options would you recommend for the Board to consider implementing in the short and long term?

Prior Work for the Chehalis Basin Strategy

During the 2015 to 2017 biennium, a Chehalis Basin BPS was explored and not completed as part of the ASRP effort. The BPS was not completed due to concerns from stakeholders that bank protection was not compatible with the goals of the ASRP. However, the goals of the BPS could be considered in the context of a Local Actions Program. It is also important to consider where bank protection techniques could be compatible as well as incompatible with ASRP habitat restoration actions or other Chehalis Basin Strategy actions that could occur in the future.

The draft goals that were considered previously for a BPS were as follows:

1. Encourage the development and continuation of natural, habitat-forming processes.
2. Educate landowners in the Chehalis Basin on stream-friendly ways to protect their property and livelihoods.
3. Proactively identify and prioritize areas where bank protection is needed
4. Provide landowners with increased certainty regarding ecologically friendly bank protection methods.

As described later in this memorandum, a near-term option for the Chehalis Basin Board to consider (in consultation with the ASRP Steering Committee and others) would be to determine the goals to guide a BPS. The previously identified goals could still be appropriate for a Local Actions Program, with input from OCB and the Chehalis Basin Board.

Available Guidance Documents and Existing Codes

The following guidance documents and existing local codes for the basin have been reviewed to develop the list of potentially suitable bioengineering techniques and requirements for their use in the basin (Table 1).

Washington State

Integrated Streambank Protection Guidelines

The Washington Department of Fish and Wildlife (WDFW) *Integrated Streambank Protection Guidelines* (WSAHGP 2003) is the primary guidance document for evaluating and selecting ecologically sound streambank protection techniques. It is also the basis for the review of proposed bank protection projects by state regulatory agencies. This integrated approach emphasizes techniques that address both site- and reach-based conditions and avoids worsening impacts to habitat. The document is part of Washington's Aquatic Habitat Guidelines program, a multiagency program to provide technical assistance for protecting and restoring salmon habitat.

Stream Habitat Restoration Guidelines

The *Stream Habitat Restoration Guidelines* (WSAHGP 2012), also part of the Aquatic Habitat Guidelines Program, focus on approaches to planning and designing habitat restoration projects. For the most part, bank protection techniques are not included, but this document is referenced as appropriate.

Placement of Large Woody Debris on State-Owned Aquatic Lands

The *Placement of Large Woody Debris on State-Owned Aquatic Lands* (DNR 2012) provides guidance to Washington Department of Natural Resources (DNR) Aquatic Resources staff for reviewing and authorizing projects involving the placement of large woody debris on state-owned aquatic lands. Per the guidance, such projects are only allowable for habitat creation, enhancement, or restoration; compensatory mitigation; bank stabilization or protection; flood management; or hydraulic alterations for those purposes. The guidance specifies the requirements related to environmental and safety review, protecting public safety, infrastructure, and critical habitat.

Federal

National Engineering Handbook Part 654

The Natural Resources Conservation Service (NRCS) developed the *National Engineering Handbook* (NRCS 2007), which provides broadly applicable guidance for common elements of the restoration design process as well as options—including bank protection elements—for site-specific activities. It promotes the use of sustainable physical, chemical, and biological processes that provide an integrated approach to restoration.

Bank Stabilization Guidelines

The U.S. Bureau of Reclamation developed the *Bank Stabilization Guidelines* (USBR 2015) for the evaluation of a wide range of bank stabilization techniques including relocating infrastructure, channel relocation, vegetation, wood and boulder structures, deflection structures, and traditional hard structures. The intent is to guide users toward solutions that fit within the geomorphic context of a river and bioengineering techniques that may be more sustainable over the long term and also have lower life-cycle costs.

National Large Wood Manual

The *National Large Wood Manual* (USBR and ERDC 2016) is intended to provide restoration practitioners and resource managers with a basic understanding of the role of wood in riverine, other aquatic, and riparian ecosystems. The document is not focused on bank protection but provides broader restoration guidance on assessing the need for wood, the use of wood in restoration projects, and managing wood that naturally enters rivers and streams. Some of the types of large wood structures described in this manual could also be used to reduce bank erosion.

The Practical Stream Bioengineering Guide

The NRCS developed *The Practical Stream Bioengineering Guide* (NRCS 1998), primarily for more arid lands east of the Cascade Mountains. The guide provides bioengineering techniques for agricultural and timber resource lands, which would be relevant in the Chehalis Basin. The focus is on establishing vegetation for long-term natural protection of banks.

Bioengineering for Streambank Erosion Control

The U.S. Army Corps of Engineers (Corps) developed the *Bioengineering for Streambank Erosion Control* guidebook (Corps 1997) for use in planning and designing ecologically friendly bank protection measures that may use a combination of living and dead plant materials and other components, such as rock, to deflect flows or protect against toe erosion.

Soil Bioengineering: An Alternative to Roadside Management

The *Soil Bioengineering: An Alternative to Roadside Management* guidebook was developed by the U.S. Forest Service (USFS 2000) to aid in reducing erosion and landslides associated with forest roads. The techniques apply to upland erosion, landslides, mass wasting, and streambank erosion. Techniques are focused on plant materials, erosion control fabrics, terracing, and various wood and crib structures.

Bridge Scour and Stream Instability Countermeasures

The Federal Highways Administration published the *Bridge Scour and Stream Instability Countermeasures* manual (FHWA 2009) to aid in the design of measures to be taken to protect bridges and roads from bed and bank scour. Both structural and non-structural measures are described and evaluated for their appropriateness for specific conditions.

Local

Guidelines for Bank Stabilization Projects

King County published the *Guidelines for Bank Stabilization Projects* guidebook (King County 1993) to provide guidance on both hard structures (such as rock revetments) and bioengineering techniques for bank stabilization.

Pend Oreille County Shoreline Bank Stabilization Guide

Pend Oreille County published the *Pend Oreille County Shoreline Bank Stabilization Guide* (Pend Oreille County 2016) to provide guidance to landowners on bioengineering techniques to stabilize banks along Box Canyon Reservoir in order to comply with their updated Shoreline Management Program to result in no net loss of ecological functions. This guide is an example of guidance provided for landowners in a specific reach of a river that addresses the primary problems that cause erosion along the shoreline.

Local Codes and Programs

Lewis County Code

The Lewis County Critical Areas Code (LCC 17.38) requires that projects and actions undertaken within critical areas and their buffers avoid, minimize, and mitigate for impacts to ecological functions. Emergency actions (such as bank stabilization) can be undertaken to protect public health, safety, and welfare, but should have the least possible impacts to critical areas. After the emergency, restoration or mitigation should be undertaken to rectify or compensate for any impacts to critical areas. Operation, maintenance, and repair of existing facilities that do not increase the impacts or further encroach into a critical area are allowed.

Lewis County Shoreline Master Program

The Lewis County Shoreline Master Program (Lewis County 2017) provides the county's policies and regulations to protect and develop shoreline areas in compliance with the Shoreline Management Act (RCW 90.58). Management policies for all shoreline designations include avoiding and minimizing uses that adversely affect the ecological function of critical freshwater habitats, and only when impacts are mitigated to result in no net loss of functions. Specifically, in-water structures are required to be designed, constructed, and maintained to ensure no net loss of ecological functions and shoreline stabilization should be designed to site or reach-specific conditions and be coordinated with adjacent property owners. Consideration of no action and bioengineering techniques is required before considering hard structures. Use of the WDFW, NRCS, and Corps guidelines is encouraged.

Grays Harbor County Code

The Grays Harbor County Critical Areas Ordinance (GHCC 18.06) requires that projects and actions undertaken in critical areas and buffers shall avoid, minimize, rectify, and mitigate impacts to critical areas. Emergency actions (such as bank stabilization) can be undertaken to protect public health, safety, and welfare, but should have the least possible impacts to critical areas. After the emergency, restoration or mitigation should be undertaken to rectify or compensate for any impacts to critical areas. Operation, maintenance, and repair of existing facilities that do not increase the impacts or further encroach into a critical area are allowed.

Grays Harbor County Shoreline Master Program

The Grays Harbor County Shoreline Master Program (Grays Harbor County 2020) provides the county's policies and regulations to protect and develop shoreline areas in compliance with the Shoreline Management Act (RCW 90.58). Management policies for all shoreline designations include balancing shoreline development with protection of natural resources and minimizing impacts to aquatic resources. The goal is to ensure no net loss of ecological functions. For shoreline stabilization, the goal is to avoid or minimize the need for shoreline stabilization and, if unavoidable, give preference to non-structural stabilization methods over structural methods.

Thurston County Code

The Thurston County Critical Areas Code (TCC 17.05) requires that non-structural or bioengineering techniques be used for shoreline protective structures, such as bank stabilization activities, unless they are determined to be infeasible. Hard structures (such as riprap) may be used as part of another allowable activity such as a bridge crossing.

Thurston County Shoreline Master Program

The Thurston County Shoreline Master Program (Thurston Regional Planning Council 1990) is currently being updated. The current program requires that structural solutions for shoreline protection should only be allowed if non-structural solutions have been demonstrated to be infeasible. The use of riprap is allowed. Shoreline protection should be designed to work in concert with natural processes such as littoral drift, erosion, accretion, and natural habitats. Shoreline protection should be developed in coordination with adjacent property owners.

Addressing Bank Erosion for the Local Actions Program

The referenced guidelines and codes promote the consideration of bioengineering techniques that reduce or eliminate the use of hard structures and materials that do not naturally occur in rivers. They tend to discourage the use of rock or riprap, structural walls, or the use of non-biodegradable grids or geotextiles. The reason the industry is moving in this direction is that hard structures can exacerbate existing problems or create a new problem in a downstream or adjacent location. For example, bank armoring can actually accelerate bed scour that will eventually undermine the structure or may deflect flows towards an opposite bank causing unintended erosion. Rock-based structures have minimal instream benefits for aquatic species, do little to promote riparian enhancement, and typically have higher life-cycle costs than bioengineering techniques because they do not become more stable over time and can require frequent rock replacement.

As part of their permit reviews, WDFW, DNR, and the Corps typically evaluate if the proposed bank protection technique(s) avoids or minimizes impacts to the aquatic environment. Only in limited circumstances would the new use of rock or other hard structures be allowed (for example, if hydraulic conditions were so severe that bioengineering techniques would not be successful at the site). Based on review of Hydraulic Project Approvals issued since 2014 in the basin, approximately 70% of projects with a bank protection element used rock or concrete elements, with about 20% of those hard structures incorporating wood or plantings. The other 30% predominantly incorporated large wood or engineered log jams to deflect flows and provide bank protection. Only a couple of the projects included bank reshaping and plantings as the primary bank protection elements. The projects that were hard solutions were predominantly for road and bridge maintenance. Maintenance of existing rock or other hard structures is allowed by the permitting agencies. However, encouraging the combination of hard and bioengineering techniques could be a more environmentally and cost-effective option.

The developed areas of the Chehalis Basin are generally in lowlands with relatively low-gradient streams and rivers where rock is not a natural material, although in some areas of the basin, bedrock outcrops or large boulders are present. The primary modes of bank erosion in the basin are bed and toe erosion, drainage from upslope that can result in smaller bank slumps and failures, or larger-scale landslides and mass wasting failures, often from saturated soils present on a slide-prone slope or more impervious soil layer.

Range of Bioengineering Techniques to Consider

After reviewing the types of bank protection techniques described in the referenced sources, several techniques appear to be most compatible with the overall Chehalis Basin Strategy and could address the Local Actions Program outcomes provided by the Chehalis Basin Board. Table 1 summarizes the techniques, what type(s) of erosion they are most effective at addressing, and the advantages and disadvantages of each technique. A short summary of the types of techniques is also provided in the following section.

Bioengineering Techniques

Fabric Stabilization Materials. A variety of biodegradable fabric materials are available to be used in combination with various types of native vegetation plantings (described in Table 1) and wood or other natural materials. Jute and coir (coconut fiber) fabrics are widely available and come in various weaves and thicknesses that provide soil stabilization and erosion resistance over typically a short-term basis (up to 5 years) until vegetation can become established and provide longer term bank stabilization. Coir logs are also available that prevent surface runoff of soil and provide some limited toe protection in low velocity areas.

Plantings. A variety of plants and planting methods can be used to provide bank and slope stabilization, including brush mattresses; fascines (bundles of live branch cuttings buried in the slope); brush layers; and plantings of cuttings, bare-root, potted stock, and seeding. Brush mattresses, fascines, and brush layers can incorporate both live and dead branches and cuttings and are layered and fastened onto bank slopes, in trenches, or partially backfilled to fill in holes and slumps. The cuttings are intended to root close to the water table and sprout for rapid cover and stabilization. These techniques can also be used with fabric and large wood materials. Willow and cottonwood pole fencing can also be used to protect the toe of banks or farther upslope or on floodplains to provide roughness to deflect flows and rapid growth of shrub and tree cover.

Large Wood Materials. A variety of wood structures can be installed in-channel, at or above the toe of bank, or in the floodplain to deflect flows, provide toe protection, reduce velocities, and spread flows out on the floodplain. Techniques include live cribs, log toes, and log deflectors that provide scour protection along the toe of a slope and/or deflect flows away from the bank. Engineered log jams in-channel can split flows, deflect flows, and reduce velocities. Buried or surface large wood and fencing on floodplains can reduce velocities of flow across the floodplain and promote sediment deposition, while providing a hard point if channel migration continues farther back into the floodplain. On bank slopes, log revetments and terraces can be used to stabilize soils and reduce erosion above the toe. These techniques are more effective if combined with native plantings.

Excavation and Grading Activities. Bank erosion and slumping and sliding can also be reduced in some cases by grading back the bank to a more stable slope that can then be vegetated or terraced and vegetated. If space and access are available, providing alternate flow paths to reduce energy by reconnecting or increasing flows into side channels or through chutes in adjacent gravel bars will more effectively spread flow and lower velocities along the eroding bank, allowing vegetation to become established. Removing fill or other materials that may have artificially confined the channel or floodplain can also reduce velocities. The introduction of gravel upstream, particularly in combination with placement of wood, can reduce channel incision and form gravel bars and islands that further disperse energy and flows.

Hypothetical Bank Erosion and Protection Scenarios

These hypothetical bank erosion scenarios are provided to highlight some common types of erosion issues in the Chehalis Basin, how to identify potential solutions, and the type of technical analysis and support that could be developed into an educational and technical assistance program.

Scenario 1. Channel Migration into Agricultural Field

Channel is migrating at a rapid rate and has already eroded pre-existing smaller riparian trees and shrubs and now has entered the agricultural field. Upstream landslides, bank erosion, and channel bed scour have contributed sediment to this reach and a large bar is building across the river. New riparian plantings cannot be established as the rate of erosion outpaces growth of plants. The field is in a low-lying area and floods regularly, causing saturation and slumping of the bank. No structures or utilities are at immediate threat of erosion, but land is being lost at a rapid rate and structures flood periodically.

Erosion protection options could consider:

A. what the rate of erosion is and if immediate attention is required;
B. whether there is potential for a combined erosion protection and ASRP restoration project (e.g., with adjacent landowners) that could address reach-scale and upstream concerns to be more effective than only addressing erosion at one property;
C. whether there is potential for combined erosion protection and floodproofing (CFAR) project to elevate house that is not in erosion danger but does flood periodically;
D. what the major contributing causes of erosion are (bank and toe scour, saturation/slumping, overbank flows scouring through bank and field, etc.);
E. if bioengineering techniques are likely to be effective;

F. identifying with the landowner one or more techniques that are likely to be effective, such as floodplain fencing, log crib, deflector log jams, log toe with bank resloping with fabric and plantings; and
G. providing technical support and streamlined permit process for landowner to implement a preferred bioengineering solution.

Scenario 2. Eroding Bank with Pipeline Behind
A high bank has a narrow riparian zone of 30-year-old alder and blackberries and is eroding slowly from the combination of water draining from upslope and causing small bank slumps that are then carried away by river flows. Some rock is already present downstream of the erosion area. A buried regional pipeline is present approximately 50 feet back behind the existing bank and it would be very difficult to move. The rate of bank erosion is about 1 foot per year. The landowner is interested in a narrow riparian zone that can be stable.

Erosion protection options could consider:

A. what the major contributing causes of erosion are (bank and toe scour, saturation/slumping, etc.);
B. if bioengineering techniques are likely to be effective;
C. identifying with the landowner one or more techniques that are likely to be effective, such as floodplain fencing, log crib, deflector log jams, mixed rock and log toe with bank resloping with fabric and plantings, buried wood back towards the pipeline for a secondary protection measure; and
D. providing technical support and streamlined permit process for landowner to implement a preferred bioengineering solution.

Scenario 3. Erosion at Bank with Regional County Road and Bridge Crossing
A steep bank with an existing rock toe continues to erode along a regional county road with a secondary road bridge crossing downstream about 100 feet. The county keeps replacing rock as it gets damaged. The river continues to erode along the roadway as it is forced to turn to go under the bridge. Relocating the road would be costly because there are numerous residences behind the road and then wetlands and a steep slope farther back from the residences. The secondary road bridge was replaced within the past 20 years but does not span the erosion hazard area.

Erosion protection options could consider:

A. what the rate of erosion is and if immediate attention is required;
B. what the major contributing causes of erosion are (bank and bed scour, etc.);
C. whether the bridge can be replaced with a wider span to avoid concentrating the flow and scour;

D. whether bioengineering elements could be incorporated into the existing rock elements that might extend the life and reduce life-cycle costs of the bank protection; and
E. identifying one or more techniques that are likely to be effective, such as incorporating wood into the rock toe, bank grading and fabric lifts with plantings above the toe, or large wood deflectors.

Options for Analyses

The key theme in the hypothetical examples and from the experience of landowners in the Chehalis Basin is that erosion issues are difficult and costly for individual landowners to address. In addition, the permitting process can be very time-consuming and require detailed technical analyses that may also be difficult for landowners to afford or develop.

Options for Near-term Analyses

The Board could consider the following:

1. Develop goals for a BPS to be incorporated into a Local Actions Program, and the types of techniques that will be promoted (such as in Table 1).
2. In consideration with the memorandum titled *Local Actions Program Near-term Technical Analyses for Office of Chehalis Basin: Potential Options for Delineating Erosion Hazards* (Anchor QEA 2020), identify one or more pilot subbasins to develop a pilot technical assistance plan for landowners.

Options for Long-term Analyses

A future step to developing a bank protection approach for the Local Actions Program would be to identify high priority bank protection areas to understand what issues are of most importance and develop potential options for stabilization on a reach- or subbasin-specific basis.

To implement bioengineering in the Chehalis Basin per goals developed by the Board, a technical assistance program will likely be needed and will also help foster coordination of funding resources between the parts of the Chehalis Basin Strategy (e.g., ASRP, CFAR). In addition, streamlining permitting will be important to provide more certainty for landowners. Longer-term options could include the following:

- Develop technical assistance position(s) at OCB or local governments to support landowners in identifying the key issues and potential solutions, such as identified for the hypothetical examples.
- Develop or modify existing standard details for the range of bioengineering techniques that landowners can use for permit submittals and to solicit contractors for the work.
- Develop streamlined bioengineered bank protection permitting process at local and state level so landowners have more certainty around obtaining permits.

- Provide technical training for local governments, maintenance crews, and local contractors, as feasible, on the installation of bioengineered techniques.
- Provide better enforcement of existing codes and regulations to reduce illegal bank protection actions.
- Monitor bioengineered bank protection techniques and report out on their effectiveness.

Table 1
Potential Bioengineering Techniques for the Chehalis Basin

TREATMENT CATEGORY	TECHNIQUE	DESCRIPTION	STREAM SCALE	ENERGY ENVIRONMENT	BANK ISSUE ADDRESSED	ADVANTAGES	DISADVANTAGES
Fabric Stabilization	Coir Logs	Cylindrical structures that may be 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	Small Streams to Large Rivers	Low to Moderate	Scour, Seepage	• Forms an immediate protective cover over the streambank • Captures sediment during flood flows • Provides opportunities for rooting of the cuttings over the streambank • Rapidly restores riparian vegetation and streamside habitat • Enhances conditions for colonization of native vegetation • Appropriate where exposed streambanks are threatened by high flows prior to vegetation establishment • Composed of biodegradable materials only	• Not applicable as a stand-alone technique for high velocity sites unless used in combination with structural toe protection placed below the coir logs • Not appropriate where scour and undercutting can undermine the coir logs • Not particularly effective for large sites • Limited to the slope above base flow levels • Should not be used on slopes that are experiencing mass movement or other types of slope instability • Irrigation is often necessary in mid to upper banks of drier site • Creates a smooth bankline providing limited roughness
	Fabric Encapsulated Lifts	Bioengineered bank stabilization consisting of constructed lifts of fabric wrapped soils, interlaced with rooted willow plants	Small Streams to Large Rivers	Low to Moderate	Toe Erosion, Scour, Seepage	• Allows establishment of vegetation that will slow erosion but not completely harden the bank • Composed of biodegradable materials only	• Only lasts 3 to 5 years, and relies on plant establishment
	Erosion Control Blanket	Biodegradable, open-weave blankets that provide temporary cover and support for establishing vegetation on bare soil areas	Small Streams to Medium Rivers	Low	Toe Erosion, Scour, Seepage	• Excellent for mitigating surface erosion • The blanket offers immediate and uniform slope protection from rain and overland water flow if it is installed in full contact with the soil surface • Composed of biodegradable materials only	• Can be labor intensive and may require more investment to install • Requires numerous wood stakes or live stems to secure the blanket • Too much grass seeded on the blanket can lead to over-competition for moisture, sunlight, and nutrients, and may result in high tree and shrub mortality
Live Plantings	Brush Mattress	Combination of live stakes, live fascines, and branch cuttings installed to cover and physically protect streambanks; eventually to sprout and establish numerous individual plants	Small Streams to Medium Rivers	Low to Moderate	Toe Erosion, Bank Erosion, Meander Migration	• Forms an immediate protective cover on slopes • Captures sediment during rainfall events and flood flows • Protects cuttings while they root and grow • Rapidly restores riparian vegetation and streamside habitat • Enhances conditions for colonization of other native vegetation	• Limited to the slope above base flow levels
	Live Stakes	Live, woody cuttings that 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 can provide rapid cover	Small Streams to Large River	Low to Moderate	Mass Wasting, Meander Migration	• Quickly and inexpensively establishes riparian vegetation • Applicable at low or high bank sites • Appropriate for repair of small earth slips and slumps that are frequently wet • Can be used to stake down surface erosion control materials • Enhances conditions for colonization of other native vegetation	• Requires toe protection where toe scour is anticipated • Only effective where the water table is high enough for cuttings to reach it • Not effective on its own where rapid erosion and scour is occurring

TREATMENT CATEGORY	TECHNIQUE	DESCRIPTION	STREAM SCALE	ENERGY ENVIRONMENT	BANK ISSUE ADDRESSED	ADVANTAGES	DISADVANTAGES
	Joint Plantings	Live stakes tamped into joints or openings between rock that have previously been installed on a slope or while rock is being placed on the slope face	Creek to Large River	Low to Moderate	Meander Migration	• 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 • Can be installed from base flow levels to top of slope, if live stakes are installed to reach groundwater	• Not always applicable as a stand-alone technique for high velocity sites unless used in combination with a toe protection technique • Thick rock riprap layers may require special tools for establishing pilot holes • Survival rates can be low due to damage to the cambium or lack of soil/stake interface
	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	Small Streams to Medium Rivers	Low to Moderate	Bank Erosion, Meander Migration	• Effective stabilization technique for streambanks, requiring a minimum amount of site disturbance • Applicable at low or high bank sites • Can trap and hold soil on streambank by creating small dam-like structures and reducing the slope length into a series of shorter slopes • Facilitates drainage when installed at an angle on the slope • Enhances conditions for colonization of native vegetation	• Requires toe protection where toe scour is anticipated • Not appropriate for treatment of slopes undergoing mass movement • Not always applicable as a stand-alone technique for high velocity sites unless used in combination with a toe protection technique
	Brush Layering/ Branch Packing	Alternate layers of live branches and compacted backfill, which stabilize and revegetate slumps and holes in streambanks	Small Streams to Large Rivers	Low to Moderate	Toe Erosion, Meander Migration	• Beneficial where streambank has already scoured out • Enhances plant colonization • Provides soil reinforcement	• Not effective in larger slump areas (greater than 4 by 4 feet)
	Rooted Stocks	Any tree, woody shrub, or herbaceous plant with established roots, including rooted cuttings, balled and burlapped, bare-root, and containerized plants Used either alone or with other methods to provide leafy cover and root strength; sends roots into the surrounding soil in weeks, faster than cuttings that may take months May be placed anywhere on the bank where it will not be removed by erosive flows	Small Streams to Large Rivers	Low to Moderate	Bank Scour, Meander Migration	• May be used for planting during the growing season when unrooted cuttings may not survive • Useful where soils are droughty, nutrient poor, where rooting of cuttings is doubtful or when cuttings of desired species are unavailable • May be added where understory vegetation already exists and larger shade-providing plants are desired • Rooted stock provides immediate vegetative cover and habitat improvement • Depending on the root distribution needed, plants may be spread evenly across the site for uniform cover or clumped for a more natural appearance [the plants vary in size from small (inches) to large (10 or 12 feet tall)]	• Containerized stock has a relatively high cost per plant • Even with established roots, rooted stock at some sites may require irrigation for one or more seasons
	Herbaceous Cover	Consists of planted or seeded herbaceous vegetation used to improve soil and bank stability and provide rapid cover for wildlife habitat and site aesthetics Herbaceous vegetation consists of grass and grass-like wetland plants and includes rushes, sedges, ferns, legumes, forbs and wildflowers. In contrast to woody vegetation, herbaceous vegetation tends to have roots	Small Streams to Large Rivers	Low to Moderate	Bank Scour, Meander Migration	• If used in combination with other bank protection and erosion control techniques, such as toe protection, and/or erosion control fabric, herbaceous cover can provide immediate protection against surface erosion • Applicable as a stand-alone treatment on a streambank that has a relatively stable toe but has poor vegetative cover and possibly some surficial erosion or modest, reach-based aggradation	• Not always applicable for sites where undercutting or mass failure occurs unless used in combination with a toe protection technique • Cannot be used as the primary method to control major bank erosion problems • Due to the relatively shallow rooting depths of grasses, this treatment should not be used on reaches where degradation and channel downcutting is widespread

TREATMENT CATEGORY	TECHNIQUE	DESCRIPTION	STREAM SCALE	ENERGY ENVIRONMENT	BANK ISSUE ADDRESSED	ADVANTAGES	DISADVANTAGES
		that are shallow, fine, and dense and form a more continuous mat across the soil surface				• May also be an excellent choice as ground cover in parks and urban areas where flood conveyance and ease of maintenance is important	• Does not provide significant shade or cover to the stream, thus only minimally improving fish habitat
	Willow Fencing	Short fence or wall built of living cuttings that may have a brush layer base intended to slow and redirect floodwaters away from a bank or floodplain area	Small Streams to Medium Rivers	Low to Moderate	Bank Scour, Meander Migration	• These structures reduce slope angle, providing a stable platform for vegetation to establish • Willow fences trap rolling rocks and sliding debris and protect vegetation growing lower on the slope • Willow fences provide support for small shallow translational or rotational failures • When the structure begins to decay, root systems of other plants will serve as the permanent feature • Most suitable in areas with high water table for willow/brush layering fence installations • Can be constructed on dryer sites, but it is important to establish deeper rooting shrubs and trees within the shelf	• Significant quantity of plant material is required • Moist site conditions are required for the fence to sprout and grow
Large Woody Materials	Live Cribwall	Hollow, box-like interlocking arrangements of untreated log or timber members with or without rootwads, 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	Small Streams to Large Rivers	Low to High	Toe Erosion, Seepage, Mass Wasting, Meander Migration	• Effective in high velocity areas • Appropriate both above and below the water, where the channel is not incising • Provides protection to the streambank in areas with near vertical banks where bank sloping options are limited • Affords a natural appearance, immediate protection, and accelerates 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	• May require higher level of investment to install • Structure may have only limited ability to adjust to toe scour • Should be used with soil bioengineering systems and vegetative plantings to stabilize the upper bank and ensure a regenerative source of streambank vegetation • Site must be accessible to heavy equipment • Materials might not be readily available at some locations
	Log Toe	Boulders and logs with root masses attached, placed in and on streambanks to provide streambank erosion, trap sediment, and improve habitat diversity	Small Streams to Large Rivers	Low to Medium	Toe Erosion, Bank Scour, Degrading Reach	• Can be anchored with boulders, pilings, or wedged through existing trees • Will tolerate high boundary shear stress if logs and rootwads are well anchored • Suited to streams where fish habitat deficiencies exist • Will enhance diversity in riparian areas when used with soil bioengineering systems • 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	• Should be used with soil bioengineering systems and vegetative plantings to stabilize the upper bank and ensure a regenerative source of streambank vegetation • Will have limited life depending on climate and tree species used. Some species, such as cottonwood or willow, often sprout and accelerate colonization. • Site must be accessible to heavy equipment • Materials might not be readily available at some locations • Can create local scour and erosion • May require higher level of investment to install

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	Large Wood Deflector (i.e., Bank Barb)	Wood structures that protrude from either streambank, but do not extend entirely across a channel, to deflect flows away from the bank and scour pools by constricting the channel and accelerating flow	Creek to Large River	Low to High	Toe Erosion, Bank Scour	• Can tolerate high boundary shear stress • Should be installed in series on the same streambank to push the thalweg away from the bank or on alternating streambanks to produce a meandering thalweg and associated structural diversity • Should be designed and located far enough downstream from riffle areas to avoid backwater effects that would drown out or otherwise damage the riffle • Must be sized on anticipated scour • The material washed out of scour holes is usually deposited a short distance downstream to form a bar or riffle area. These areas of deposition are often composed of clean gravels that provide excellent habitat for certain species. • Should be used in channels with low physical habitat diversity, particularly those that lack stable pool habitat	• Should be combined with vegetative plantings to stabilize upper banks/slopes • May require higher level of investment to install • Deflectors placed in sand bed streams may settle or fail due to erosion of sand, and in areas a filter layer or geotextile might be needed underneath the deflector • Site must be accessible to heavy equipment • Materials might not be readily available at some locations • Response can be unpredictable, creating undesired local scour and erosion
	Engineered Log Jam	Structures composed of large woody materials installed in the channel to redirect flows	Creek to Large River	Low to High	Toe Erosion, Bank Scour, Degrading Channel, Meander Migration	• Can tolerate high boundary shear stress if well anchored • Can be anchored with boulders, pilings, or wedged through existing trees • Will tolerate high boundary shear stress if logs and rootwads are well anchored • Suited to streams where fish habitat deficiencies exist • 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 • Response can be unpredictable, creating undesired local scour and erosion • May requirement higher level of investment to install
	Buried Wood Set-Back	Buried large woody materials, typically rootwad logs installed on the floodplain in an excavated trench; typically installed down to the elevation of the river bottom to create a limit for future channel migration	Creek to Large River	Low to Medium	Bank Scour, Meander Migration	• Does not require working in the channel, minimal environmental impacts	• Site must be accessible to heavy equipment • May require higher level of investment to install • Will only be effective once erosion and channel migration has occurred
	Floodplain Roughness	Placing or partially burying woody materials to increase roughness and reduce velocities on the floodplain	Creek to Large River	Low to Medium	Mass Wasting, Bank Scour, Meander Migration	• Relatively low cost • Can be constructed using on-site materials	• Woody material is more prone to degrade and wash away • Not as effective in high energy environments • Does not address toe erosion
	Floodplain Fencing	Combination of timber pilings and other woody materials buried into the floodplain to limit meander migration and accumulate additional woody material as bank erosion occurs	Creek to Large River	Low to High	Bank Scour, Meander Migration	• Helps recruit additional large wood, creating a more natural feature • Effective in a range of energy environments	• Site must be accessible to heavy equipment and have room for excavation and installation
	Tree Revetment	A pervious line of wood materials, made from whole trees cabled together and held in place with rock and anchors buried in the bank	Creek to Large River	Low to Medium	Toe Erosion, Bank Scour, Meander Migration	• Relatively inexpensive, semi-permanent form of protection • Slows and deflects high bank velocities; limits toe erosion • As it collects sediment and begins to revegetate, it becomes more natural in appearance and function • Can provide cover for aquatic species	• Cables and other anchor materials are seen as non-natural and may not be desired • Have a limited life and must be replaced periodically. Loss of trees through damage or deterioration will expose the bank to the current. If revetment is not repaired, bank will continue to undercut and erode.

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	Log Terracing	Uses alternating terraced logs to stop surface erosion on eroding slopes, which is critical for successful revegetation efforts. Specifically, log terracing shortens slope length and gradient between each structure, providing stable planting areas throughout most of the slope face.	Creek to Large River	Low	Bank Scour, Seepage	• Logs create terraces reducing length and steepness of slope, provides stable areas for establishment of other vegetation such as trees and shrubs	• Labor intensive and with potential safety hazards on steep slopes
Grading Activities	Bank Shaping	Regrading streambanks to a stable slope; placing topsoil and other materials needed for sustaining plant growth; and selecting, installing, and establishing appropriate plant species	Small Streams to Large Rivers	Low	Toe Erosion, Mass Wasting, Aggrading Reach, Meander Migration	• Applicable at low or high bank sites • Successful on streambanks where moderate erosion and channel migration are anticipated • Enhances conditions for colonization of native species • Streambank soil materials, probable groundwater fluctuation, and bank loading conditions are factors for determining appropriate slope conditions	• Additional toe reinforcement may be necessary • Must be used in conjunction with other protective practices if flow velocities exceed the tolerance range for available plants, and where erosion occurs below base flows
	Benching	Excavating a floodplain bench into a steep eroding bank, typically done to an elevation at or just above the ordinary high water mark, with the intent of spreading floodwaters to reduce local velocities and allow riparian vegetation to re-establish	Small Streams to Large Rivers	Low to Medium	Bank Scour, Mass Wasting	• Inexpensive approach • Will help establish riparian vegetation by lowering bank elevations	• Additional toe reinforcement may be necessary • Will not halt channel migration unless vegetation can establish • High velocities may prevent vegetation establishment
	Reconnection of Side Channel	Excavating to promote flow (or more flow) into an existing or constructed side channel to reduce energy acting on an adjacent eroding bank	Small to Large River	Low to High	Toe Erosion, Bank Scour, Meander Migration	• Promotes natural processes • May not require any additional bank stabilization measures	• Site must be accessible to heavy equipment • Can be higher in cost if extensive channel excavation is required • Only suitable for locations with existing channels or swales or low floodplain
	Gravel Bar Chute	Excavating one or more channels through an adjacent gravel bar (e.g., on opposite bank) to reduce energy acting on an eroding bank	Small Streams to Large Rivers	Low to High	Toe Erosion, Bank Scour, Meander Migration	• Cheap and relatively simple approach • May not require any additional bank stabilization measures	• Requires access and permission to adjust adjacent gravel bar • May only reduce energy over short term (1–5 years) • Site must be accessible to heavy equipment • Should be used in combination with revegetation or other techniques that will provide long-term stabilization
	Removal of Fill	Removing fill or regraded areas in the channel or floodplain to create more room for the river and promote natural stream processes	Small Streams to Large Rivers	Low to High	Bank Scour, Meander Migration	• Removes confining fill or hillslopes that are causing high velocities and erosion • May not require any additional bank stabilization measures	• Site must be accessible to heavy equipment • Need a disposal site for these materials
	Gravel Augmentation	Importing and dumping gravel upstream of a sediment supply-limited reach to encourage deposition downstream and reduce stream power	Small Streams to Large Rivers	Low to High	Degrading Reach	• Promotes natural processes and channel equilibrium • May not require any additional bank stabilization measures	• May have higher life-cycle costs if it needs to be repeated • More of a reach-scale approach; may not help a localized site • Site must be accessible to heavy equipment

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