Bank Protection

Figure 1. Shaped by erosion and sediment deposition, the Musselshell River valley provides a living example of the dynamic, opposing forces that drive river and floodplain function. Understanding these forces and their interaction with human modifications is key to properly evaluating channel stability/bank protection need and feasibility.

Applicability

This summary and discussion of bank protection strategies has been developed to support well informed decisions regarding treatments for bank protection as well as future sustainability of the Musselshell River and associated resources. Issues of economics, risk assessment, stream dynamics, bank and channel characteristics, floodplain function, and potential impacts to associated resources were evaluated along with the experiences of landowners along the Musselshell River. The information is for use by land managers in the river corridor who have experienced bank erosion and/or lateral channel movement and want to determine if the investment in bank protection is warranted and feasible.

Description

Regardless of size, all waterways, whether manmade or natural in origin, tend toward a condition of balance, or dynamic equilibrium, where the amount of sediment transported is in balance with the energy available for that transport. The primary source of the sediment transported is usually the bank and bed of the stream, although a portion is also contributed by the uplands in a healthy watershed. As sediment moves downstream, it is continually reworked - deposited in areas of low energy such as point bars and eroded in areas of higher energy such as cut banks. When the balance between energy and sediment is upset, instability can result. Unstable channels can fill in (too little energy) or enlarge (too much energy). Major floods can cause instability, and after floods channels typically have to adjust to regain an equilibrium condition. Long-term adjustments in channel length and width typically result. Riparian vegetation is also a critical part of the balance as it helps banks physically resist erosive energy; its removal also causes most streams to destabilize. In addition to major floods and vegetation removal, other human impacts such as overgrazing, certain agricultural disturbances, channelization, water withdrawal, dams, and floodplain alteration can lead to greater swings in sediment deposition or erosion. When erosion or deposition occur at rates greater than those of a stream in balance, the channel is likely unstable.

Understanding whether bank erosion is the result of simple channel meandering or is caused by larger system instability is key to identifying optimal alternatives. Protecting high value infrastructure is relatively straightforward when the erosion is typical for the channel and there is no underlying instability. If accelerated erosion is a symptom of overall channel instability, crafting the best solution may require a much greater understanding of the site and system. Ill-informed treatment of an eroding bank may only address the symptom rather than the actual problem. This treatment may cause problems elsewhere or result in failure. The most cost-effective solution may be to allow the channel to adjust naturally so it is able to recover its equilibrium. Because we <u>can</u> fix it doesn't always mean we <u>should</u> fix it.

This Bank Stabilization BMP addresses a number of bank protection considerations. Each alternative presented has inherent strengths and weaknesses relative to the specific treatment site and desired goal. Some solutions may represent knowing when to avoid treating eroding sites. These considerations are discussed below for each strategy. Specific information regarding design and installation details are not presented here due to length and complexity. For more information on each method and required permits, please consult the *Montana Stream Permitting Handbook at* http://dnrc.mt.gov/Permits/StreamPermitting/PermittingBook.asp and/or a knowledgeable, professional stream engineer.

I. **No action** – when taking a wait and see or no action approach is the best solution.
II. **Rock riprap**: using an engineered rock blanket to armor a bank against erosion.
III. **Flow deflectors**: placing structures to deflect energy and flow away from a bank.
IV. **Bioengineered approaches**: the use of living and non-living plant materials in combination with synthetic support materials to stabilize slopes, manage streambank erosion, and establish vegetation
V. **Hybrid methods**: Combining several bank stabilization strategies to reduce or eliminate bank erosion.
VI. **Making the decision** – factors to consider when contemplating bank protection.

I. No Action

Since bank armor stops bank erosion, it prevents channels from moving laterally across their floodplains. Locking a river in place can have a devastating impact on river process, since balanced channel migration creates areas for riparian and floodplain renewal, recruits spawning gravels from banks, and allows the channel to adjust to fluctuating inputs of flow and sediment. Placing even short sections of bank stabilizing armor should be thoroughly evaluated. In unstable settings, treating an isolated eroding bank is even more challenging as it often does not address the root cause of the erosion. In fact, extensive bank treatment in this situation may do greater harm by preventing the system from making needed adjustments in grade or channel width/depth following a disturbance. For example, the Musselshell River continues to make large scale adjustments following the 2011 flood, when the river lost 26 miles of length in three weeks.

Fundamentally, landowners should be fully aware of the potential long-term costs and ecological consequences of installing bank armor on a dynamic stream. Taking no action may make the most economic and practical sense while waiting to see what the river's response will be after such a large disturbance in 2011.

II. Rock Riprap

Considered a 'hard', long-term approach, rock riprap is generally discouraged because of high costs and potential negative impacts on channel stability and fisheries. Riprap is usually limited to sites where no risk is acceptable; that is, when high-value property is seriously threatened and where flow and energy stresses are high rendering other methods impractical. Bridge abutments, irrigation structures, and buildings are typical sites where the use and expense of rock riprap can sometimes be justified. Additionally, rock of sufficient strength and durability is not locally available in much of the middle and lower Musselshell River corridor. Transporting suitable rock from a distant quarry can raise the cost significantly. A few important caveats when considering rock riprap:

- Carefully evaluate potential impacts to up and downstream banks and adjacent properties.
- Incorporate native vegetation into the design whenever possible (See Hybrid Methods below) and use ‘dirty’ rock or rock that has some soil incorporated into the rock matrix to encourage vegetation.
- Excavate and ‘key in’ the base or ‘toe’ of the rock blanket below the elevation of anticipated bed scour as this is the zone of highest erosive stress from water, ice, and the weight of the rock above.
- Utilize a gravel filter blanket beneath the rock in sites with sandy soil to retain soil fines.
- Use angular rock properly sized for the energy setting. Concrete and round rock are unsuitable as riprap.
- Avoid placing rock on slopes that are steeper than 2H:1V.
- Always have a qualified professional engineer and/or hydrologist evaluate, design, and oversee installation of rock riprap projects. This may help to avoid failure and treatments that simply ‘band aid’ a larger stream stability issue. Bank armor is notorious for being flanked, requiring costly repairs.

Figure 2. High flows flanked this rock riprap now sitting in the middle of the channel adding to the overall stability problems. Photo Credit: K. Boyd.

III. Flow Deflectors

Flow deflectors redirect flow and energy away from an eroding bank so that impacts on adjacent banks and fisheries is minimized compared to blanket rock riprap. Material and expense is usually much less than for rock riprap, however the degree of risk is greater. Flow deflectors mimic natural structures found in rivers that perform this important function. Following are several types of flow deflectors:

a. *Barbs or Vanes* are designed to deflect the current, ice, and debris away from the bank on gentle outside bends or straight reaches. They are usually constructed of a series of evenly spaced, large diameter stone or log structures (or a combination of both). The structure angles from the bank down and upstream, typically at an approach angle of 20 to 30 degrees , not exceeding about one-fourth of the channel width. Eddies resulting from improper use or construction will cause erosion and failure.

b. *Bendway Weirs* are a modification of a barb or vane for gently meandering, larger streams (> 100’ bankfull width). Typically constructed of large rock, it mimics a low angle sill (30 to 45 degrees). Because of the greater forces associated with a larger river system, careful consideration of design variables, materials, and installation techniques is critical for success in a river the size of the Musselshell. Both barbs and bendway weirs require long-term maintenance and can have impacts on downstream banks if adequate spacing and numbers are not installed. Landowners should avoid using bendway weirs on streams having more than gentle meander bends as erosion of downstream bends is likely due to altered flow dynamics.

c. *Rock V and W Weirs* are rock boulder, grade control structures that are used to alter channel geometry (width to depth ratio) as a means of addressing bank erosion and other purposes such as irrigation diversions. A 'V' shape is used for narrow channels and the "W" used for wider channels or for flow splits. The upstream facing V and W reduces erosion by directing flow away from both banks toward the middle of the channel and forms a deep, scour pool below the weir which can also benefit fisheries values where needed. An experienced professional is needed to design and install these structures especially in systems with larger instability issues. Maintenance must be carefully assessed to avoid problems with undermining or sediment passage. Costs are relatively high due to the size of rock boulders required but cost is usually less than riprap. They do typically carry higher risk than other approaches.

d. *Tree Revetments and Root Wads* represent an approach to deflect flows using locally sourced material. Tree revetments utilize large, whole trees, typically cottonwood, to protect the bank. Cables and tie down anchors are used to hold overlapped trees in place against the bank. Rocks or other weight must be securely placed to keep the trees from floating during high flows. *Root Wad* structures are positioned and spaced so that the root mass is placed in an upstream position to deflect energy away from the bank. These structures usually are less expensive because the cost of rock is eliminated, however, the risk of failure is greater if not carefully designed and installed. Because the wood will eventually deteriorate, these structures depend on trapping sediment and allowing native vegetation to establish for long-term performance.

IV. Bioengineering

Bioengineering is a 'soft' approach. Landowners must consider the level of erosion protection needed, and whether the project is to 'restore' or 'stabilize'. While stabilizing practices are intended to rigidly hold a bank in place, *bioengineering* is intended to mimic the role of native vegetation on channel processes yet allows for some channel migration at rates normal for the stream setting. A few considerations on use of bioengineering approaches are:

- A restoration objective is usually preferable from a cost and ecological point of view since it generally costs less and has fewer negative impacts on other resources but is not appropriate where accelerated erosion due to system instability or a high value/low risk asset is present.
- The inclusion of engineering design concepts makes it more than just planting vegetation, however, the level of risk must be acceptable for the site since bioengineering typically carries higher risk than traditional engineered approaches.
- All bioengineering materials are intended to be temporary in nature by restoring native riparian vegetation to provide the long-term bank protection long after the material itself is gone. While lower in materials and machinery cost, bioengineering is labor intensive by nature.
- Use locally harvested native plants and materials that are best adapted to the conditions at the site.

a. *Erosion protection fabrics,* known as geotextiles, are made of a variety of biodegradable materials. Natural fiber from coconut, jute, excelsior, or straw is woven in different combinations and thicknesses.

This fabric is placed and anchored as a mulch mat to resist wave and shoreline energy. Seed and live plants typically are used in combination with fabric. These techniques are usually not appropriate for high energy situations or where tall banks or mass slumping is active.

b. *Soil lifts* are another technique designed to mimic the strong, natural sod banks that occur on healthy streambanks. Geotextile blankets are used to build overlapping, fabric-wrapped lifts of soil that are planted to native plants. As the blankets deteriorate, the plants grow a sod and root mat to anchor the bank and resist erosion.

c. *Wattles and fascines* are long, cylindrical bundles of live, dormant stems that are buried in the target bank. Their function is to provide physical resistance to erosion while also growing into new native trees and shrubs. Locally adapted species of willows are typically used to create these living structures.

d. *Brush layering and mattresses*. As the name implies, layers of branches are used in conjunction with alternating layers of soil to reconstruct a sloped bank from which the dormant cuttings grow to provide stability and erosion resistance.

e. *Dormant plantings (cuttings, poles, and root balls).*Suited for smaller scale sites, individual live, dormant cuttings of various diameter and size are used to provide some erosion resistance before growing into protective vegetation. Root balls are dug from suitable nearby harvest sites and planted at the target site. Younger, smaller materials typically have a fairly low success rate so large numbers of cuttings are often used compared to fewer, higher investment root balls.

Figure 3. High flows can damage properly installed bank protection treatments when the system is not in balance. This weir and bioengineered bank will require maintenance for some time into the future. Photo Credit: T. Pick.

V. Hybrid Methods

When bank protection is warranted, it's becoming more frequent for bank restoration projects to utilize the best of both 'hard' and 'soft' treatments which saves money and minimizes negative impacts. As an example, angular rock is keyed in at the toe of an eroding slope to provide more protection at this critical, higher energy position, while the upper bank is benched. The lower and upper bank slope is then treated with a geotextile fabric and planted and seeded with adapted native vegetation. Short –term protection is provided by the rock toe and long-term resistance to erosion is provided by native vegetation. The bench allows high flows to access the expanded floodplain and riparian vegetation to access the water table, both of which help to assure success.

VI. Making the Decision

Economics The evaluation of economic considerations in deciding whether to engage in bank protection should begin with the question of what is to be protected. The monetary value of expected damage to the property or structure to be protected should be compared to the annualized cost of the protection given the expected lifespan of the protection. Large bank protection measures will also require mitigation from permitting authorities as a trade-off. Economic analysis usually concludes that only high value assets justify the high cost of 'hard' bank protection. On dynamic, unstable river systems, reapplication or heavy maintenance will likely be necessary to avoid channel adjustments that will cause bank treatment to eventually fail. The cost of mitigation and maintenance must also be considered in the calculation.

Example cost/benefit analysis - it is determined that the loss of an acre of land valued at $1,000 is possible without treatment. An engineering investigation determines that adequate treatment, maintenance, and mitigation will cost $25,000 with a 20-year lifespan. The annual cost of treatment (using seven percent interest) is nearly $1,900/year. The annual cost is greater than the benefit ($1,000) so the cost/benefit analysis would not support the treatment.

Risk is defined as the potential for loss. Inherent to assessing risk is deciding how much tolerance for failure or loss is acceptable. The less risk tolerated, the more protection and expense may be necessary as long as the benefit will justify the greater cost (see calculation above). To fully evaluate risk associated with bank protection, it's important to have a clear understanding of the river processes driving the erosion, as discussed earlier. Channel Migration Zone (CMZ) Maps, where available, are an excellent tool to help evaluate historic channel erosion rates and the inherent channel migration risk associated with particular locations. Where CMZ maps are not available, study historic aerial photos available at the county USDA office to get some idea of past channel location and bank movement rates. Risk must also consider the liability of potential off-site impacts to adjacent property.

The preceding caveats make a good case to avoid unnecessary placement of valuable infrastructure in a near channel or floodplain position where bank stabilization likely will be required sometime in the future.

Assessing ecologic impacts to be considered include effects on fisheries, wildlife, and overall channel /floodplain function in the broader area. Successful stream restoration projects should tend to make the overall stream channel, riparian corridor, and floodplain function better and this typically is difficult to do with individual, spot bank erosion treatment that is not part of an overall, coordinated plan. Many times, it is better for neighbors to work together to determine what is best for a larger reach of river and then work to implement that plan in a manner that benefits everyone. Consult your local conservation district or Musselshell Watershed Coalition and their partners for assistance with planning and carrying out a collaborative stream assessment that can help to address many of the considerations raised in this Bank Protection BMP.

Sources of Additional Information.

Montana Department of Natural Resources and Conservation – Guide to Permits.
http://dnrc.mt.gov/Permits/StreamPermitting/Guide.asp

Montana Department of Natural Resources and Conservation – Montana Stream Permitting Handbook.
http://dnrc.mt.gov/Permits/StreamPermitting/PermittingBook.asp

USDA Natural Resources Conservation Service Stream Corridor Restoration Handbook:
http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/water/?cid=stelprdb1043244