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Streambank Soil Bioengineering Considerations For Semi-Arid Climates

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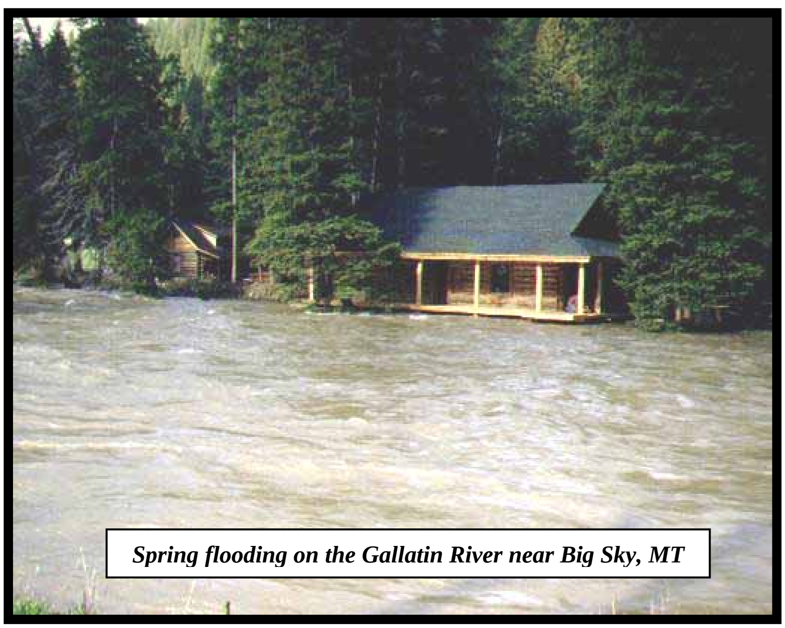
Abstract:

As a result of increased public awareness of the riparian environment, many federal, state and local agencies as well as grass-root organizations are actively engaged in implementing soil bioengineering treatments to stabilize streambanks.

There are many regional considerations which must be taken into account for the successful application of soil bioengineering techniques. Regional areas that are particularly problematic include the semi-arid regions of the Western United States. These semi-arid regions require significantly more attention to detail than the wetter areas of the country when trying to establish riparian and streambank plantings. This paper focuses on popular streambank soil bioengineering treatments that are being used in drier areas of the American West. It includes a general discussion on riparian zones, plant materials selection criteria, and streambank soil bioengineering treatments including installation guidelines and materials requirements.

Introduction

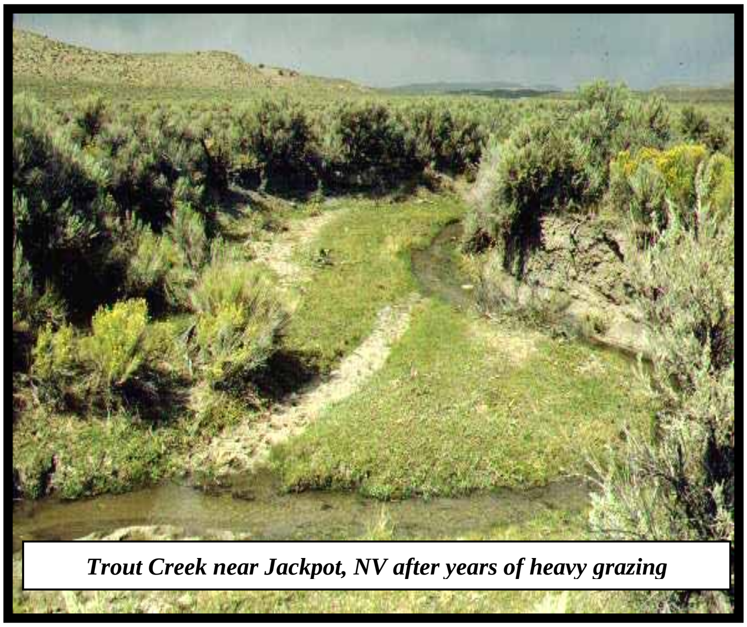


Spring flooding on the Gallatin River near Big Sky, MT

Riparian areas are shaped by the dynamic forces of water flowing across the landscape. Flooding, for example, is a natural and necessary component of riparian areas. Many riparian plant species such as cottonwood require floods to regenerate. Geomorphological characteristics of the stream valley such as floodplain level, drainage area, stream capacity, channel slope, and soils are some of the factors that influence the frequency, duration, and intensity of flooding (Leopold et al. 1964).

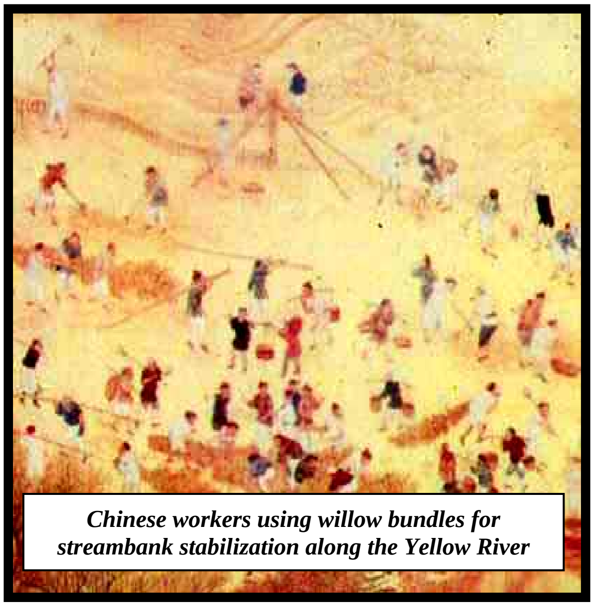
Flooding, in turn, influences the size and structure of the stream channel and composition of the riparian vegetation (Hupp and Osterkamp 1996).

Healthy streams and riparian areas are naturally resilient which allows recovery from natural disturbances such as flooding (Florsheim and Coats 1997). Streambank stability is a function of a healthy riparian area and adjacent uplands. When a stream and associated riparian system is degraded, this resiliency to natural disturbances is diminished. Excessive flooding, erosion, and sedimentation often increase. Streambank bioengineering is a way to use native riparian vegetation, both herbaceous and woody, with their extensive root systems and resilient top growth to increase the strength and structure of the streambank and to provide a means of energy and sedimentation reduction.



Trout Creek near Jackpot, NV after years of heavy grazing

Streambank soil bioengineering is defined as the use of live and dead plant materials in combination with natural and synthetic support materials for slope stabilization, erosion reduction, and vegetative establishment (Allen and Leech, 1997). Streambank soil bioengineering treatments use plants as the primary structural component to stabilize and reduce erosion on streambanks rather than using plants just for aesthetics. This means that the successful establishment of the plants, both herbaceous and woody is extremely important.



Chinese workers using willow bundles for streambank stabilization along the Yellow River

Streambank bioengineering has been around for centuries. Tapestries have been found in Chinese emperor's tombs that show Chinese workers using willow bundles for streambank stabilization along the Yellow River in 28 BC. In Europe, bioengineering techniques were used by Celtic villagers to create walls and fences. Romans used wattles and poles for hydroconstruction. In the 16th century, streambank soil bioengineering treatments were used throughout Europe. A soil bioengineering manual was published in 1791 by Woltmann that illustrated live stake techniques. About 1800, bioengineers in Austria were using brush trenches to trap silt and reshape channels. In the early 1900's, European bioengineers were using many of the treatments that we use today. In the 1930’s, Arthur Von Kruedener, the father of modern soil bioengineering used the treatments in pre-war Germany to save money (Finney, 1993). In 1934, Charles J. Kraebel, USDA Forest Service, installed willow wattles above a road near Berkeley, CA. Two years later the Soil Conservation Service, now the Natural Resource Conservation Service (NRCS), began a study of bluff stabilization techniques using live fascines, brush dams, and live stakes along the shores of Lake Michigan. After World War II, the availability of cheap energy, high cost of labor, the availability of surplus bulldozers and dump trucks, and advent of cheap, well designed steel and concrete structures meant that hard structures took over from the soil bioengineered structures as the preferred methods for treating streambank erosion. In the past few years, it has become apparent that these hard structures have inherent problems that have caused a breakdown of the riparian ecosystem because of their over use. A movement back to streambank soil bioengineering treatments has come from this realization.

Semi-Arid Climates

Since plants are a key component of streambank soil bioengineering treatments, a clear understanding of the factors that affect their survival, how to plant them, and where to plant them in the riparian zone is important. The primary limiting factor in a semi-arid climate is water availability. The amount and seasonal availability of water is important for the long term survival and the distribution range of plants. Most plants require good moisture conditions during establishment. In addition, most plants can survive with much lower available moisture including precipitation once they are established. Supplemental moisture to ensure plant establishment in water short areas may be a very important consideration. In the semi-arid West, drought tolerance is also a major consideration when selecting a plant species.

Much of the semi-arid west (excluding the mountains) only receives 10-40 cm (4-16 inches) total annual precipitation. In the western sections of the semi-arid west (east of the Cascade Mountains) 60 - 80 percent of this precipitation comes in the form of snow or winter precipitation. In the eastern sections of the semi-arid west (east of the Rocky Mountains) 30 - 40 percent of the precipitation comes in the form of snow or winter precipitation. Most of the growing season precipitation comes in the spring with very little falling during the summer months. Another climatic problem is the temperature extremes in this region. Regional extremes in temperatures affect a plant’s range of adaptability. A plant’s hardiness is generally limited by latitude and elevation.

Flooding along the Snake River near Riverton, ID

Flooding in the semi-arid west usually occurs in the spring or early summer as the snow melts.

High water often lasts for two weeks to a month or more depending upon snow pack and elevation. Once the high water period has passed, the water level generally decreases gradually through the summer. On smaller river systems, this often leaves the streambank toe zone exposed. In semi-arid climates, water control structures, such as dams, irrigation diversions, pumping plants, etc. often exacerbate the low stream flow conditions during the summer.

In some areas, stream channels are used as irrigation water transportation systems where irrigation water is moved from a reservoir to irrigated farmland via the stream channel. This causes the water level to be higher in the middle of the summer when normally it would be at its lowest level. This can cause major problems in establishing vegetation in the bank zone.

Benefits of Streambank Soil Bioengineering

Streambank soil bioengineering has many aesthetic benefits. Most planners and designers are interested in specific benefits. Gray (1977), Bailey and Copeland (1961), and Allen (1978) discuss five mechanisms through which vegetation can aid erosion control: reinforce soil through roots; dampen waves or dissipate wave energy; intercept water; enhance water infiltration; and deplete soil water by uptake and transpiration. Klingeman and Bradley (1976) point out four specific ways vegetation can protect streambanks.

1. The root system helps to hold the soil together and increases the overall bank stability by their binding network structure, i.e., the ability of roots to hold soil particles together.
2. The exposed vegetation (stalks, stems, branches, and foliage) increases the resistance to flow and reduces the local flow velocity, causing the flow to dissipate energy against the deforming plant parts rather than the soil.
3. The vegetation acts as a buffer against the abrasive effect of transported materials.
4. Close-growing vegetation can induce sediment deposition by causing zones of slow velocity and low shear stress near the bank, allowing sediments to deposit. Vegetation is normally less expensive than most structural methods; it improves the conditions for fisheries and wildlife, improves water quality, and can protect cultural/archeological resources.


Volunteers installing bioengineering treatments in ND

Streambank soil bioengineering projects are often very cost effective if applied appropriately. Erosion areas often begin small and eventually expand to a size requiring costly traditional engineering solutions. Installation of streambank soil bioengineered systems when the problem is small provides economic savings and minimizes potential construction impacts to adjoining resources. Many soil bioengineering projects can be installed by landowners and/or volunteers. The use of locally collected native plant materials provides additional savings. The primary cost of using locally collected materials is usually labor for harvesting, handling and transporting materials to the project site. Indigenous plant species are often readily available and well adapted to local climate and soil conditions. In addition, the use of indigenous materials often has some aquatic and terrestrial habitat value.

Streambank soil bioengineering work is often useful on sensitive or steep sites where heavy machinery is not feasible. Years of monitoring have demonstrated that streambank soil bioengineering systems are strong initially and grow stronger with time as vegetation establishes. Even when plants die, roots and surface limbs and organic litter continue to play an important role during the establishment of other plants. Once plants are established, root systems reinforce the soil mantel and remove excess moisture from the soil profile. This often is the key to long-term soil stability. Streambank soil bioengineering provides improved landscape and habitat values (Lewis 2000).

Streambank soil bioengineering is especially useful as a transition between conventional inert bank stabilization and the upland zone. Abrupt transitions from conventional projects such as inert riprap to the upland zone are often prone to damage from flowing water. Established bioengineering treatments can act to smooth this transition and reduce the possibility of failure.

Structural benefits are varied. The root systems from the woody and herbaceous species increase the strength and structure of the soil. They create a heavy matrix of large and small roots that resist streambank erosion forces. Roots tend to give and move rather than being rigid like most hard structures. They are also capable of regrowing if they are broken off or uprooted by high water velocities. They capture nutrients, remove nitrogen and phosphorous from the soil, and trap and retain pollutants. If the plant species are appropriately chosen, the entire project tends to be self-healing.

The above ground biomass is important because it provides roughness along the stream channel that reduces stream velocities and allows sediment to drop out. The above ground biomass is a buffer along the stream channel that provides numerous benefits. This buffer increases water infiltration by slowing the flow velocity, provides protection to the streambank by lying down as the high water flows go past, provides fish and wildlife habitat, and traps sediment (Eubanks and Meadows 2002).

Monitoring and Maintenance

While soil bioengineering projects should be self-renewing and grow stronger with time, project areas do require periodic monitoring and maintenance. Maintenance is especially important on highly erosive sites. Maintenance should include tasks such as removal of debris, removal of invasive or undesirable species, and replanting spot areas. Figure 1 represents an idealized plot of a typical comparison of costs between traditional inert bank protection and a bioengineering approach. The plot illustrates the typical situation where a bioengineering approach will have repeated expenditures for monitoring and maintenance while an inert structure approach will have higher initial costs, minimal or no maintenance but eventually require replacement (Allen and Leach, 1997). The plot also illustrates that the reconstruction costs of a soil bioengineering approach is often significantly less than those associated with hard structures.

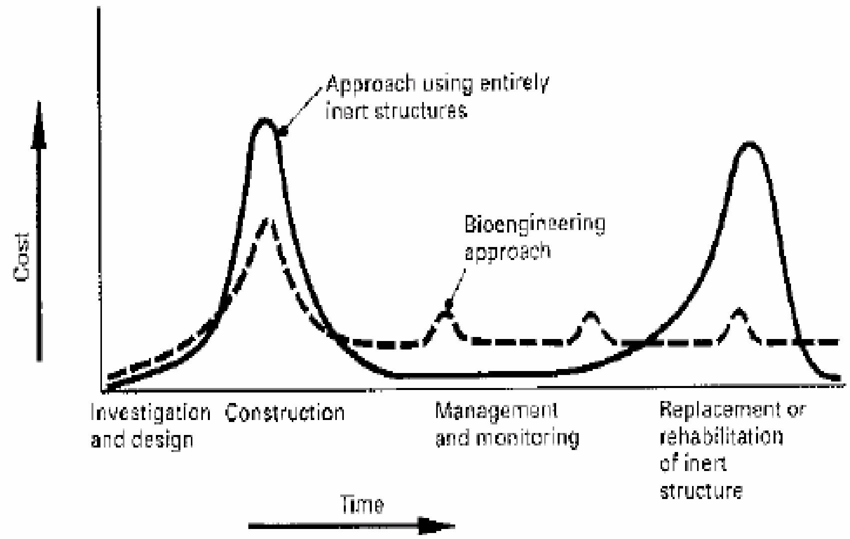


Figure 1: Illustration of expenditure profiles for soil bioengineering and inert structures (from Coppin and Richards 1990)

The success of a soil bioengineering streambank stabilization project depends on the establishment and growth of the vegetative component. Allen and Leach (1997) note that it is especially important to monitor bioengineering projects early after project completion to assure plant survival and development. For example; if it is exceptionally dry, supplemental irrigation may be necessary for plant establishment. Other issues that should be considered include the possible need to apply a fungicide or insecticide if insects or disease are an issue. Beaver, geese, livestock and other herbivores may also impact the plants in a streambank soil bioengineering project. The loss of a predetermined percentage of planting may be used to trigger a requirement for remedial planting.

If a moderate storm occurs before establishment of the vegetative component of a streambank soil bioengineering project, there is a potential for significant damage to the project. In fact, depending on the nature of the stream and the project, this damage may be severe enough that the vegetative component may be unable to recover. Therefore, it is recommended that soil bioengineering projects be inspected after moderate flows as well as on a periodic basis. The possible remedial action, which may be triggered by these inspections, should be identified in at least a general sense.

Limitations of Streambank Soil Bioengineering

Streambank soil bioengineering is not appropriate for all sites and situations. There are problems with using vegetation. Those problems include: failure to survive and grow; vulnerability to drought; soil nutrient and sunlight deficiencies may effect establishment and growth; plants may be uprooted by freezing and thawing, damaged by ice and debris, subject to undermining currents, wildlife and livestock feed on or trample it; and it may require special management measures to ensure long-term project success (Allen and Leech, 1997).

Limiting Velocity and Shear

The affects of the water current on the stability of any streambank protection treatment should be considered. This evaluation should include the full range of flow conditions that can be expected during the design life of the project. Two approaches that are commonly used to express the tolerances are allowable velocity and allowable shear stress. Variations in published recommendations for limiting velocity and shear exist and some are summarized in the table below as a guide. It is important to note that many of these recommendations are empirically determined and, therefore, most applicable for the situations in which they were derived.

The designer should consider modifying recommendations based on site specific conditions such as duration of flow, soils, temperature, debris and ice load in the stream, plant species, as well as channel shape, slope and planform.

Treatment	shear		Velocity	reference
	lb/ft2	N/m2	fps	
Fascine revetment	1.4	69		Schoklitsch, 1937
Live Fascine (immediately after construction)	1.2	60		Schiechtl and Stern, 1994
Live Fascine (after 3-4 seasons)	1.6	80		Schiechtl and Stern, 1994
Fascine	2.1	103		Gerstgraser, 1999
Wattle (woven, coarse sand between)	0.2	10		Schoklitsch, 1937
Wattles (woven, gravel between)	0.3	15		Schoklitsch, 1937
Wattles (woven, parallel or oblique to current)	1.0	49		Schoklitsch, 1937
Wattle fence (immediately after construction)	0.2	10		Schiechtl and Stern, 1994
Wattle fence (after 3-4 seasons)	1.0	50		Schiechtl and Stern, 1994
Wattle fence	1.0	49		Gerstgraser, 1999
Willow Brush Layer (immediately after construction)	0.4	20		Schiechtl and Stern, 1994
Willow Brush Layer (after 3-4 seasons)	2.9	140		Schiechtl and Stern, 1994
Cuttings of willows/willow stakes	2.0	100	9.8	Gerstgraser, 1999
Willow posts			5 to 8	USACE TR EL 97-8
Live Stakes in riprap (immediately after construction)	4.0	200		Schiechtl and Stern, 1994
Live Stakes in riprap (after 3-4 seasons)	6.0	300		Schiechtl and Stern, 1994
Live cuttings in coarse gravel (immediately after construction)	1.0	50		Schiechtl and Stern, 1994
Live cuttings in coarse gravel (after 3-4 seasons)	5.0	250		Schiechtl and Stern, 1994
Brush mat (immediately after construction)	1.0	50		Schiechtl and Stern, 1994
Brush mat (after 3-4 seasons)	6.1	300		Schiechtl and Stern, 1994
Willow Brush mat (immediately after construction)	4.1	200		Florineth, 1982
Willow Brush mat (after 3-4 seasons)	8.2	400		Florineth, 1982
Brush Mattress w/willows	6.5	320		Gerstgraser, 1999
Stone sill with live joint plantings	3.0	150		Schiechtl and Stern, 1994
Rootwads			8	USACE TR EL 97-8

*More information on allowable shear stresses applicable for grass lined channels can be found in ARS 667, “Stability Design of Grass-Lined Open Channels”.

Risk

Livestock grazing on willows in the Cub River, UT

The goal of many streambank soil bioengineering stabilization projects is to mimic natural conditions. Natural channels in many environments can be expected to move and suffer erosion during large storms. Therefore, it should be recognized that, even with an established project, the bank will often not be static and periodic bank erosion should be expected in many stream systems. The consequences of this flexibility, which is inherent to a streambank soil bioengineering stabilization project, should be assessed.

Landowner objectives and protection of riparian health and property should be primary considerations. When a river is about to take the landowner’s house, vegetation should not be recommended as a quick fix. Another factor to consider is the health of the riparian buffer zone. Streambank stabilization is an important goal, but because natural channels do move and suffer

Issue	Concern	Possible Action or Design Modification
Duration of inundation	Some plant species can not withstand long flooding duration	1- Choose plant materials that can withstand long inundation such as willow which can take upwards to 6 months of duration. Do not choose plant such as choke cherry which are limited to 24 hours of inundation 2- Use inert material in areas of prolonged inundation
Susceptibility of plant materials to disease or insects	Loss of plants could endanger the project	1- Apply a fungicide or insecticide 2- Use a diversity of species in the plant mix so that the loss of one species will not endanger the entire treatment area.
Excessive velocity	High velocities could destroy the project	Compare estimated velocity and/or shear at site to published recommendations for limiting velocity and shear when selecting project type (see summery in Appendix).
Increased resistance to flood levels	Increased roughness resulting from project may result in more frequent out of bank flows	1- Choose plant material, which remains supple. Avoid plant material, which will be tree-like and form an obstruction to the flow. 2- Coordinate possible affects with floodplain regulatory authorities 3- Excavate floodway to account for lost conveyance
Predation by herbivores	Loss of plants could endanger the project	1- Fence the project area 2- Fence planting areas within the project. 3- Choose plant material, which is thorny or otherwise unappetizing to the expected herbivores.

erosion from large storms, the riparian buffer must be in good shape with an abundance of herbaceous and woody plants and their associated root systems. While the width of a riparian buffer zone is the subject of intense research, a good rule of thumb is that it should be twice the stream channel width (Bentrup and Hoag 1998).

Generally, the risk of failure is higher with soil bioengineering treatments when compared to hard structures. This risk should be considered by examining the limitations of the design approach in conjunction with the expected conditions of the site. Some of these risks can be accounted for as indicated in the table above:

Selecting Plant Materials

Local expertise and guidelines should be consulted when selecting the appropriate plant material. Most streambank soil bioengineering treatments involve material that is collected from adventitiously rootable stock (plants that will easily root from a hardwood cutting such as, willow, cottonwood, and dogwood species). When possible, it is best to collect plants from areas that are similar to the project location. Planting will be most successful where the soil, site, and species match a nearby stable site. If possible, harvest two or more species from different locations.

PMC crew harvesting cottonwood poles for planting

Most species should be harvested when the plants are dormant. This is typically in the late fall to early spring, after leaf fall and before the buds swell. Choose and harvest healthy material that is free of splits, rot, disease, and insect infestation. While it is often appropriate to include material that ranges in age up to 4 years, material should be harvested from plants that are at least 2 years old. One year old stock should not be used. Young material is often too small and does not have enough stored energy for good root establishment. When harvesting live material you should leave about one third of the parent plant intact. The harvesting equipment should be sharp enough to make clean cuts.

Soaking willow cuttings on Fox Creek, Driggs, ID

Soak the cuttings before planting for a minimum of 24 hours in cool, aerated water. Optimum time for soaking is 7 to 14 days but they can also be planted the same day as harvested. If it is necessary to harvest material significantly before installation, the cuttings should be stored dry at approximately 33 to 40 degrees F. Live hardwood cuttings can last up to four months if refrigerated. Stored material should be soaked before planting. If the harvested material is stored under wet conditions for longer than 14 days, the rooting process may start. The initial roots are typically very tender making it difficult to use the cutting material in many of the treatments without damaging the roots.

Hardwood cuttings can be divided into four general categories: whips, poles (sometimes referred to as stakes), posts, and bundles. Whips are typically one year old material. Because of their small size, they should not be used in drier areas or areas without consistent water. Pole cuttings can be made from shrub and tree species and usually ranges in diameter from ¾ to 3 inches. Post cuttings are from tree species and range in diameter from 3 to 6 inches. Bundles include smaller diameter cuttings to larger diameter cuttings (whip to pole size) with the branches left intact and tied together to form a cigar shape.

Riparian Planting Zones

A riparian zone is often described as the area between land and water. In the semi-arid West, they are long linear areas along rivers and streams that are occasionally flooded by those bodies of water. They can be identified by having: 1) vegetation that requires free and unbound water or conditions wetter than normal and 2) saturated soil conditions during at least part of the growing season. Simply stated, riparian areas are where water saturates the soil more than adjacent areas and where water-loving vegetation is concentrated. Riparian zones are very important because they provide erosion control by regulating sediment transport and distribution, enhance water quality, produce organic matter for aquatic habitats, and provide fish and wildlife habitat.

Understanding general vegetation concepts in riparian areas is extremely important. The vegetation is adaptive and can withstand high flows if it is established in the correct planting zone. When establishing vegetation, success is dependent on many site specific conditions such as soil compaction, soil type, nutrients, salinity, ice load, debris load, sediment load, flooding,

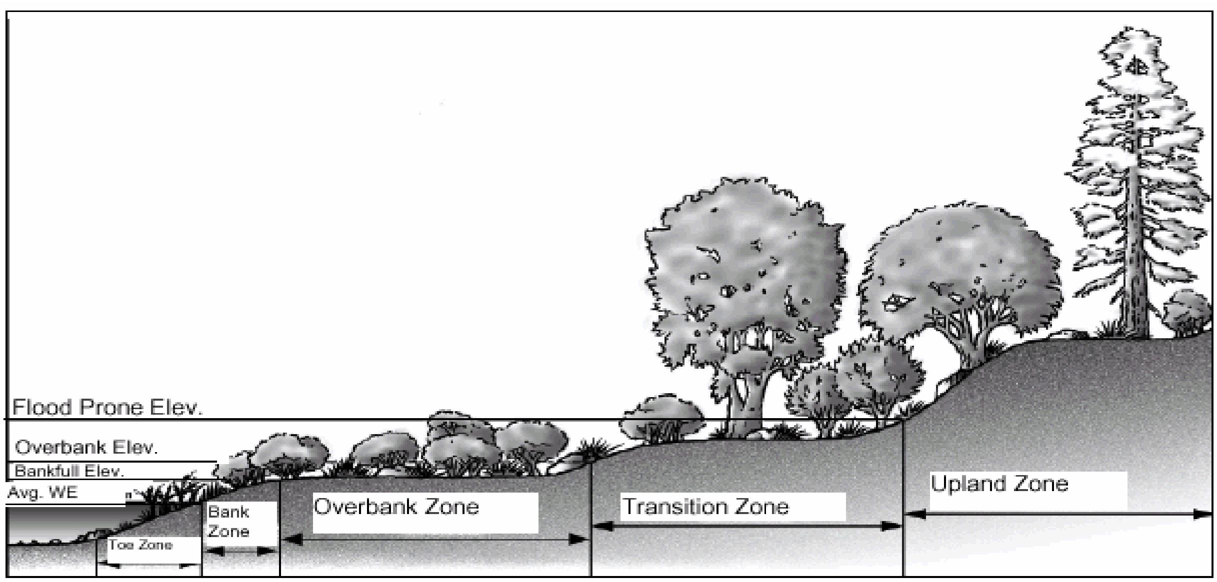


Figure 2: Riparian Planting Zones (Riparian/Wetland Project Information Series No. 16)

inundation time, water availability, drought, hydrology, plant availability and climate, to name a few.

The success of streambank soil bioengineering treatments is dependent on the establishment of riparian plant species. The success of the plants, in turn, is dependent on the species used, their procurement, planting and handling techniques, and their location relative to the stream. Therefore, it is important to observe the location and types of existing vegetation in and adjacent to the project area. Proposed streambank soil bioengineering projects should be assessed and designed in terms of the relative location of the plants to the stream and water table. The elevation and lateral relationships can be visualized and described in terms of Riparian Planting Zones. Figure 2 illustrates an idealized depiction of these zones, as well as a brief description of each. Not all streams will exhibit all of these zones.

Toe Zone: This zone is located below the average water elevation or baseflow. The cross-sectional area at this discharge often defines the limiting biologic condition for aquatic organisms. Typically this is the zone of highest stress. It is vitally important to the success of any stabilization project that the toe is stabilized. Due to the long inundation, this zone will rarely have woody vegetation. Often stone or some inert protection is required for this zone.

Bank Zone: The bank zone is located between the average water elevation and the bankfull discharge elevation. While it is generally in a less erosive environment than the toe zone, it is potentially exposed to wind generated waves, wet and dry cycles, ice scour, debris deposition, as well as freezing and thawing cycles. The bank zone is generally vegetated with early colonizing herbaceous species, flexible stemmed willows, and low shrubs. Sediment transport typically becomes an issue for flows in this zone, especially for alluvial channels.

Bankfull Channel Elevation: Bankfull stage is typically defined at a point where the width to depth ratio is at the minimum average annual level. Many practitioners also use other consistent morphological indices to aid in its identification. In many situations, the flow at the bankfull stage has a recurrence interval of 1.5 to 2 years. Due to the high stream velocities and frequent inundation in this zone, many practitioners recommend rock or other hard structures in conjunction with streambank soil bioengineering treatments below this elevation.

A bankfull flow is often considered to be synonymous with channel-forming discharge in stable channels and is used in channel classification as well as for an initial determination of main channel dimensions, plan and profile. In many situations, the channel velocity begins to approach a maximum at bankfull stage. In some cases, on wide, flat floodplains, it has been observed that the channel velocity can drop as the stream overtops its bank and the flow spills onto the floodplain. In a situation such as this, it may be appropriate to use the bankfull hydraulic conditions to assess stability and to select and design streambank protection. However, when the floodplain is narrower or obstructed, channel velocities may continue to increase with rising stage. As a result, it may be appropriate to also use a discharge greater than bankfull discharge to select and design streambank protection treatments.

Overbank Zone: This zone is located between the bankfull discharge elevation and the overbank elevation. This zone is typically relatively flat that can be formed from sediment deposition with layered soils. It is flooded about every 2 to 5 years. Vegetation found in this zone is generally flood tolerant and may have a high percentage of hydrophytic plants. Shrubby willow with flexible stems, dogwoods, alder, birch and other riparian woody species may be found in this zone. Larger willows, cottonwoods and other trees may be found at the upper end of this zone.

Transitional Zone: The transitional zone is located between the overbank elevation and the flood prone elevation. This zone may be inundated about every 50 years. It is not exposed to high velocities except during very high water events. Hydrophytic species generally transition to larger upland species in this zone. As a result, this is the first zone (from the channel invert) where tree type species should be considered. The plants in this zone do not need to be especially flood tolerant.

Flood Prone Elevation: Many practitioners estimate the flood prone elevation at twice the maximum depth of the bankfull elevation. A calculation of an entrenchment ratio, which is defined as the ratio of the width of the channel at the floodprone elevation to the width of the bankfull channel, is used in channel classification. The area below this elevation may include the active floodplain and the low terrace.

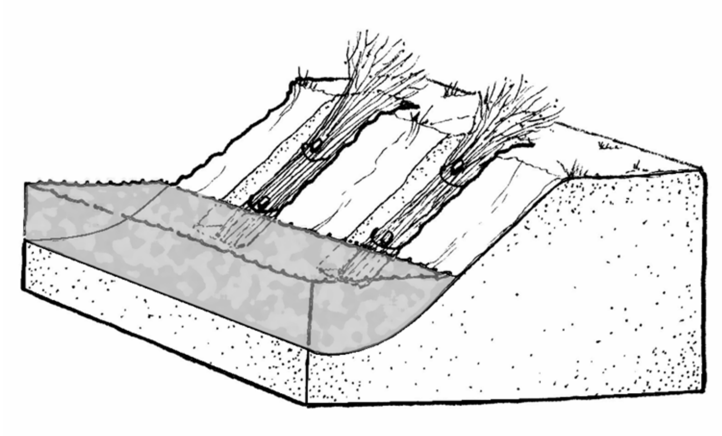
Upland Zone: This zone is found above the flood prone elevation. Erosion in this zone is typically due to overland water flow, wind erosion, improper farming practices, logging, development, and improper grazing practices. The upland zone is typically vegetated with upland species. Drought tolerance is one of the most important factors in species selection for this zone.

Streambank Soil Bioengineering Treatments

Streambank soil bioengineering projects may be installed during the late fall (dormant season), winter, and early spring. This is the best time to install streambank soil bioengineering practices and often it is the period when other construction work is slow (Lewis 2000).

There are many types of streambank soil bioengineering treatments that have been used throughout the country. The following are some of the streambank soil bioengineering treatments that are applicable to low precipitation semi-arid areas. It is important to note that it may be appropriate to modify these treatments to account for site specific conditions and material availability.

- Pole Plantings
- Brush or Tree Revetments
- Brush Mattress
- Fascines
- Vertical Bundles
- Brush Layering
- Brush Packing
- Log Cribwalls
- Crimping and Seeding
- Wattle Siltation Fence
- Wattle Siltation Fence as an



Erosion Stop

- Stone Sill with Live Joint Plantings
- Live Brush Sills
- Brush Trench
- Brush Spurs
- Willow Clump Planting

Details on the description and design of each treatment, plant material collection, installation procedures, and management implications can be found in several publications including (but not limited to):

1998. *The Practical Streambank Bioengineering Guide* by Bentrup and Hoag

2002. *Streambank Soil Bioengineering Field Guide for Low Precipitation Areas* by Hoag and Fripp.

Conclusion

The use of streambank soil bioengineering treatments is increasing for a number of reasons including aesthetics, regulatory agency scrutiny, water quality benefits, and fish and wildlife habitat. Regional considerations will determine the successful application of these treatments. This is especially true in the semi-arid areas of the country where attention to detail can mean the difference between success and failure.

Understanding where the lowest watertable of the year is and making sure that the plants used in the different treatments are in the lowest watertable is crucial. Understanding the riparian planting zones is also important to ensure that the plants are planted in the correct zone. The characteristics of the various plants can be used to increase roughness along the stream without sacrificing water conveyance.

Streambank soil bioengineering treatments are a viable alternative to hard structures in many instances as long as the risks are understood and planned for. In most cases, a combination of hard and soft structures can increase the benefits of both as well as strength and structure of the treatments.

There are a variety of streambank soil bioengineering treatments that can be used for streambank stabilization. These treatments can withstand varying shear limits and velocities. It is important that one understand the idea behind the treatment and how it is installed to ensure that it is placed in the appropriate location. The maximum velocity and shear that the treatment can withstand is usually based on the plants becoming established.

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