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Streambank Soil Bioengineering: A Proposed Refinement of the Definition

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Abstract:

Eroding stream and river banks can threaten agricultural assets, riparian infrastructure, and can significantly impact the environment. There are many different approaches to stabilizing and restoring stream and river banks. Streambank Soil Bioengineering is one of the approaches that are gaining favor for being both cost effective and environmentally sensitive. The term ***"Streambank Soil Bioengineering"*** is a broad category of treatments that is often used to encompass any stabilization technique that includes some plant material. The current paper proposes that this broad use of a definition is inadequate for many decision making situations. Communication would be enhanced if techniques are subdivided based on the intended flexibility of the mature and established treatment. This paper proposes that Streambank Soil Bioengineering treatments be classified as either ***structural based*** streambank soil bioengineering treatments or ***plant based*** streambank soil bioengineering treatments. This distinction is not just based on the material used in the construction of the treatment. The distinction is based on how the resulting bank is to behave over time. Two example projects are presented in this paper which illustrate this distinction.

Introduction:

Streambank Soil Bioengineering is a broad category of stream bank treatments that are viewed by many as being more ecologically beneficial than traditional stabilization approaches. The treatments that fall under this broad definition generally include the use of living, riparian plants as part of the design. While the last decade has seen this approach of including plants in the stabilization of stream and river banks become more popular, many of the techniques which fall under the characterization of Streambank Soil Bioengineering are not new.

The advantage of using living plants to stabilize stream and river banks has been recognized for many years. There are records of willow bundles being used for streambank stabilization along the Yellow River as early as 28 BC. Leonardo Da Vinci (1452-1519), recommended using rootable, living willow branches to stabilize agricultural irrigation channels, thus creating living streambanks. A soil bioengineering manual was published in 1791 by Woltmann that illustrated live stake techniques (Stiles, 1991). By the 1900's, European soil bioengineers were using many of the treatments that we use today (Stiles, 1988). There is a solid history of using techniques that are categorized as Streambank Soil Bioengineering in the United States as well. One of the more notable historical examples in the United States is treatments installed in Vermont along the Winooski River in the 1930s (USDA-NRCS 1999). Today there are many design documents that describe Streambank Soil Bioengineering techniques that are applicable for a variety of conditions, purposes, and climates (FISC 1998, Hoag and Fripp 2002, Grey and Sotir 1996, USDA 2007).

While the use of hard structures that rely on materials such as rock, concrete, and steel have always been part of stream bank stabilization they did not eclipse the techniques which are considered to be Streambank Soil Bioengineering in the United States until after World War II. The use of hard materials became so prevalent in the 1950's through the 1980's that they are now referred to as "***traditional***" approaches to bank stabilization. While applicable in many circumstances, these hard, traditional approaches do involve several inherent cost and aesthetic drawbacks. As a result, many federal, state and local agencies as well as grass roots organizations are looking for a different approach. With recent strong interest in stream restoration and ecologically sensitive stabilization, there is an increased emphasis in any bank stabilization treatment which can be given a 'green' label. In an effort to satisfy the demand for environmentally friendly work, there are an increasingly wide range of bank stabilization treatments that are being categorized as Streambank Soil Bioengineering.

This paper submits that the term ***"Streambank Soil Bioengineering"*** has become so broad of a term in its application that it can hinder communication and decision making among practitioners. This paper proposes that the wide range of treatments that are now considered to be Streambank Soil Bioengineering be sub categorized by the expected behavior of the resultant project.

Problems with the Definition of Streambank Soil Bioengineering:

Practitioners in many different fields have long noted that words have power. Proper and clear definitions can communicate important information and assure that users are clear about the issues that are under consideration. But vague or misleading definitions can confuse the issue under consideration. Categories that are too broad or all inclusive do not capture important distinctions between items.

The term ***"Streambank Soil Bioengineering"*** has been used to refer to a large number of techniques. There are many definitions of Streambank Soil Bioengineering in the literature but all basically define the category by the material that is used in the techniques. The definition of Streambank Soil Bioengineering that is used in the recently released NEH 654 (USDA, 2007) is as follows:

> *Streambank soil bioengineering is defined as the use of living and nonliving plant materials in combination with natural and synthetic support materials for slope stabilization, erosion reduction, and vegetative establishment.*

This is a good definition of the broad category of Streambank Soil Bioengineering. For example, it is a definition that distinguishes between a traditional riprap placement on a graded streambank and a combination of riprap and willows on a graded bank. This definition is likely sufficient for many discussions and decision making situations. However, it is still based on the material used in the treatments and only vaguely refers to the performance of the treatment. Therefore, this definition applies equally to a large number of techniques regardless of the resultant performance of the treatment. For example, the installation of vertical bundles and vertical bundles with a rock rip rap toe would both fall under this category because they include a vegetative component. However, the former would function as flexible bank stabilization while the latter would generally be used where a static toe defined by the rip rap would be desired. In other words, this conventional definition does not make a distinction between a treatment that would result in a static, but vegetated bank line and treatment that would result in a bank line that would behave more naturally but dynamically.

A definition which focuses on materials is conceptually attractive to disciplines that traditionally deal with the design aspects. However, many disciplines that are involved with important decisions in ecologically sensitive projects need to address behavior of the final project. The category of Streambank Soil Bioengineering covers techniques with broad range of flexibility. A definition that defines a group has to be sufficiently broad to encompass a group of techniques and thus simplify discussions. On the other hand, it must be sufficiently discriminating as to distinguish between categories.

Flexibility as a Streambank Soil Bioengineering Performance Criterion

Stream restoration and stabilization projects can have many goals and objectives. Projects can be initiated for such varied purposes as to improve some targeted habitat, enhance aesthetics over what is currently there, or provide better recreational opportunities at a site. However, a sizable number of projects are often initiated because there is observed bank erosion (NRRSS, Bernhardt et. Al. 2007). Essentially, the current condition in these situations includes some unacceptable level of dynamism in the bank. The goal of the project is to reduce this dynamism to some acceptable amount.

Some projects seek to stabilize a channel grade, section, or planform in place. These are usually applied when there is some riparian infrastructure that is of value that is at risk. The project is to perform such that the bank does not move. As a result, the project produces a static bank. The acceptable level of dynamism is none. While this non flexible bankline provides a defined line of protection, most natural systems do not behave in this manner.

Other projects seek to reduce an unnaturally high amount of dynamism to what is viewed as a natural or ‘better’ level of dynamism. The erosion may have been initiated by poor grazing practices on the bank, a fire, or a large flood event. The difference is that the projects types used to address these conditions do not result in a static bank line. The bank is flexible and free to continue to move, albeit at a slower rate. The acceptable level of dynamism in the bank is what should be seen in non-impacted reached of a similar system. This type of approach results in a bankline whose location is more uncertain but one that ideally behaves in a more natural manner.

Treatments that are identified as Streambank Soil Bioengineering have been used to successfully address these two conditions. However, the techniques used for each condition involve a reliance on very different materials. The techniques which are designed to produce a static bankline rely fundamentally on inert material while those that are intended to produce a flexible bankline rely more on plants. Therefore the proposal is to subdivide Streambank Soil Bioengineering treatments into ***structural based*** streambank soil bioengineering treatments and ***plant based*** streambank soil bioengineering treatments. Using the predominant material in a definition is attractive since it brings to mind the general types of treatments.

Structural Based Treatments

A Structural Based Streambank Soil Bioengineering approach is successful when it results in a fairly static bank. The treatments that would fall in this category rely on rock, manufactured products, or other inert material to result in a fixed condition. Treatments involving stone toes, vegetated gabions, and stone deflectors generally fall in this category. Examples of such Structural Based Streambank Soil Bioengineering treatments are shown below in Figures 1, 2 and 3.


Figure 1: Vertical bundles placed behind a stone toe. Under construction and after 4 years


Figure 2: Log Crib. Under construction and after 10 years

Figure 3: Vegetated wire face MSE wall. Under construction and after 2 years.

Treatments such as these are generally applied at high risk sites and areas where additional bank movement is unacceptable. Installed plant material certainly provides aesthetic and habitat benefits to such projects. Plants may also increase strength and shielding to the structure but, fundamentally, the bank line limits are defined by the installed structural material. A successful project is a static project. The bank line for these projects should remain in a defined location over the life of the project. If the structural material fails, the project fails. Self healing is not really an option with these sorts of treatments.

Plant Based Treatments

The banks of streams and rivers are not naturally static over time. They advance and retreat in response to changing flows and sediment loads. Large movements are generally prevented or damped by riparian vegetation.

A Plant Based Streambank Soil Bioengineering approach does not intend to produce a static bank line. A successful project is a flexible project. The treatments may include inert components and even grading but they fundamentally rely on riparian plants to provide long-term strength to the bank. These treatments are applied to sites where the goal is to slow the dynamics of the system to a more natural rate. Additional bank movement after construction of the project is acceptable and expected during high flows. A plant based treatment is characterized by reliance on such treatments as live clumps, fascines, vertical bundles, brush barbs, brush revetments, and live cuttings. Examples of Plant Based Streambank Soil Bioengineering Treatments are shown in Figure 4 and 5.


Figure 4: Brush Mattress under construction and after 2 years.


Figure 5: Vertical bundles and brush revetment. Under construction and after 3 years.

Inert material may be used but it is generally only used to temporarily reduce hydraulic pressures so that the planted live material can become established. With time, the planted material will provide the design strength for the bank. Large flows and extreme events can result in more bank movement in a plant based approach rather than in a structural based approach. However, the reliance on plants over the long term results in a project which is more self healing rather than one that fundamentally relies on structural measures.

Application of the Refined Definition

Many of the design analysis used in a Structural Based Streambank Soil Bioengineering approach are applicable to the design of a Plant Based Streambank Soil Bioengineering approach. The distinction is between these two categories is in performance. A designer who uses a Structural Based Streambank Soil Bioengineering technique has identified a target cross section or defined bank line. Movement beyond this established threshold is not acceptable. The designer who utilizes a Plant Based Streambank Soil Bioengineering technique has a situation where it is permissible to allow the bankline to adjust over time.

This distinction is illustrated by comparing the design and performance of two projects that were constructed on the Carson River in Nevada. One project was constructed in 1998 and the other in 2002. Both projects were considered to be demonstration Streambank Soil Bioengineering Projects. They utilized different approaches but both are viewed as successful by landowners, regulatory agencies, and the designers.

The Plant Based Streambank Soil Bioengineering approach was used on the site referred to as the Ambrose site. This site is located on land owned by the City of Carson City and managed by the Parks and Recreation Department. It was constructed to address approximately 300 feet of severe erosion along a left bend in the stream, along the right descending bank of the Carson River. The primary goal of the Ambrose project was to slow the rate of bank loss to a natural dynamic stability. This project includes brush stream barbs, live clumps, live cuttings, vertical bundles, and brush revetment. A limited amount of rock was used to anchor the brush spur key and as rock bolsters for the brush revetment. Soil anchors were used for the portion of the brush spurs that extends into the river. Photographs of the project under construction are shown in Figure 6.

Figure 6: Ambrose Project site nearing completion in 2002.

The Structural Based Streambank Soil Bioengineering approach was used on the site referred to as the Glancy site. This site is located along the left descending bank of the Carson River downstream of the Ambrose site. The bank in this area was severely eroding and threatening private structures. Additional bank line retreat at the site was not permissible. The project was constructed to provide for a more fixed bank line than the Ambrose site. The Glancy project includes stone stream barbs, longitudinal peak stone toe (LPST), as well as vertical bundles, brush revetments, live clumps, erosion control fabric, brush mattress, and a brush mattress with a rock toe. Photographs of the Glancy project under construction are shown in Figure 7.

Figure 7: Glancy project nearing completion in 1998.

The performance of any stream or river project is best evaluated after it has experienced high flows over some time period. In projects that rely, at least in part, on the establishment and growth of plant material, the evaluation time should also include periods of low water. Since the construction of both projects, high and low flows have been observed in the Carson River. Within a few months of construction of the Ambrose project, the Carson River experienced several high flow events through the winter and early spring. One of these approached a 5-year event. The installed plant materials had not had a chance to root and become established at either project site. The Glancy site was partially protected by the structural treatments but the vegetative treatments installed at the Ambrose site had to rely on the brush barbs and revetment material which was held by soil anchors and rock bolsters. Good design and construction allowed both projects to withstand the stress. A photograph of the Ambrose site in the summer of 2003 is shown in Figure 8.

Figure 8: Ambrose Site, summer 2003

High flows continued to test the sites. In 2005, the Carson River had flows between the 5- and 10-year event and in 2006 flows were in excess of the 20-year event. In 2007, low flow conditions are being experienced. Although pre-project banks were bare, vegetative cover at both sites is well established. During an evaluation conducted in the summer of 2007, vegetative cover was nearly 100 percent for most of both projects. Photographs of the Ambrose site are shown in Figure 9 and photographs of the Glancy site are shown in Figure 10. It should be noted that the flows in the Carson River are exceptionally low during this assessment. As a result, more of the bed is visible than normal.

Figure 9: Ambrose Project during low flows in summer 2007.

Figure 10: Glancy Project during low flows in summer 2007.

Further bank retreat has been effectively reduced on both sites. The toe of the Ambrose site is more dynamic than the Glancy site but that is to be expected given the vegetative based design approach at Ambrose. At the Ambrose site, the roots have firmly anchored the bank material. The bank structure at the Ambrose site is dominated by a dense root and vegetation mass which is characteristic of the naturally stable reaches of the Carson River. Photographs of the bank area of the Ambrose site are shown in Figure 11.

Figure 11: Bank at the Ambrose Site, summer 2007

The Glancy site is protected by both inert material as well as established plant growth. Vegetation is also becoming part of the bank structure at this site in a manner similar to that of the Ambrose site. In several areas, sediment deposition has covered the rock which has allowed for vegetation to hide inert material. However, in other areas, the transition between rock toe material and soil has prevented vegetation from completely covering the bank. Photographs of the bank area of the Glancy site are shown in Figure 12.

Figure 12: Bank at the Glancy site, summer 2007

Local interests view the instream habitat and resultant fish populations as generally better at the Ambrose site rather than at the Glancy site. Several fish species were noted during the site visit as well as evidence of recent recreational fishing activity. Invertebrates were also observed in and among the brush spurs. The benefits that the Ambrose site qualitatively shows over the Glancy site may be due to the aggradation that is apparent in the reach through the Glancy project area.

Conclusion

Streambank soil bioengineering is a proven approach to stabilizing and restoring streambanks. Both the plant based and the structurally based streambank soil bioengineering approaches are applicable on most river systems. Choosing between the two should be based on cost, tolerance for risk, and amount of acceptable bank movement. Table 1 summarizes some of the distinctions between the ***structural based*** streambank soil bioengineering treatments and ***plant based*** streambank soil bioengineering treatments.

Table 1: Summary of ***Structural based*** streambank soil bioengineering and ***Plant based*** streambank soil bioengineering treatments

Treatment / Features	**Structural Based Streambank Soil Bioengineering**	**Plant Based Streambank Soil Bioengineering**
Bank Line	Determined by designer and defined by placement of the hard material	Approximated by designer and defined over time by natural processes
Dynamism	Low to none. A successful project is relatively static	Moderate. A successful project is as dynamic as a natural, unimpacted reach
Material used	Structural material enhanced with plantings	Living riparian plants. Inert materials may be used to provide temporary stabilization until plants are established
Self healing	Limited. Once structural component fails, the treatment is compromised	Significant. Plant material can be severely impacted yet recover over time
Ecological Benefits	Terrestrial and aquatic benefits provided by plants and placement of inert material	Terrestrial and aquatic benefits provided by plants and the dynamic nature of the resulting project
Typical Applications	Urban or suburban situations where high value infrastructure is adjacent to the waterway	Suburban, rural, or park situations where some movement of the bank line will not endanger life or property
Example treatments	• Rip Rap with live cuttings • Vertical bundles with a rock toe • Log Cribs • Green Gabions • Vegetated Wireface MSE wall • Vegetated geocells • Stone stream barb • Permanent erosion control fabric	• Live cuttings • Vertical bundles • Fascines • Brush Mattress • Wattles • Vegetated stream barb • Brush revetment • Bio-log • Willow Pole & Clump Planting • Temporary erosion control fabric

Both example projects successfully used Streambank Soil Bioengineering treatments to meet project objectives. The treatments at both sites were designed to both strengthen banks and reduce hydraulic forces. The plantings strengthened banks, slowed velocities, and dissipated energy at both sites. The structural treatments, stone stream barbs at Glancy and brush stream barbs at Ambrose, redirected flows and reduced hydraulic forces against the bank. The structural based approach, as illustrated by the Glancy project, is more static and potentially lower in risk. The plant based approach, as exemplified by the Ambrose project, offers the advantage of immediately providing more beneficial woody material along the bank zone as compared to the structurally based approach. Both approaches are generally considered to be more aesthetic and ecologically friendly than traditional bank stabilization approaches.

Interdisciplinary teams are being used with greater and greater effectiveness in planning and designing stream projects. While the disciplines of some decision makers focus them on materials, other disciplines focus on the final result of the project. When discussing different treatment approaches, it is important to be sure that communication is clear. Considering treatment approaches in terms of the intended resultant behavior of the project will help assure that the decision makers are truly in concurrence with a selection. A classification of treatments as either ***structural based*** streambank soil bioengineering treatments or ***plant based*** streambank soil bioengineering treatments can facilitate these discussions.

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