RECLAMATION

Managing Water in the West

Fort Hall Monument Bank Stabilization Conceptual Alternatives

Snake River, Idaho

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Introduction

The Fort Hall bank stabilization site is located in eastern Idaho upstream of the American Falls reservoir in an area known as the Fort Hall Bottoms. The Secretary of the Interior designated the Fort Hall site as a national historic landmark in 1961. Recent investigations uncovered historic artifacts and the land holds spiritual significance to the Shoshone-Bannock Tribes. Rapidly eroding banks from a migrating meander bend along the Snake River, Idaho, threaten the Fort Hall area. The tribes and the Bureau of Reclamation wish to protect the site from future losses due to bank erosion.

This report begins with a description of the project site. The next section overviews bank protection methods including vegetation, direct armoring, channel relocation, and indirect protection to provide a context for the third section, potential stabilization schemes. The final section discusses some additional data collection requirements.

USBR (2002) studied the site to determine causes of historic and current bank erosion. The study included surveying topography of the Snake River, collecting samples of material, and evaluating aerial photography. The report proposed several conceptual ideas for bank protection. This report examined past data and proposes specific alternatives for the Fort Hall site alone.

Site Description

The Snake River in the vicinity of the Fort Hall monument consists of an actively migrating channel over a gravel and cobble substrate with sandy banks. Figure 1 shows the project location.

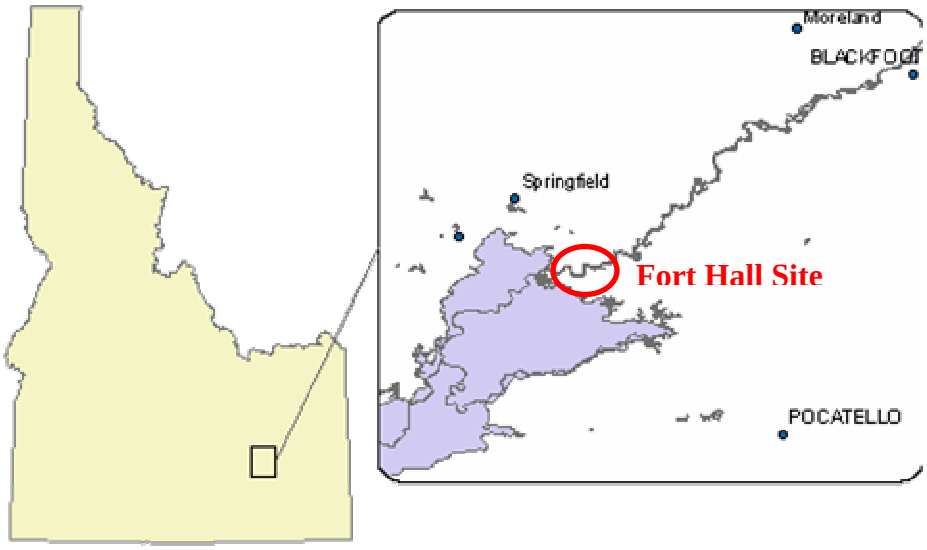

Figure 1 – Site Location

The area includes three hydraulic features relevant to a bank stabilization project. The channel on the left side of the valley conveys the majority of the flow through a sharp actively migrating bend. Though the main channel currently threatens the site, a historic path on the right side of the valley may recapture flow in the future to result in impinging flow. The final hydraulic feature consists of an oxbow lake within the Fort Hall monument providing wetland habitat. Evidence of relic paths shows the channel migrating over the entire area.

The bend in the main channel, located on the left side of the valley, turns on an 800 foot radius of curvature. Prior hydraulic models using HEC-RAS computed mean channel velocities up to 10 feet per second during the 1997 flood of 18,700 cfs. The bank instability threatening the Fort Hall site from this area occurs from channel migration through the sharp curve.

The historic channel on the right merges with the left main channel at an angle perpendicular to the Fort Hall site. Hydraulic conditions during the 1997 flood were modeled as overbank flow with a mean velocity around 3 feet per second through this path. If the historic channel were to capture more flow, velocities could increase resulting in high flows striking the bank at a right angle.

An abandoned oxbow lake in the Fort Hall Bottoms provides wetland wildlife habitat. Maintaining the character of the area requires incorporating enough connectivity with the channel to inundate the area during high flow events.

Types of Protection

Bioengineering (Vegetation of the Upper Bank)

Bioengineering reshapes the bank to a stable slope and plants vegetation at elevations above the water line. The surface growth reduces near-bank velocities while the underground roots increase soil cohesion. Advantages include aesthetics, habitat, and potentially improved water quality. However, Biedenharn et al. (1997) lists several disadvantages and cautions. Vegetation engineering design contains significant uncertainty. Seasonal and climatic considerations impose restrictions on construction. Bioengineering cannot extend below the water line and requires additional toe protection to prevent undercutting.

Direct Armor Protection

Direct armor places a physical boundary between the stream and the bank. Material may consist of stone, concrete blocks, or other immobile objects. The revetment may cover the entire bank or only a portion. Watson et al. (1999) lists a high degree of design certainty as an advantage of armor protection. Material costs, construction costs, and aesthetics are disadvantages.

Transverse Features

Richardson et al (2001) describes a variety of indirect methods for altering the flow path including spurs, bendway weirs, and Iowa vanes. Transverse features protrude into the stream laterally or at an angle to block and redirect flow. Peterson (1996) lists some of the goals for transverse features: blocking side channels, concentrating flows, realigning channels, and bank protection. Transverse features can be constructed in increments and damage to can be repaired before flows threaten the bank. Watson et al. (1999) lists habitat as another advantage. Transverse features are susceptible to degradation over time due to continual exposure to the flow and are susceptible to ice and debris loads. Additionally, protrusions into the stream may constitute a navigation hazard.

Curve Shaping

Curve shaping shifts the alignment of the thalweg in order to direct flow away from the problem area or smooth the flow path to simplify other protection schemes. The minor realignment of a channel typically results in eroding point bars on the inside of a bend to increases the radius of curvature. Realignment uses in channel structures such as dikes, bendway weirs, and direct armoring to protect the reshaped bank line.

Channel Relocation

Channel relocation moves a length of channel to an entirely new location. Unlike curve shaping, which may push a channel against one bank, relocation requires forming an entirely new boundary. Realigning a channel may combine earthwork efforts to fill in the old channel and overbank areas, a pilot channel to use the river to shape the boundary, and in-channel structures to prevent flow recapture and induce or prevent scour where

appropriate. Channel realignment pushes the river away from the problem area resulting in a high degree of safety, but the design and implementation requires significant effort.

Potential Stabilization Schemes

Design Criteria

The design for Bank protection must consider the location of fixed points, channel width, channel depth, and thalweg alignment (Peterson, 1996). At Fort Hall, the selection of an alternative is subject to several considerations.

- Preservation of the Fort Hall monument requires maintaining the bank line in the current location.
- The importance of preserving the Fort Hall Monument imposes a high cost to a failure to prevent further erosion of the bank line warranting a high factor of safety.
- Wetland habitat preservation requires maintaining the connectivity between the river and the oxbow near the monument.
- Changes in channel planform including shifts in alignment and recapture of the flow in the historic channel on the right over bank

In addition to engineering considerations, evaluation criteria include characteristics such as:

- Habitat: bank conditions, hydraulic characteristics, etc.
- Aesthetics: general appearance
- Maintenance: frequency of work required to keep the bank protection functional

The end product will combine a main left channel with a historic right channel scheme to protect the entire area regardless of future flow conditions. Each channel may use a different method.

Main (Left) Channel Schemes

Bioengineering with Stone Toe Protection

Figure 2 shows a conceptual cross section of the bank stabilization scheme using bioengineering and stone riprap toe protection. Vegetation stabilizes the portion of the bank above the average high water mark while stone or concrete blocks protect the basal endpoint from scour and prevent undercutting.

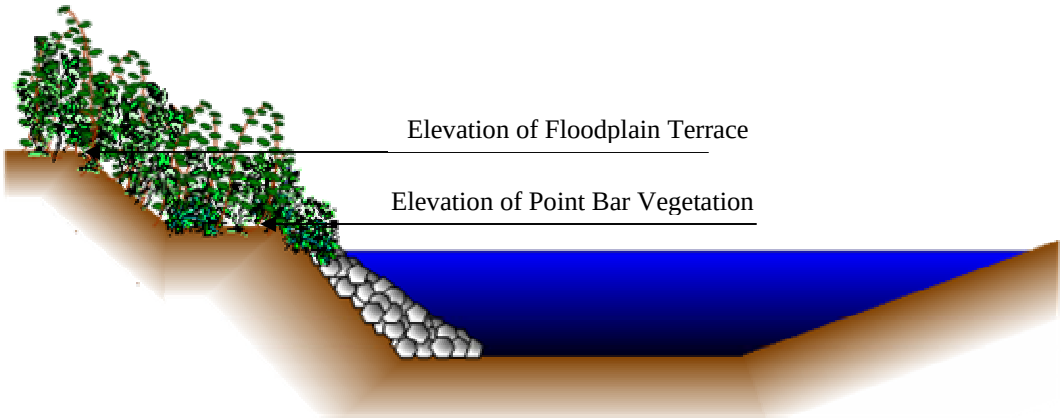

Figure 2 – Conceptual Cross Section of Bioengineering with Stone Toe Stabilization

A reshaped upper bank provides a more gradual and stable slope. Installing a stone toe preserves vegetation along the upper bank to improve aesthetics while saving on material costs. The extra thickness at the toe provides protection for launching when the bed may scour during low flow events. Figure 3 shows bioengineering and stone protection in plan view.

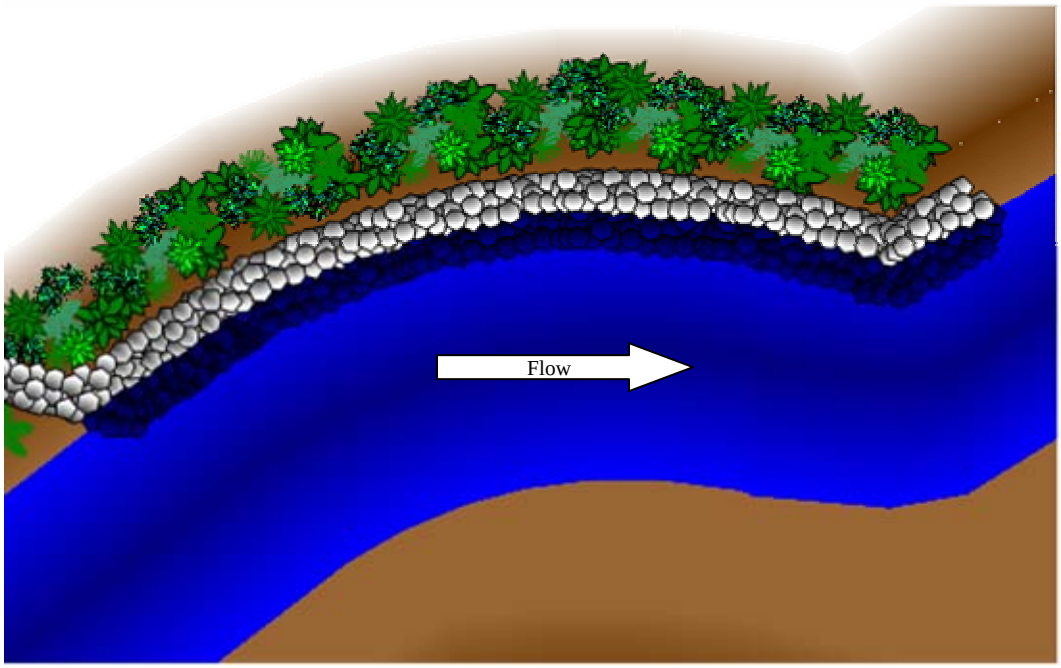

Figure 3 – Conceptual Plan View of Bioengineering with Stone Toe Stabilization

The length of bank protected by rock extends across the entire outside edge of the bend. Both the start and the end of the riprapped sections require special consideration to prevent the stream from circumventing the protection. The figure shows the rock at the start of the reach guiding flow into the channel. The end of the section would curl around the Fort Hall point to stop any eddies from flow separation from cutting into the back of the bend.

A more robust protection scheme could place a line of AJAX structures under the riprap. The interlocking AJAX provide extra protection through the interlocking arms, while the surface rocks improve aesthetics and provide a first layer of protection.

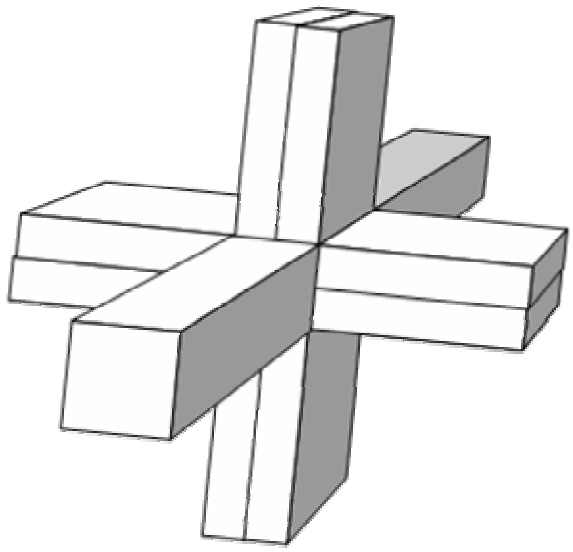

Figure 4 – A Single Element in an Ajax Protection Scheme

Earth Fill Curve Shaping

Curve shaping seeks to smooth the river planform and lessen the stresses created by flow around a bend. Figure 5 shows a line of stone toe installed away from the bank to protect earth fill.

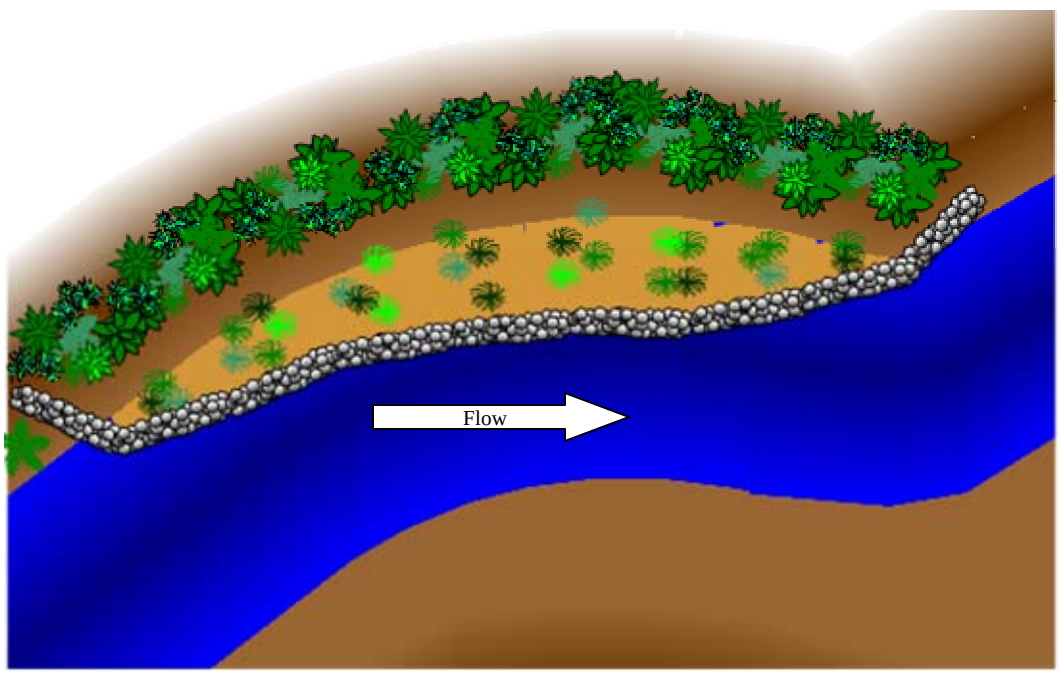

Figure 5 – Conceptual Earth Fill Curve Shaping Plan View

The protrusion will concentrate flow over the point bar eventually eroding enough material to form a new, milder curve. Figure 6 shows a cross section of the earth fill curve shaping.

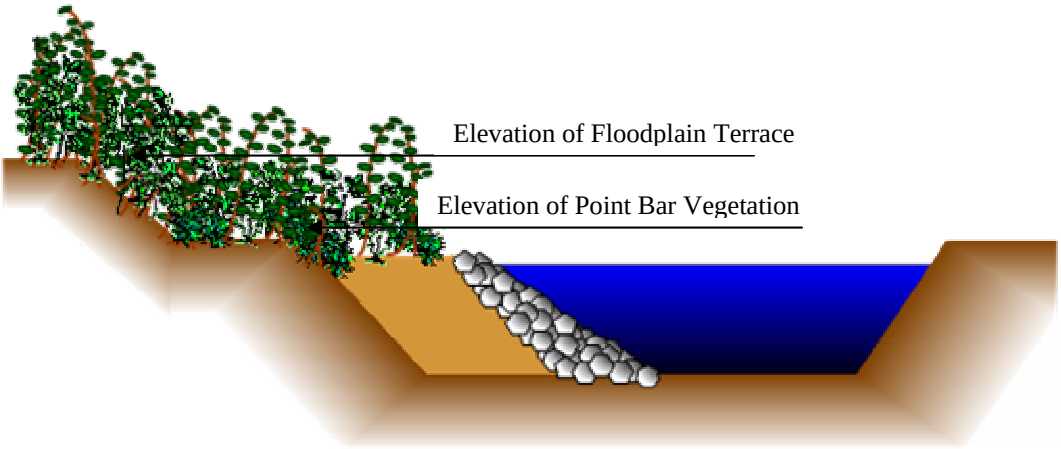

Figure 6 – Conceptual Earth Fill Curve Shaping Cross Section View

Stone Spur Curve Shaping

Stone spurs provide an alternate method to reshape a curve. Figure 7 shows a stone spur installation in plan view. Figure 8 shows the cross section of a single spur.

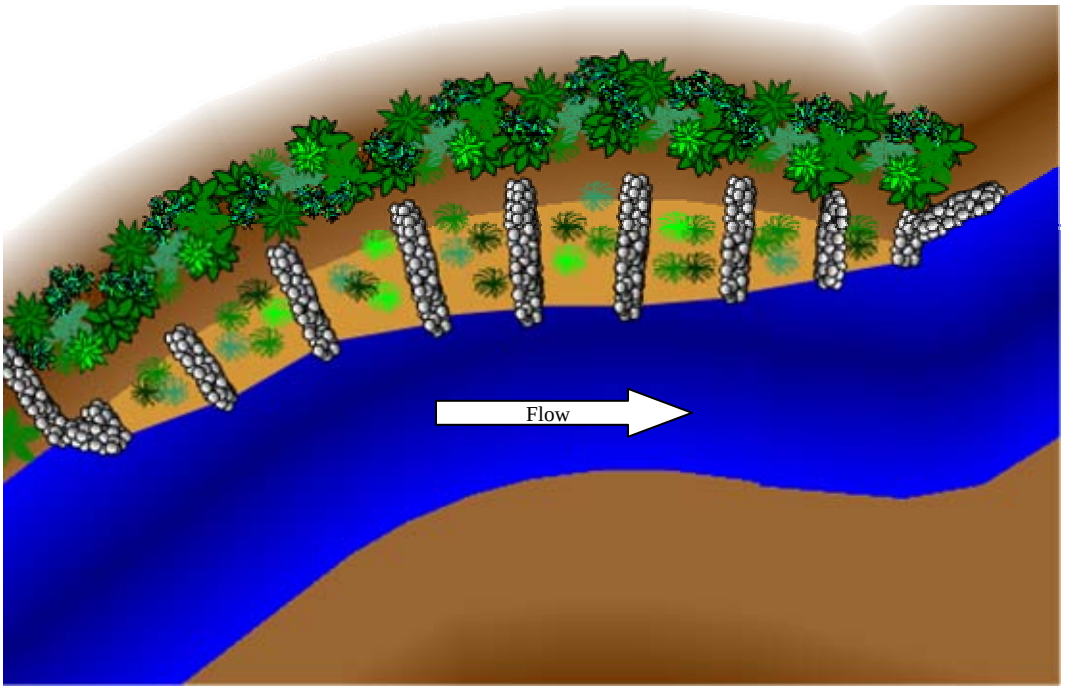

Figure 7 – Conceptual Stone Spur Curve Shaping Plan View

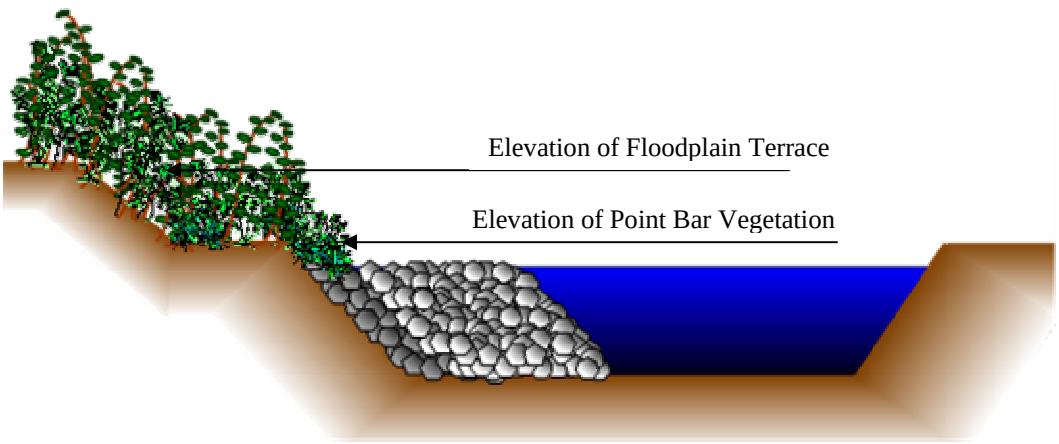

Figure 8 – Conceptual Stone Spur Curve Shaping Cross Section View

Unlike bendway weirs, stone spurs block the entire range of flow depths. The stone wall concentrates flow towards the inside of the bend. The point bar will erode leaving a milder curve. Material deposits behind the spurs and fills in between the gaps resulting in a final product similar to the earth fill. Unlike earth fill, the spurs provide flanking protection all the way back to the original bank, but may require more stone than earth fill.

Historic (Right Overbank) Channel Schemes

Bioengineering with Revetment Bank Protection

A riprap revetment across the bank with bioengineering on the top bank will protect against impinging flow under a scenario where the historic channel on the right overbank captures the majority of the flow. The riprap will need to extend high on bank due to The uncertainty in design and weaker strength of vegetation make a bioengineered bank less suitable for this scenario. Figure 9 shows a plan view

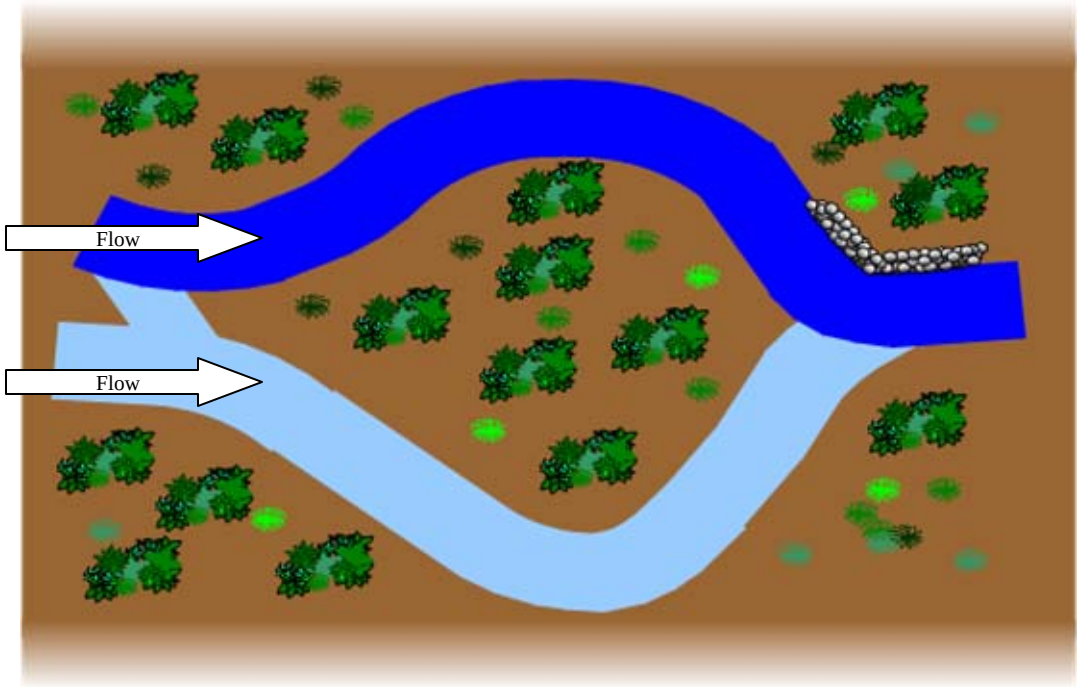

Figure 9 – Conceptual Plan view of historic channel bioengineering with bank protection

Oxbow Flow Retention

Preserving habitat in the oxbow requires maintaining connectivity with the channel through a protection scheme. This requires creating a hydraulic break in the bank engineering where the oxbow connects to the channel. Figure 10 shows a generic structure placed across the junction with the current channel.

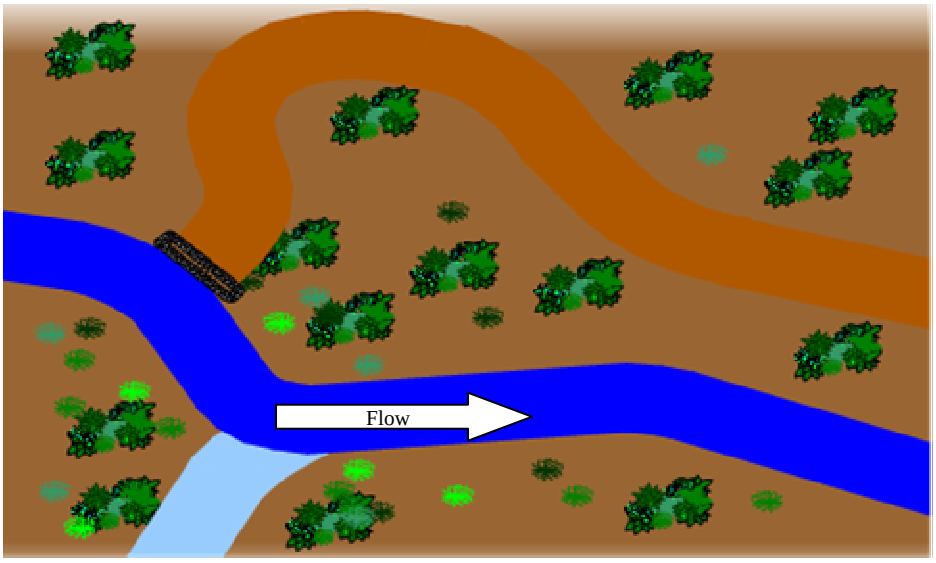

Figure 10 – Conceptual Plan view of oxbow flow retention

The next sections describe different types of hydraulic breaks in the protections scheme including some advantages and disadvantages for each select.

Solid Riprap Weir Entrance

Figure 11 shows a riprap weir entrance to the oxbow channel. Where a sill restricts the quantity of flow into the wetland area and riprap armored sides create a break in the bank protection.

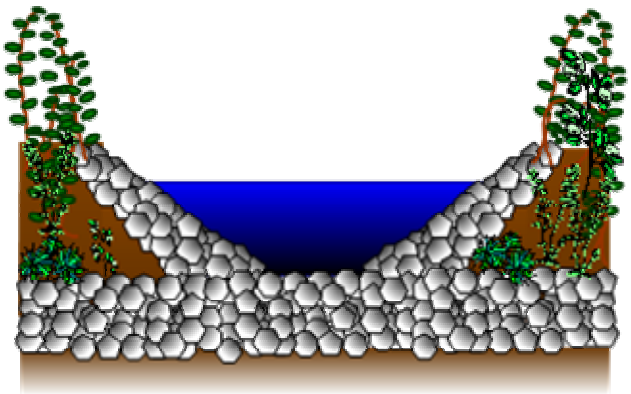

Figure 11 – Conceptual Front View of Weir Entrance Through Bank Protection

This type of structure is simple and easy to construct but increases the risk of flow flanking the surrounding bank protection.

Porous Entrance

A porous riprap wall provides a continuous line of bank protection while still allowing water to flow through the interstitial spaces and inundate the area behind the rock material. Figure 12 shows a porous riprap wall.

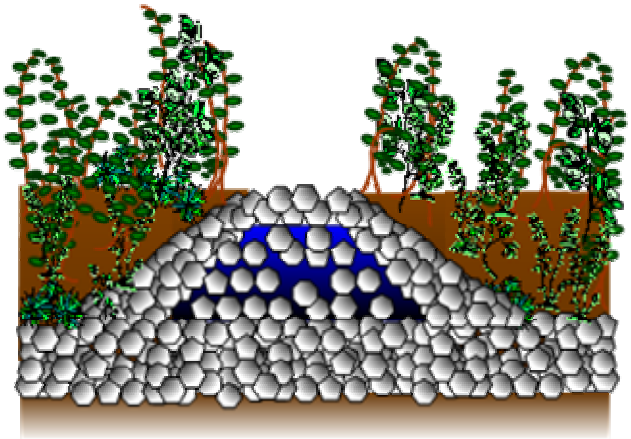

Figure 12 – Conceptual Front View of a Porous Riprap Wall

Disadvantages to the structure include a high degree of uncertainty in the quantity of water able to pass through as well as the potential for sand to deposit within the structure and clog the pours.

Culverts

A structure consisting of one or more culverts installed at the thalweg of the oxbow provides controlled hydraulic connectivity without breaking the line of bank protection. Figure 13 shows a line of culverts.

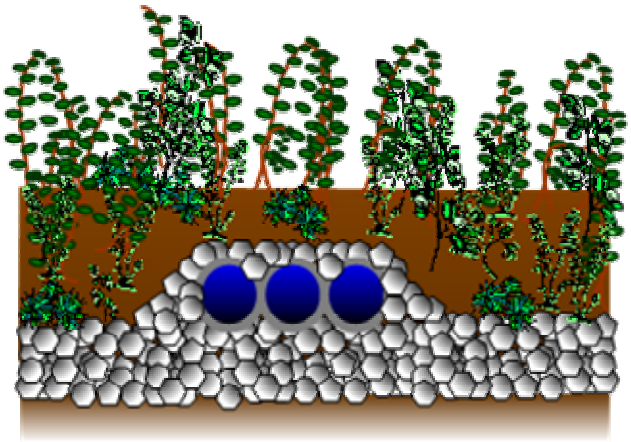

Figure 13 – Conceptual Front View of a Culvert Entrance

The number of culverts may vary in the final design. As with the porous wall, aggradation may fill the entrances and exits of the culverts and require maintenance. Unlike the wall, the culverts can be more easily cleared.

Aerial Extents

Appendix A contains schematics for several of the main channel and historic channel alternatives overlain on top of aerial photos. These representations do not show final construction plans, but rather illustrate the location and general extent for each alternative as applied specifically to the Fort Hall Site. The final stabilization plan should incorporate a selection to address each of the hydraulic features: the main left channel, the historic right overbank, and the oxbow flow retention.

Considered and Excluded Alternatives

Main (Left) Channel Schemes

Bendway Weir Transverse Features

Bendway weirs consist of rock structures installed below the water level and angled upstream to redirect flow way from the banks. Figure 14 shows the bioengineering and stone to protection combined with Bendway weirs.

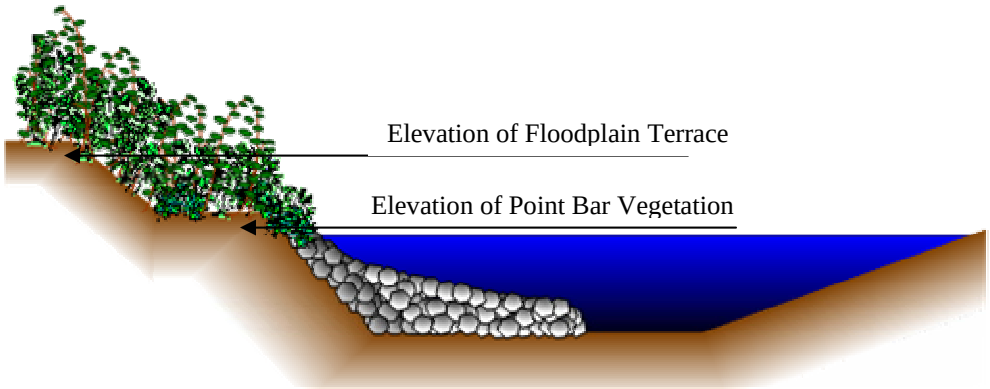

Figure 14 – Conceptual Cross Section View of Bendway Weirs with Bioengineering and Stone Toe Protection

As with stone toe protection, a large discharge event may scour the tip of the weir resulting in launching and burying some of the stones. Extra material added during construction accounts for this process. The sloping crest concentrates flow in the main channel away from the bank, but the primary protection comes from the upstream angle. Figure 15 shows the bendway weir scheme in plan view.

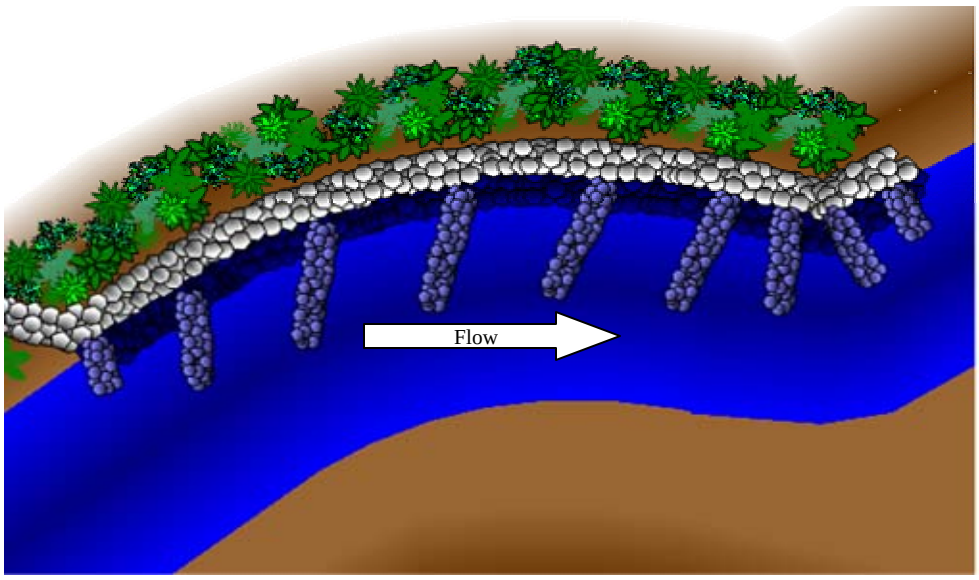

Figure 15 – Conceptual Plan View of Bendway Weirs with Bioengineering and Stone Toe Protection

The figure illustrates the concept and general appearance of a bendway weir project. The actual angle and spacing of the weirs must be determined through hydraulic calculations. As the flow passes around the bend, the streamlines turn and leave at an angle perpendicular to the edge of the weir. The weir guides the streamlines around the curve and reduces the angle of attack on the bank. The entrance to the bed slowly begins the constriction of the channel and the exit guides the flow around the sharp point to reestablish flow in the downstream direction.

Adding the weirs to the bioengineering with stone toe protection plan provides an additional degree of safety and may allow smaller riprap sizes along the bank and reduced maintenance. Damage to the weir structures may become apparent before the banks become threatened. The additional structures may increase protection costs, and by protruding into the stream, weirs may create a navigation hazard.

Bendway weirs were not considered for the full alternative exploration due to the high rate of failure from shifts in planform. The active meanders of the Snake River would most likely change the entrance angle and reduce the effectiveness of the weirs.

Channel Relocation

Due to the severe bend, shifting the channel into a more gradual curve improves the chance of long term success. Figure 16 shows a plan view of channel relocation.

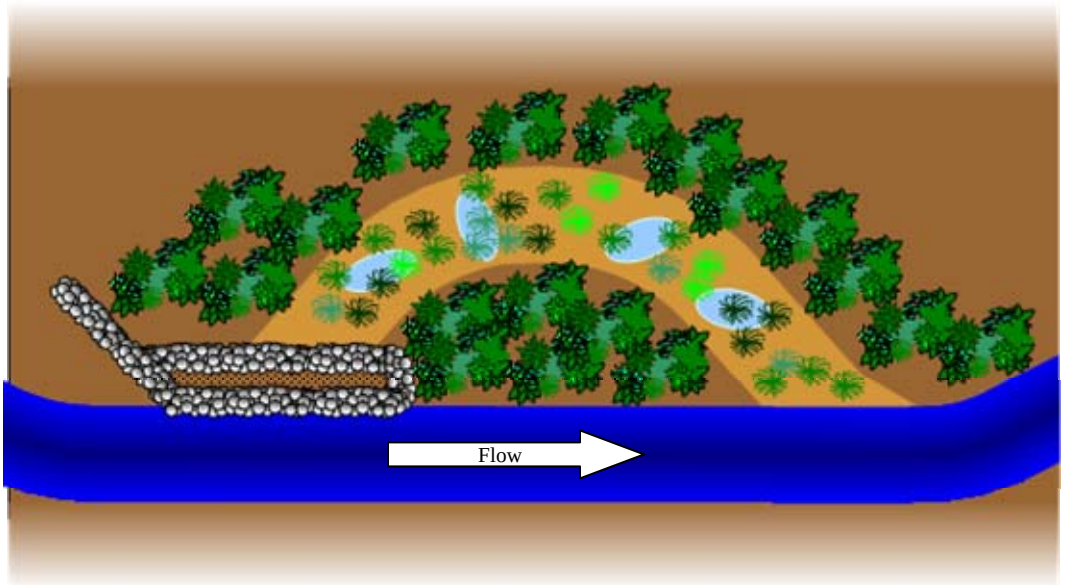

Figure 16 – Conceptual Channel Relocation Plan View

A stone dike blocks flow to the old channel while either a pilot or fully excavated new channel captures the flow. The old channel becomes an oxbow lake and deposition may occur. Figure 17 shows a cross section view.

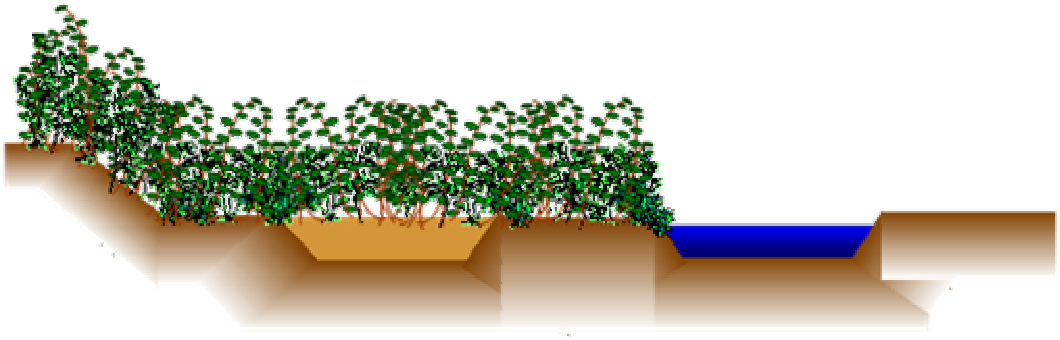

Figure 17 Conceptual Channel Relocation Cross Section View

Channel relocation can be costly depending on the material and requires consideration of future meanders but reduced maintenance and provides additional assurances of success may make the option worthwhile.

Relocation was not considered for the Fort Hall site due to the high costs of construction, presence of cultural resources, and the ease with which the channel could shift back into old flow paths.

Historic (Right Overbank) Channel Schemes

Recapture Prevention

Rather than allow a shift in the plan form to the historic right channel, a series of dikes across hydraulic connections would prevent recapture of the stream and avoid the change of creating the impinging flow condition on the Fort Hall site, Figure 18.

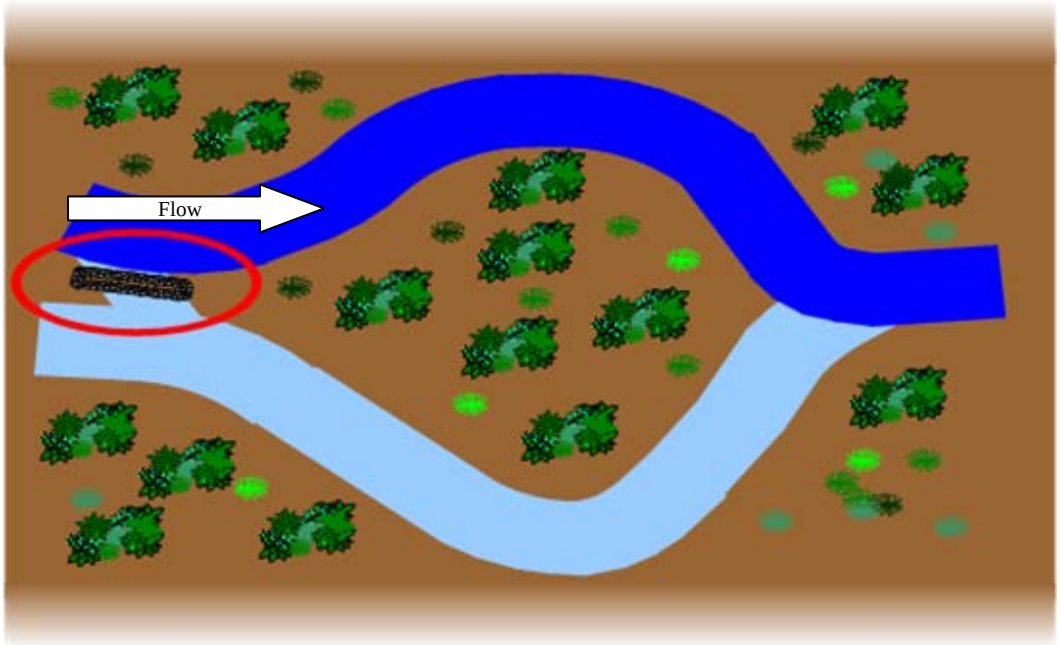

Figure 18 – Conceptual Plan View of Recapture Prevention

The numerous potential paths requiring blocking and high potential for flanking flow make this alternative unsuitable for the Fort Hall site.

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Appendix A – Aerial Extent of Conceptual Alternatives