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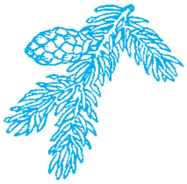


Technical Tip

Erosion Protection of a Clay Bank of Keogh River Using Spurs (Debris Groins)

Mike Feduk

As part of the watershed restoration efforts in the Keogh watershed, a high clay bank in the lower Keogh River was recommended for bank protection. The works were to meet the objectives of limiting sediment recruitment from the high bank, improving rearing habitat, and providing an opportunity to test a unique bank protection technique using large woody debris (LWD) as the primary construction material. This article covers some basic technical theory in the design and layout of spurs (debris groins) for bank protection and follows with the case study at the Keogh River clay bank.

A spur is a structure that projects from a stream bank into the river channel and causes redirection of water away from the bank towards the tip of the spur. This characteristic of spurs can benefit the stream by:

- protecting stream banks from erosion and limiting sediment recruitment,
- reducing velocities near the banks,
- creating still water areas that encourage deposition, and
- channeling flows to reduce widths and create a defined channel.

These features are illustrated in Figure 1, which shows a typical LWD installation.

Many factors govern the use of spurs at a particular location. Criteria related to the design of spurs for traditional river engineering applications have been developed by government transportation agencies (U.S. Dept. of Transportation, 1991; Neill, 1973) . Using these established techniques as a basis for

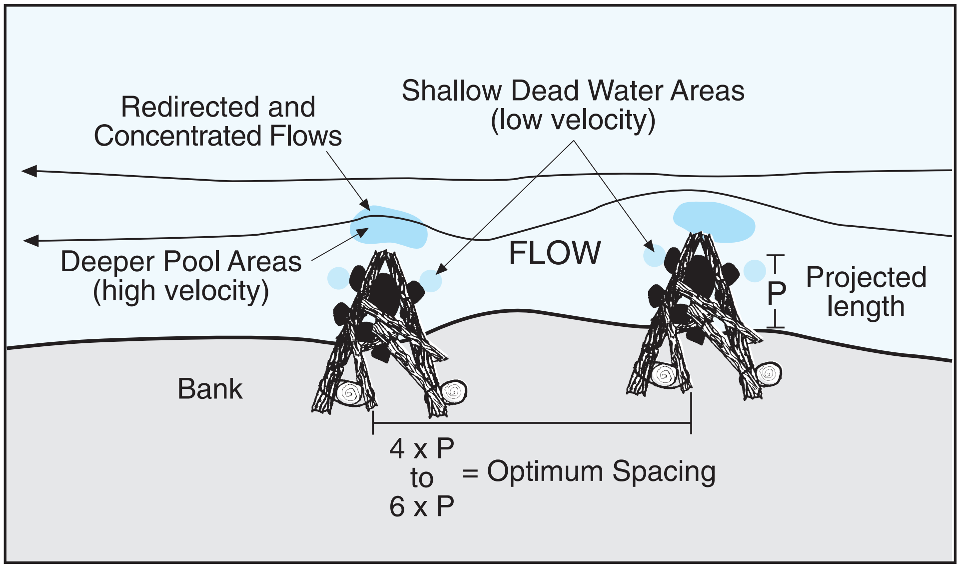


Figure 1. Large Woody Debris functioning as a spur.

watershed restoration projects, there are three key considerations for spur design:

1. limits of protection;
2. spur length and spacing; and
3. type of spur and its susceptibility to scour.

1.0 Spur Design Guidelines for Habitat Restoration

Traditionally, spurs have been used for river engineering to prevent bank erosion and migration, and to protect infrastructure such as roads, bridges and dwellings. However, it is clear that the characteristics of spurs have desirable biological benefits. Redirecting and concentrating stream flows away from a bank increases local flow velocities at an obstruction. These higher velocities create deep scour holes at the tips of spurs. The area behind the spur adjacent to the bank is a low velocity zone (Figure 1).

These flow patterns at spurs provide key features for fish habitat restoration including:

- deep pools at the tips,
- cover for fish if LWD is used for construction;
- protection of eroding banks and a reduction in sediment loads in the river, and
- still water to fast moving flow transition areas, which create complexity in the stream flow and diversity in fish habitat.

Large woody debris used as a construction material accentuates the habitat features of a spur. Using classical spur design methods, the placement of LWD can be designed to achieve optimum benefit for both fish habitat and riverbank protection.

These spur design guidelines are intended to provide practical support for improvement of LWD designs where fish habitat restoration is the primary goal. LWD structures should only be used **for their intended purpose and within established and accepted design limitations.** For example, simple LWD spurs can be used for complexing and preventing bank erosion and designed according to these guidelines. The same spurs would not be used to control erosion near a bridge in a high-energy system with expected scour. More comprehensive guidelines (U.S. Dept. of Transportation, 1991) should be consulted where river training is being used to protect high value infrastructure, or on high-energy streams. "Rehabilitating Stream Banks" (Babakaiff, S. et al., 1997), provides a guideline for selecting appropriate LWD and rock structures for streams of varying stream energy.

1.1 Limits of Protection

The location of the upstream starting point and the downstream termination point influence the success of the spur installation. An approach to determining these limits is shown in Figure 2. Other considerations are:

- shaded area is for optimum bank protection;
- helical currents that will produce the largest pools will be in the shaded area;

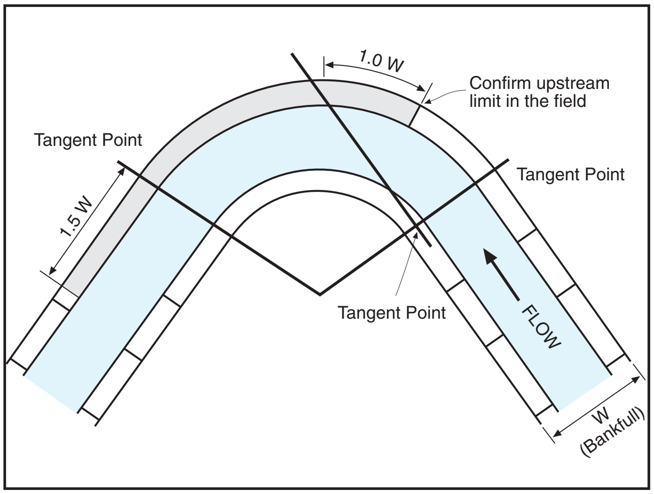


Figure 2. Extent of Protection required at a Channel Bend (U.S. Dept. of Transportation, 1991).

- upstream limit is critical to prevent outflanking of the upstream end of the spur field;
- fine-tuning of the limits of protection must be determined in the field;
- the tips of the spurs should follow a smooth curve through the bend starting with a smooth transition at the upstream end. The spur tips should trace the desired thalweg location.

1.2 Spur Length and Spacing

The length of bank that is influenced by a group of spurs is directly proportional to the length and spacing of the spurs (refer to Figures 3, 4 and 5). Spur length is defined as the projected length perpendicular to the main flow in the channel from the bank to the effective tip of spur (Figure 3). Traditionally, the amount of bank protected by a single spur is about **two to four** times the projected length of the spur; this spacing can be increased when spurs are placed in groups (Figures 3 and 4).

Longer spurs protect more bank but have a greater impact on the opposite bank and the upstream and downstream channel (Figure 5). Shorter spurs are less prone to damage because they encroach less on the main channel than long spurs.

For habitat restoration applications where bank protection is not the primary concern, and structures are placed in groups, a spacing of **four to six** times the projected length is recommended for design (Figure 1). This spacing should be confirmed based on site specific conditions.

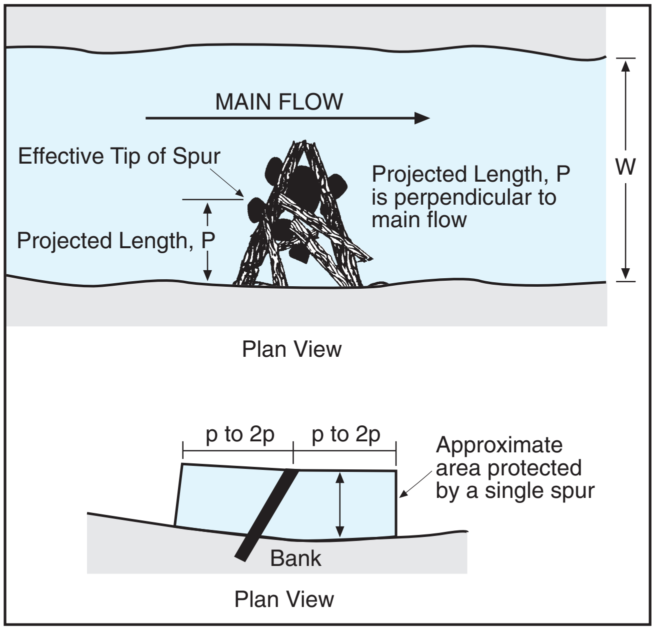
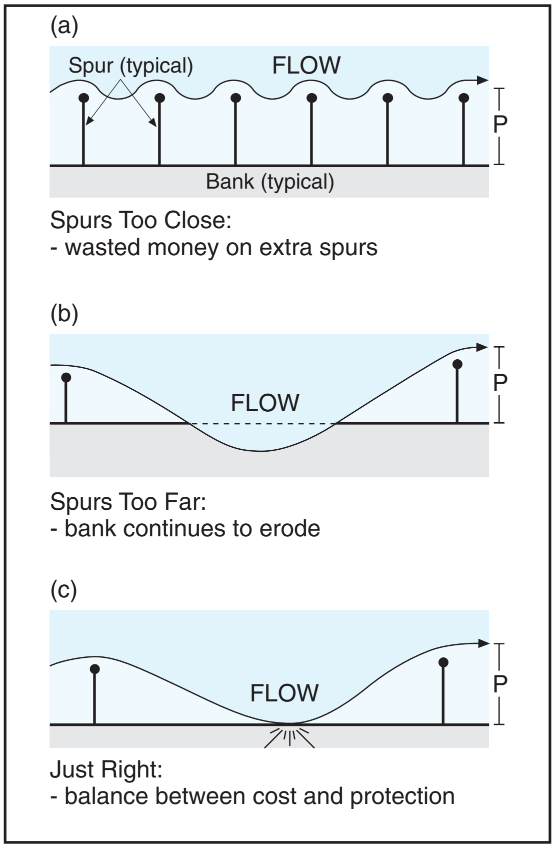


Figure 3. Projected length and spacing of spurs.



Spurs Too Close:
- wasted money on extra spurs

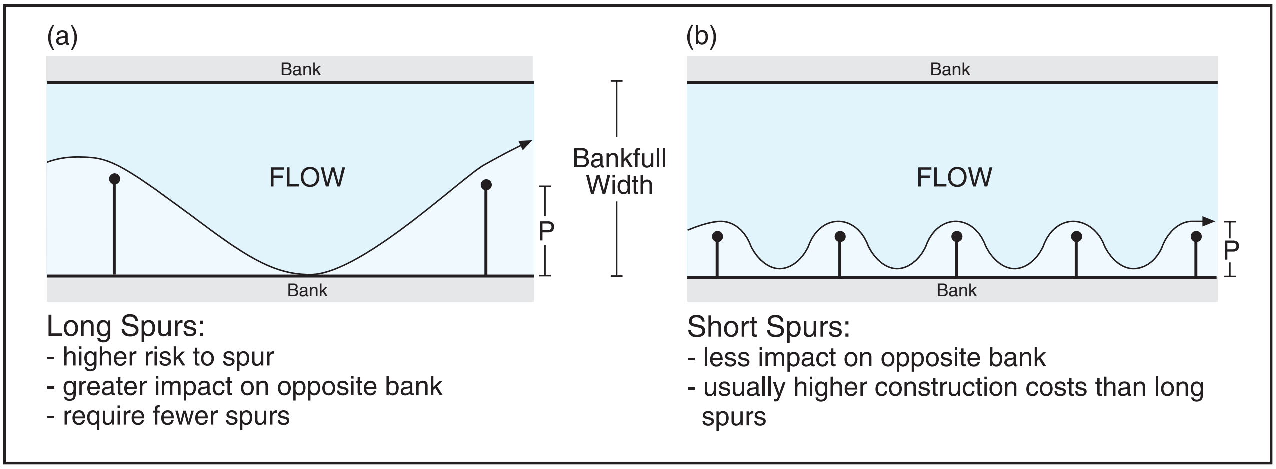
Spurs Too Far:
- bank continues to erode

Just Right:
- balance between cost and protection

Figure 4. Examples of spur spacing.

As spur lengths increase they become more susceptible to scour, require more maintenance and have a greater impact on the opposite bank. U.S. Dept. of Trans. (1991) suggests a diminishing rate of return for spurs greater than 20% of channel width, although many successful installations lie in the 3 to 30% range. Permeable spurs (spurs that allow water to pass through them) can encroach up to 25% of the channel and have minimal effect on the opposite bank. Impermeable spurs can be up to 15% for the same effect. LWD installations tend to plug up with debris and pass less water so **15% to 20%** encroachment would be a reasonable target. In some cases, however, some erosion on the inside of a bend or the opposite bank would not be a concern if the encroachment is up to 30% (i.e., in an over-widened reach). Site-specific design is required to determine the optimum encroachment into the bankfull width.

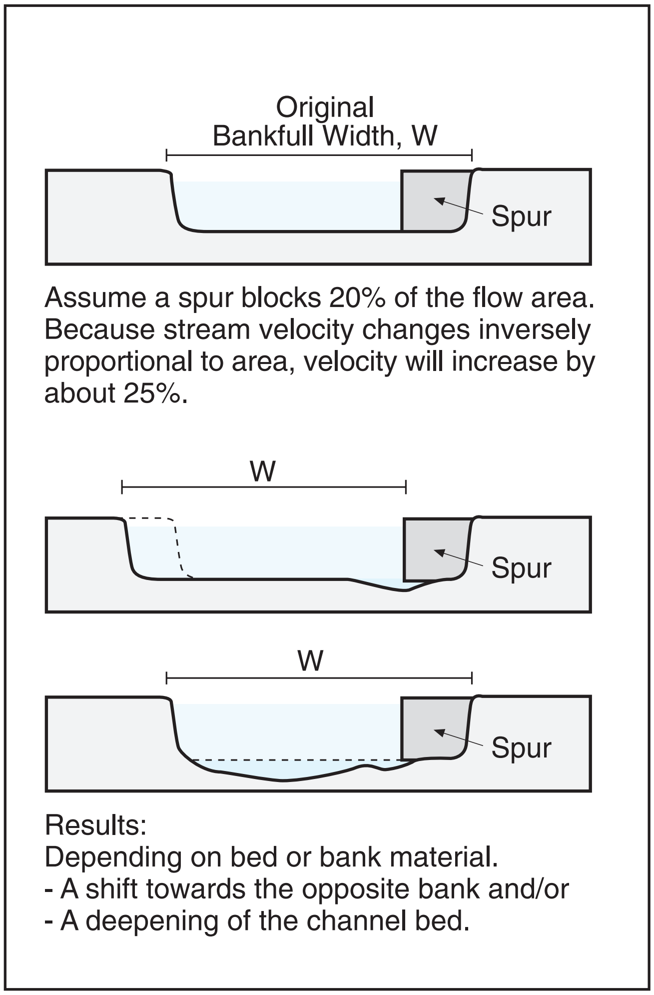
Simple velocity-area calculations will yield an indication of the effects of constricting a channel more than 20% with a spur (Figure 6). Constricting a channel causes the average velocity to proportionally increase in the channel. This will cause material to



Long Spurs:
- higher risk to spur
- greater impact on opposite bank
- require fewer spurs

Short Spurs:
- less impact on opposite bank
- usually higher construction costs than long spurs

Figure 5. Examples of spur length.



Assume a spur blocks 20% of the flow area. Because stream velocity changes inversely proportional to area, velocity will increase by about 25%.

Results:
Depending on bed or bank material.
- A shift towards the opposite bank and/or
- A deepening of the channel bed.

Figure 6. Effect of spurs on flow area and bankfull width.

move that was previously stable and result in the channel widening or deepening depending on the materials in the bank and bed. In addition, while the channel is adjusting to the changed width, other changes in flow characteristics may occur such as backwater effects and changes in depth of flow. These processes will continue until the channel adjusts to its new width.

In equation form, the key criteria from the previous discussion are:

$P \le (0.15 \text{ to } 0.20) \times W$ *and*

$S = (4 \text{ to } 6) \times P$ (Habitat Complexing) *or*

$S = (2 \text{ to } 4) \times P$ (Bank Protection) *where*

P = projected spur length (Figure 3)

W = bankfull width (Figure 3)

S = spur spacing (Figure 1)

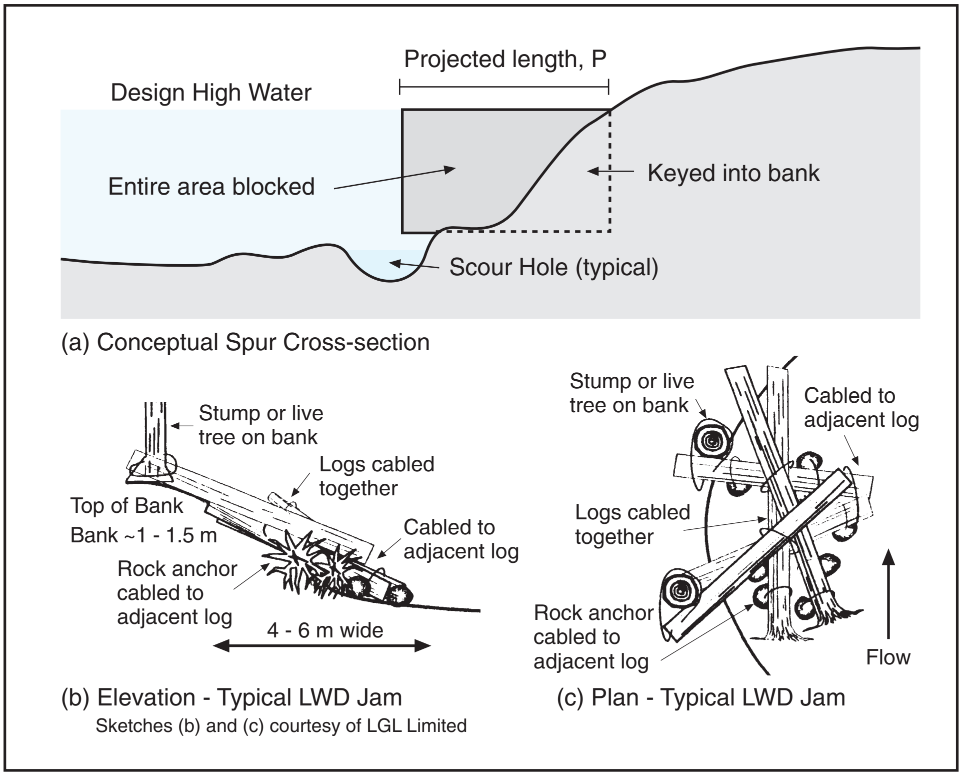
Actual spur length and spacing depend on site specific field conditions such as erodibility of the banks, location in straight or curved reach and channel cross-section. The bankfull channel width referred to here is one that would occur in a relatively stable, uniform reach. In bedrock controlled reaches, or reaches that are considerably over-widened because of aggradation, the spur length and spacing relationship given here may not be applicable and the restoration prescription design should be referred to a suitably qualified professional.

1.3 Type of Spur

The performance of a spur is directly related to its physical features such as shape, orientation angle, construction material, porosity and crest height. Because this article assumes that the habitat restoration structure is being constructed according to established guidelines such as in Babakaiff, et al.

(1997) or D'Aoust and Millar (1999), these parameters are considered fixed for spur design. In other words, once an appropriate material has been chosen for habitat restoration, the structural elements can be properly designed and then the layout planned according to this guideline. A LWD structure with ballast is shown in Figure 7 compared to a classical spur obstruction. Some general observations are:

- a classical spur obstruction is very efficient at deflecting flows and protecting banks, and produces the greatest scour at the tip;
- wood structures are more permeable and less efficient at deflecting flows compared to a solid rock structure;
- flow through spurs may be beneficial to some fish species (such as trout) where moving water and cover are the preferred habitat. However, leaving gaps in the spur reduces the efficiency of the spur to deflect water. If the water is not fully deflected some of the characteristics discussed earlier will not be as pronounced (i.e., reducing velocities near the bank, deep scour hole at the tip, and still water areas behind the spur);
- bigger is better; the structure must be robust and the elements designed to withstand the design flows;
- Figure 7 shows the importance of keying the structures into the bank to prevent outflanking of the spur which is one of the main causes of spur failure;
- Babakaiff, et al. (1997) provides guidelines for spur crest heights for LWD. The crests should usually be placed at design high water level on a high bank or level with the floodplain on a low bank. If the design calls for the overtopping of the spurs, appropriate features must be included to deal with this condition.



(a) Conceptual Spur Cross-section

(b) Elevation - Typical LWD Jam

(c) Plan - Typical LWD Jam

Sketches (b) and (c) courtesy of LGL Limited

Figure 7. LWD Spur Layout.

1.4 Scour

Deep, structure-threatening scour holes can form at the tip of spurs where flow velocities are much higher than the average channel velocity. The depth of scour hole (residual pool depth) can be up to 1.0 to 1.7 times the design flow depth upstream of the pool (at the riffle) for an impermeable spur. Scour decreases as a spur becomes more permeable. This local scour must be considered in the design. Scour can be accounted for by burying the material below the expected scour depth, by accommodating the movement as a result of the scour hole, or by protecting the foundation with rock riprap.

The techniques covered in Babakaiff, et al. (1997) (p. 6-19 to 6-22) provide guidelines for rock and large woody debris integrated designs that generally account for scour. This is done by choosing structures appropriate for the energy of the stream thus limiting the risk of damage by scour.

2.0 Case Study- Keogh River Clay Bank

The clay bank on the Keogh River is located just off Rupert Main below Highway 19 leading to Port Hardy. The main purpose of the works constructed at the clay bank was to limit recruitment of sediment into the system by preventing erosion of the toe of the slope.

Providing fish habitat and evaluating an alternative bank protection scheme were secondary objectives.

In Summer 2000, three spurs were constructed in the river using the guidelines from this report. The structures were constructed using a triangular layout and ballasting consistent with D'Aoust and Millar (1999). Modifications to the design were made to two structures, spurs A and B, to suit local conditions. These modifications were meant to make the structures more robust and included keying or excavating the ends into the bank because of a lack of bank anchors; partially backfilling the structure with gravel and cobbles for added stability; extra ballast and riprap placed at the leading edge; and upstream ramp logs to add weight and stability and to encourage deposition of LWD above high water.

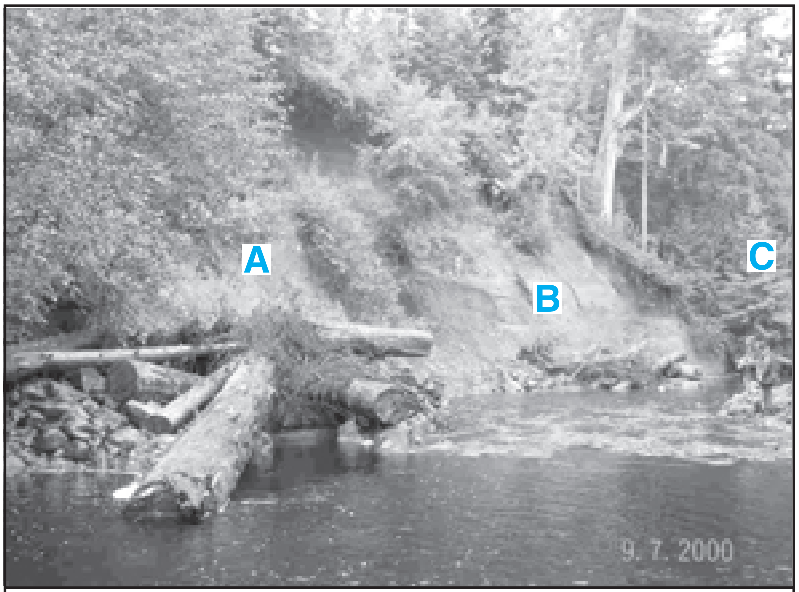
Additional rootwads were placed in the structure to make the structure more impermeable but still add complexity to take advantage of the pool development. The third spur, spur C, was constructed in the typical triangulated A-frame configuration. Other techniques for constructing debris groins (spurs) have been presented in Streamline 4:2 and 5:1 (Finnegan and Slaney, 1999; Finnegan, 2000).

Costs associated with constructing the structures included purchasing, hauling and loading material, helicopter placement, walking excavator, and labour.

A breakdown of these costs for a single spur is as follows:

• purchasing 8 logs, 10m long, 0.8 to 1.0m in diameter	$2000
• ballast and rootwads were no cost	$0
• 1/2" steel core cable, clamps, epoxy, bits	$250
• hauling and loading rock and wood	$350
• flying - 1/2 hour with Sikorsky S-61, (10,000 lb. lift)	$1800
• walking excavator (Spyder) - 6 hours	$900
• Labour: supervision & 2 man crew - 1day	$700
Total cost of one spur - Approximately	**$6000**

The $6000 is an average cost and the third spur C being much smaller would have been less than half the cost.



Spur group details:

Spur	Approximate Projection* (P)	Spacing (S)	Spacing Ratio (S/P)
A	6 m		
		32 m	5.3
B	6 m		
		34 m	6.2
C	5 m		

* from outside edge of bank/water to effective tip of spur

Structure A
- riprap at leading edge
- height - 0.3 m minimum above estimated bankfull depth
- gaps filled to prevent water going behind structure

Figure 8. Looking downstream at spur group.

Figures 8 and 9 show details of the layout of the spurs including the critical projected length and spacing measurements.

Figure 10 is an aerial view of the project taken in Winter 2000 during less than a bankfull discharge. Comments concerning hydraulic features are included in the figure.

3.0 Concluding Remarks

These structures are expected to remain stable and provide erosion protection of the bank for many years. However, as with all river engineering structures, some form of maintenance may be required periodically throughout the life of the structure and particularly after a flood event. Maintenance may include

Structure A

- Logs ballasted consistent with D'Aoust and Millar
- Backfilled with cobbles/gravel to add mass to structure
- 1/2" steel core cable
- For additional stability and to prevent outflanking, bottom logs are keyed into clay bank
- Structure is relatively impermeable
- Bottom logs would provide better habitat with root wad attached

Figure 9. Looking upstream at Structure A.

repositioning ballast and tightening cables. This particular structure is relatively fixed at the bank ends and unable to rotate into a scour hole that may develop. If the scour at the tip becomes excessive (desirable for fish habitat, not so desirable for structural stability) extra rock and ballast may be required to be placed to keep the structure from being undermined and losing the material from inside the spur.

Other general guidelines with respect to spur design and layout for habitat restoration projects are:

- a smooth transition into the spur group at the upstream end should be provided to prevent outflanking of the first spur.
- spacing of spurs can be 4 to 6 times the projected length where there is no property at risk; spacing may be closer in tight bends.
- spurs should not encroach more than 15 to 20% of the channel width to reduce impact on the opposite bank.
- length of spur should be optimized with spacing considering the effects on the opposite bank, upstream and downstream conditions, and cost.
- design of individual elements of the spur (rock and wood size, cabling, rock ballast requirements, anchoring and construction details, and scour calculations) must be done by a qualified designer.

Large woody debris used as a construction material accentuates the habitat features of a spur. Using classical spur design methods, the placement of LWD can be designed to achieve optimum benefit for both fish habitat and riverbank protection.

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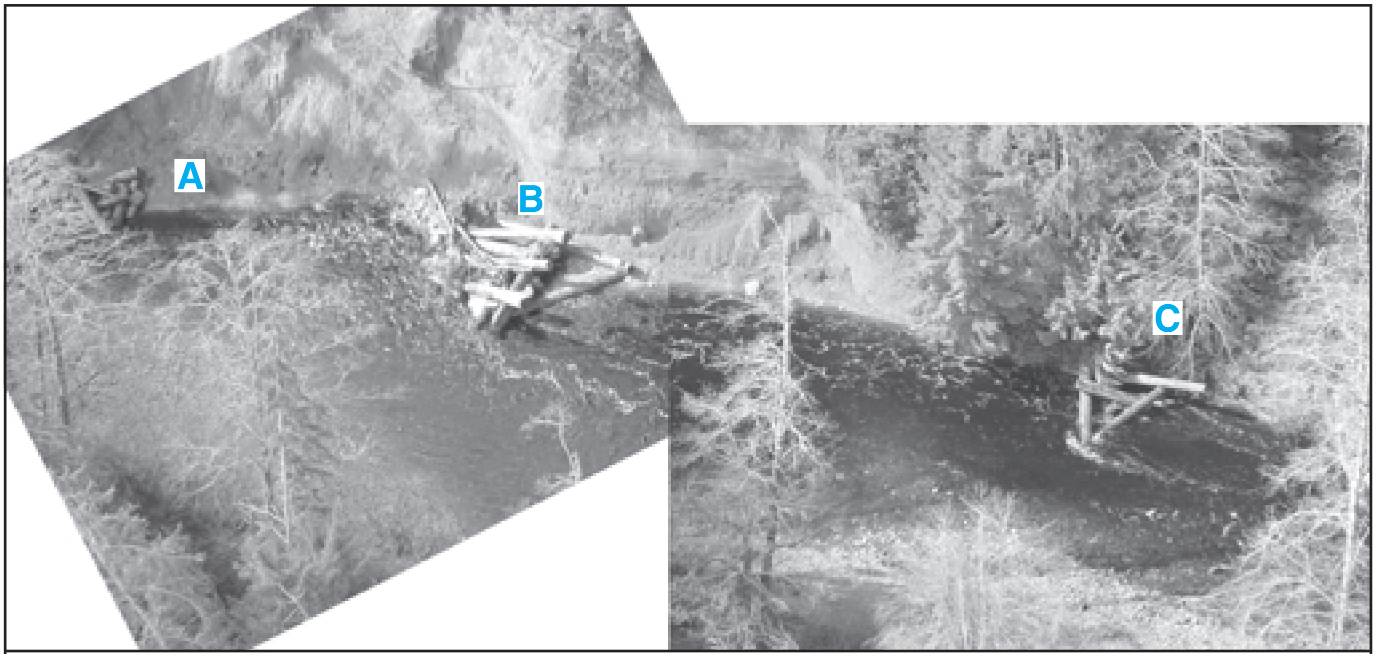
Technical Tip



Hydraulic Comments and Observations

- Spacing details are in Figure 8

- Spur B is deflecting flow away from bank
  - -note flow streamlines off tip
  - -note dead water area on downstream (right hand) side of spur
  - -this dead area dictates where the next spur should be placed downstream; typically no more than 4 to 6 times the projected length of the upstream spur. Spacing may be tighter in a river bend.

- Spur A has created a similar dead area upstream of spur B
  - -the deflected current is hitting close to the base of spur B indicating the spacing is a little too large. Spur B could have been placed about 5 m upstream for its optimum position.

- Spur C is a typical triangulated LWD structure and is much more permeable than spur A or B.
  - -because the structure is porous and slopes down from the bank to the streambed, the effective length of the structure is less than spur A and B.
  - -although it is located nicely with respect to spur B it could have been moved upstream a few meters if the clay bank was longer.

Figure 10. Aerial view of spur group (flow is left to right).

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