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Five Years of Restoration at Sinmax Creek

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Introduction

In the spring of 2000, a small group of watershed rehabilitation professionals watched as fish biologist Jerry Mitchell identified several coho salmon among the group of small fry swimming around in a blue plastic container. The fish had been caught during a salvage operation as part of an instream work session on Sinmax Creek. The small fry, with their sickle shaped and white edged anal fin, were the first confirmation that coho salmon were still actively present in the system, and that they were using habitats created by recently completed restoration works. It was also a sign that five years of restoration effort in the creek may be playing a positive role in the local recovery of this blue-listed species.

Figure 1. September 1998. Sediment fan formed by Sinmax Creek in Adams Lake.

Work in Sinmax Creek began in the mid-1990's when forest licensee Adams Lake Lumber, a division of International Forest Products, decided to take a pro-active role in the assessment and restoration of the watershed. Sinmax Creek drains approximately 195 square kilometers of forested and cultivated land into Skwaam Bay on Adams Lake in the Southern Interior of British Columbia. Officials at Fisheries and Oceans Canada (FOC), as well as local First Nations bands, were concerned about the apparent decline in coho stocks and the visible deterioration of fish habitat in the lower reaches of Sinmax Creek. The Adams Lake Band used to have a traditional coho fishery at Skwaam Bay however depleted stocks have resulted in it's elimination. Residents of the Sinmax Creek valley expressed concern over apparent increases in peak flows and stream bank erosion rates in the lower mainstem channel. Channel migration and widening in Sinmax Creek had damaged bridges, felled power poles and resulted in the loss of many hectares of productive farmland.

Working in partnership with the Adams Lake Band, Adams Lake Lumber acted as lead proponent, bringing together various stakeholders in the Sinmax Creek watershed. First Nations groups, miners, farmers, foresters, ranchers and sport fishermen all agreed to work together. Efforts were not focussed on past activities and delegation of responsibility for damage. Instead, resources from any available sector were marshalled in an attempt to restore what was once an important fisheries stream. To date, more than $450,000 for restoration have been obtained

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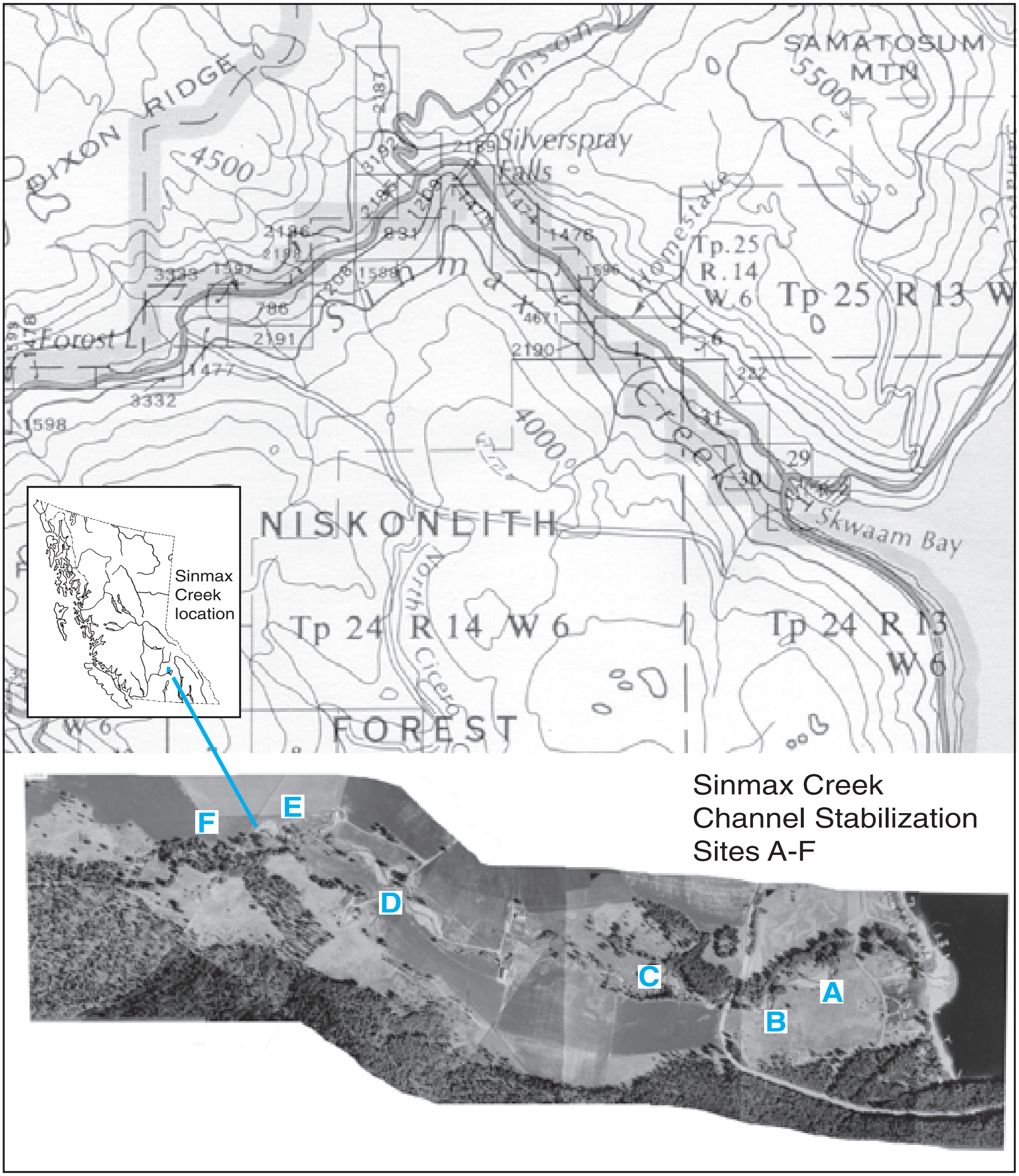

Figure 2. The maps at the top show the location of Sinmax Creek within B.C. and within the Niskonlith Forest. The aerial photo below shows Sites A -F, the locations of the restoration works.

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from several funding sources, including the Watershed Restoration Program (WRP), Habitat Restoration and Salmon Enhancement Program (HRSEP) and Fisheries Renewal BC (FsRBC).

The Works

In 1997, a Reconnaissance Channel Assessment (ReCAP) identified six high priority restoration sites along a two-kilometre stretch of lower Sinmax Creek. It was suggested that sediment generated by these six sites was causing extensive channel widening and aggradation downstream. A sizeable sediment fan (Figure 1) had formed at the mouth of Sinmax Creek in a surprisingly short period of time (less than 20 years). This sediment fan caused braiding and dewatering of the channel near the lake, affecting fish access to the creek during typically low late-summer and fall water levels. As mature, natural riparian vegetation no longer existed to control bank erosion at these six sites, it was recommended that bank protection and reparation be undertaken to control these sediment sources as soon as possible.

Over the next four years, work was carried out at these sites (Figure 2) as allowed by funding, fisheries and planting work windows and weather and stream conditions. Prescriptions were updated as work progressed and channel conditions changed. The focus gradually evolved from emergency bank stabilization to instream and off-channel fish habitat improvements. What follows is a listing of the works carried out at each site, in the order they took place. The final step at each of these sites involved the protection of riparian areas with fencing and planting with rooted stock, including both deciduous and coniferous species.

Site A

- 70m of rock and rootwad revetment was constructed on the right bank
- Three bar stabilizers, each composed of 60m of low profile rock revetment were installed on the left bank
- An off-channel fish habitat pond was excavated at the base of site where an historic channel connected with the current channel
- A debris groin was built at the entrance of the pond to protect the adjacent bank while maintaining fish access to the pond
- Random boulders were placed in the channel throughout the entire length of Site A

Site B

- An 80m long rock and rootwad revetment was constructed along the base of a 4m high cutbank (Figures 3, 4 and 5)
- Revegetation of the bank was initiated using brush layers, live staking, grass seeding, and planting with rooted stock

Figure 3. March 1999. Eroding right bank at Site B prior to construction.

Figure 4. April 1999. Site B during freshet immediately following construction. Note low velocity areas created by rootwads.

Figure 5. July 2000. Site B after two seasons' growth. Note elevated rootwads.

Feature

Site C

- A 40m rock and rootwad revetment was constructed on the right bank. Revegetation was begun using a single brush layer, followed by live staking and grass seeding
- On-site large logs and rootwads were re-arranged to improve fish habitat, maintain current channel location and reduce bank erosion. Logs were anchored using duckbill anchors and galvanized steel chains
- A debris groin was constructed to encourage narrowing of the active channel

Site D

- A 70m rock and rootwad revetment was constructed on the left bank. Revegetation of the bank was initiated using a single brush layer, followed by live staking and grass seeding
- The freshet in April 1999 caused rapid erosion of an unprotected section of the right bank. Sandbags were placed to control the erosion and guide the main flow away from the bank
- Following freshet, a revised prescription was developed for Site D that saw construction of rock spurs for left bank protection, and a channel-spanning rock (Newbury) riffle aimed at dissipating energy and ultimately reducing channel width (Newbury 1993)
- A 50m rock and rootwad revetment was built upstream of the spurs on the right bank. An off-channel fish habitat pond was excavated on the right bank immediately downstream of the rock riffle
- A second Newbury riffle was constructed upstream of first riffle, to reduce stream energy, reduce scour along bridge abutments upstream and backwater the off-channel pond in Site E
- A third Newbury riffle was constructed to dissipate energy at the downstream end of Site D, where the channel returns to its original width
- Trapped sediment behind the first rock riffle following freshet was excavated to allow sediment to be captured during the next freshet

Site E (1700m upstream of Adams Lake)

- A 70m rock and rootwad revetment was constructed on the right bank to protect a private bridge
- A second 80m rock and rootwad revetment was constructed on the left bank, upstream of the first revetment
- Revegetation of the protected banks was begun using brush layers, live staking and grass seeding
- A rock riffle was constructed in the middle of the site, between the previously constructed right and left bank revetments
- On the left bank, immediately upstream of the bridge, a third off-channel pond was constructed. A low profile berm was subsequently constructed to protect the pond/channel connection

Site F

- A 90m low profile rock revetment with large woody debris was constructed on the left bank to protect a 5m high cutbank (Figure 6) and maintain a natural 'S' bend in the creek

Figure 6. April 1999. Highly erodible left bank (4m high) at Site F during freshet. Note discoloured water along toe and active sloughing.

Feature

- Downstream on the right bank, additional rock and rootwad revetments (60m) were constructed to incorporate some existing LWD. Some rock was also added to the left bank downstream to protect a sharp bend and augment an existing debris jam near the lower end of the site
- Re-vegetation of the re-sloped bank was initiated using brush layers, live staking, grass seeding and by planting with a variety of rooted stock
- Four debris groins were built to protect a sharp left turn near the upstream end of the site while maintaining existing undercut banks (fish habitat). The debris groins were ballasted with boulder pairs and anchored to the bank using duckbill anchors
- An existing off-channel pond was enlarged and protected using anchored pieces of large woody debris.

At sites A, C, D and E un-vegetated widened sections of the creek channel were planted with live cuttings in machine-dug furrows to form brush traverses. This occurred prior to the final riparian plantings and fencing.

Successes and Failures

Fish are using restored habitat
Since the construction of off-channel habitat, fish sampling surveys have confirmed the presence of juvenile fish in all of the constructed off-channel ponds (Figure 7). Juvenile and adult fish have also been observed making use of the cover provided by both the rootwads and crevices created by oversized rock in the revetments.

Channel is downcutting downstream of Site D.
Apparent degradation (downcutting) of the channel has occurred in Sinmax Creek, downstream of Site D. Previously deposited gravels have been re-scoured, revealing cobble substrates and exposing buried woody debris. The re-emergence of this debris has improved fish habitat complexity, with no direct work being necessary at specific sites.

This apparent channel condition improvement is likely the result of reduced sediment loads in the lower channel. This was achieved by two methods:

- the control of sediment at source through bank protection and,
- the capture and removal of sediment upstream of the rock riffle in Site D.

Figure 7. July 2001. Off-channel pond constructed at Site E.

Large boulder has rolled out of rock and rootwad revetment in Site B.
In Site B, a large boulder from the rock and rootwad revetment has rolled into the stream. Poor placement of rock and scour along the toe of the revetment likely caused the failure. Downcutting has also been significant through Site B and this may have contributed to the failure. The boulder remains instream nearby and has increased local habitat function by creating an eddy beneath the cover of the rootwad. An advantage of using oversized rock is that boulders are independently stable should they roll into the stream. A danger may be that the added obstruction formed by the rock increases velocities along the toe of the revetment, causing increased scour. Revetments should be constructed with adequate thickness, so as to prevent total failure of the revetment should one or two rocks roll off the face, or the boulders should be attached to the rootwads.

Brush layers have out-performed live staking
Throughout the Sinmax Restoration project, brush layering has by far out-performed live staking. Rapid growth and good survival rates were obtained at all brush layer sites, for both spring and fall plantings (Figure 8). Hand crews experienced difficulty in achieving prescribed depths for live stakes. Machine planting ensured good planting depths (usually to water table) and allowed the use of longer, larger diameter cuttings.

Isolation and pumping of work areas effectively controlled sediment
The use of sandbags and filter cloth to isolate a worksite, and the use of pumps to remove dirty water from within the site worked well when working in close proximity to the stream (Figure 9). As long as the site was sufficiently enclosed, the pump would

Feature

Figure 8. July 2001. Site A showing brush transverses planted the preceding fall.

Figure 9. July 1999. Using sandbags and trash pump to control sediment during construction of revetment at Site F.

draw down the water surface within the enclosure. This meant that clean water would be drawn into the site and little or no sediment could flow out into the stream. Dirty water was pumped onto adjacent fields and into low spots where it was lost to infiltration.

Rock riffles must be constructed from both banks before rocks can be placed instream

When constructing rock riffles, it is important to protect both banks before proceeding with any construction in-stream. Flow follows the easiest route and will quickly scour around the end of any rock projections placed in the channel. Make sure rocks are continuous from both banks to the waters edge first, and that they are higher than the invert of the completed riffle. Once this has been done, rocks may be placed in-stream and the water surface raised without danger of the main flow moving to a new location, scouring banks and substrates in the process.

Conclusions

A key element in the long-term recovery of Sinmax Creek is the re-establishment of a functioning riparian corridor. Channel and bank stabilization serve only to buy time until riparian function is restored. If banks can be protected long enough to allow the re-establishment of mature riparian forest, it is hoped that the channel will become self-sustaining. Co-operation from local landowners is also critical.

Several innovative combinations and/or variations on existing techniques have been used as part of the Sinmax restoration project. Monitoring the success and failure of these innovations may provide valuable information for future restoration projects. While routine monitoring has been carried out, Sites A and D will be subject to detailed monitoring this fall by the Thompson Basin Fisheries Council.

It is important to note that a significant flood event has not occurred since the majority of the restoration works in Sinmax Creek have been completed. Many of the restoration works have not been tested, either by high water or extreme velocities.

Future monitoring is critical in determining the success of this project. In recognition of this fact, the Adams Lake Indian Band has initiated a program of spawner enumeration in Sinmax Creek using a fish counting fence that will monitor fall salmon runs for as long as funding allows. Eventually, it is hoped that returns of coho will allow the local native bands to re-establish their traditional fishery.

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Feature

What is soil plasticity? How does it allow you to prevent slope failures?

Hardy Bartle

Inexpensive management of surface water could have prevented the slope failures illustrated in Figure 1. The slides occurred upon a creek escarpment on the east coast of Graham Island, Queen Charlotte Forest District. Since it was harvested in the early 1990's this escarpment has produced an estimated 50 landslides, from 20 slide zones. Slope stability investigations have revealed that the escarpment is composed of medium plastic till. The till is among the most plastic (clay-like) of the soils a forestry worker can reasonably expect to encounter along coastal British Columbia. Inexpensive management of surface water would have prevented the worst of the slope failures upon the escarpment. Had the rock quarries in Figure 2 been built to be free draining, the slides in Figure 1 should not have occurred.

Preventing landslides upon such terrain is simple and cost effective. Forestry workers need to:

- know how to detect similar soils (Figures 3 to 7),
- be aware of the slope stability significance of their observations (see below), and
- take appropriate remedial actions.

Once similar soils have been detected, the measures outlined below will prevent most landslides on clay-like terrain:

- ensure ditches and rock quarries are free draining,
- conduct wet season road inspections to detect, and remedy in a timely manner any seasonal areas of water ponding or concentrated natural slope drainage,
- be generous with cross drains, culverts, and cross ditches when building or deactivating road in similar terrain,

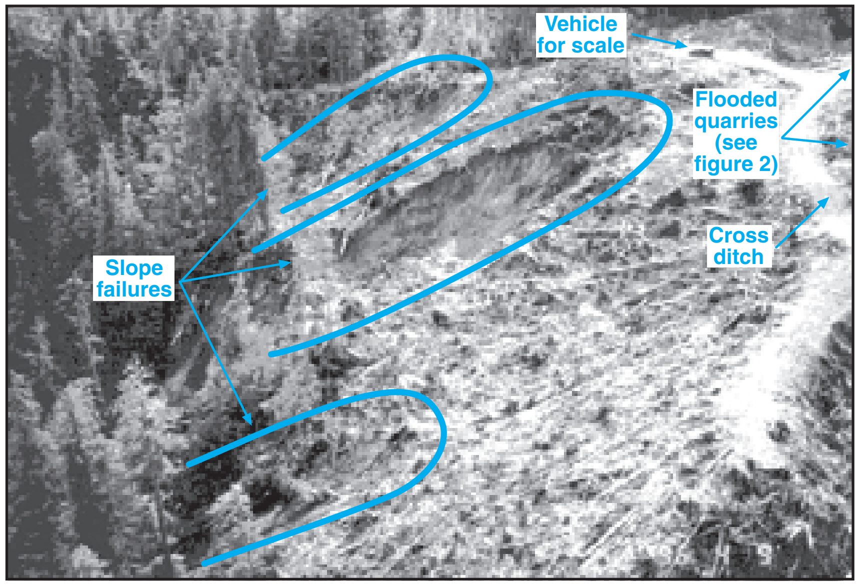

Figure 1. Large slope failures in a plastic or clay-like till. Notice the flooded quarries and cross ditch above the slide headwalls that chronically moistened and softened the clay-like soil.

Figure 2. Flooded quarry above headwall of largest slide visible in figure 1. Immediately to the right of this photograph there was a second flooded quarry (see figure 1).

Feature

- build height of land or 'ridge top' roadways to minimize road induced disturbance of natural slope drainage,
- deactivate roads upon similar terrain in a timely manner. Pay special care and attention to conservation of natural slope drainage when working in clay-like soils, and
- ensure that skidder and back spar trails do not inadvertently concentrate surface water.

Such measures are inexpensive, effective landslide mitigation techniques.

The balance of this paper elaborates upon the principles, technical issues and soil assessment procedures summarized above.

What is soil plasticity?

Soil plasticity is an engineering concept borrowed from the pottery industry about a hundred years ago (Holtz, R.D. et al. 1981). Plasticity testing enables inexpensive identification of the:

- least stable and water tolerant of the fine-grained soils and
- somewhat more stable and water tolerant, silty soils. Silty soils may be fine grained but do not exhibit clay-like behaviour.

The engineering community's interest in plasticity testing was driven by the timeless observation that some fine-grained soils lose and subsequently regain approximately 99% of their inherent shear resistance to sliding as they absorb or lose water (Carter, M. 1991). Significantly plastic soils can be transformed from a solid, to a putty-like and ultimately fluid-like state by adding water to the matrix of the soil. In the language of geotechnical engineering increasing the moisture content of a plastic soil reduces the soil's shear resistance to sliding. High plasticity soils (soils most similar to high quality pottery clay) turn into sticky mud when mixed with water. The pottery industry supplied the engineering community with a host of field and laboratory procedures to detect and rank such soils (Holtz, R.D. et al. 1981).

Early identification and extra diligent management of surface water on plastic or pottery clay-like terrain is well advised in order to ensure hillslope work does not turn to mud and consequently flow away.

Without substantial local experience it is easy to mis-identify such soils. Hence the engineering community's enthusiasm for the pottery industry's soil plasticity detection and ranking procedures.

The above principles correlate quite well with many forestry workers' field experience. Slope failures which initiate below cross ditches are a leading source of deactivation related landslides. Fine-grained soils are frequently associated with such slope failures (Prov. of B.C., 1997). Chatwin et al. (1994) have also noted that slope failures, in fine-grained soils, tend to:

- be unusually large and frequent,
- occur upon unusually gentle sideslopes, and
- be associated with cohesive soils.

The phrase 'cohesive soil' is one of many technical and practical terms a forestry worker might use to describe a significantly plastic soil. As this article is an attempt to translate technically advanced engineering details into concepts and techniques useful to every day forest workers, these terms are not used in a technically or scientifically precise manner. Although many other terms exist, for the purposes of this article I will use the terms plastic or clay-like interchangeably.

Field identification of plastic (clay-like) soils

In general, glaciomarine (salt or brackish water) or glaciolacustrine (lake) deposits are the only clay-like soils that can be readily identified by solely visual means. The failure prone, clay-like, behavior of these materials is well known to most forestry workers.

The field identification of clay-like tills is more problematic. The occurance of clay-like tills, in select portions of B.C. is well documented (Chatwin et al. 1994). A host of field indicators and laboratory testing procedures have been developed to detect soils.

The most widely used field procedures to detect clay-like soils in the forest sector are the cast and ribbon tests. Figures 3 and 4 illustrate these test procedures. The samples were prepared, in general accordance with the United States Corps of Engineers (USCE) field procedures, by:

- successively moistening and remolding the sample, and
- picking the sand and gravel large enough to interfere with the tests (about 0.5 to 1.0 mm in diameter) from the sample using one's fingers during remolding.

When remolded at an appropriate moisture content the till produces an excellent cast (Figure 3) and a strong, ~15 cm long, soil ribbon (Figure 4). Therefore, the till is a clay-like soil.

Supplemental, field orientated testing procedures referred to but not described within Appendix 1 of the Forest Road Engineering Guidebook include the USCE's Dilatancy, Toughness and Dry Strength tests (Office, Chief Engineers 1953).

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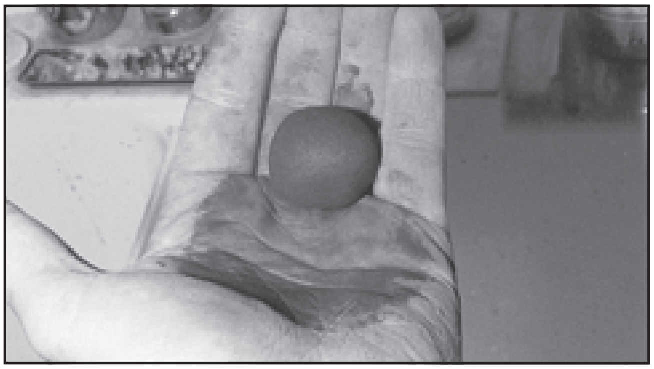

Figure 3. The clay-like tills responsed to the cast test. Tills form a strong, durable, cast which can be repeatedly throw from hand to hand without breakage. Silty or granular (non-plastic) tills may form a weak cast but readily fragment with handling.

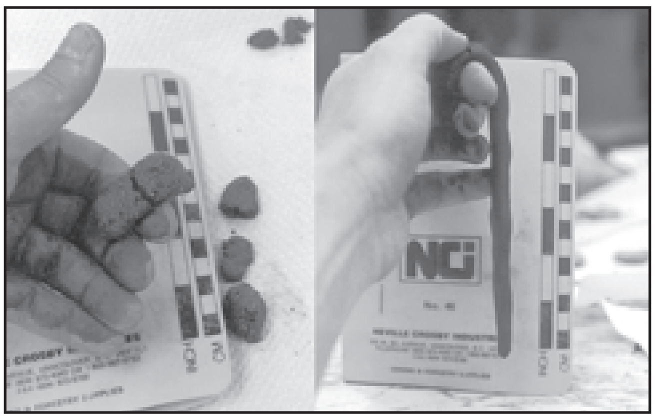

Figure 4. A silty and the clay-like till responsed to the ribbon test. The soil on the left is a silty till. Soil on the right is a medium plastic till. The test is a crude measurement of the soil's plasticity (how clay-like the soil is) at a specific moisture content. At appropriate soil moisture content the soil on the right is sufficiently clay-like to support it own weight to a length of approximately 15 cm. Silty or non-plastic soils typically form ribbons two to three cm long. Soils that produce ribbons longer than about three cm are usually somewhat to significantly plastic. The longer the soil ribbon the greater the plasticity and the more clay-like the soil.

The clay-like till extracted from the slope failure illustrated in Figure 1:

- Exhibited almost no reaction (shine or glossy coating) in response to shaking of a hand sample (Figure 5). This negative reaction to the Dilatancy Test suggests the fines fraction of the soil is clay-like rather than silty or granular.
- Could be readily worked into quite a long, tough soil worm, (Figure 6). This positive response to the toughness test suggests the till is a significantly plastic or clay-like soil. Non-plastic or granular soils can not be worked into a soil worm. Weakly plastic soils can be worked into, weak, fragile, soil worms.

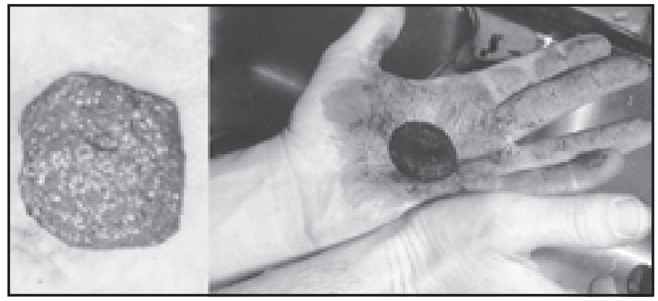

Figure 5. An example of the dilatancy (jarring or shaking) test. The dilatancy test is a crude measure of how silt-like a soil is. Granular and silty soils, as characterized and defined in engineering literature, slightly decrease in volume (compact) with shaking. As silty soils decrease in volume any resulting "excess" water flushes to the surface of the freshly compacted soil. This gives the surface of the soil sample a shiny or glossy appearance (see photo on left above). To conduct a dilatancy test a pat of moist soil is placed in one hand and struck by the opposing hand (see photograph on right above). If the soil develops a shiny or glossy "liver-like" appearance upon striking, the fines fraction of the soil is predominately granular or silt-like in nature. How readily water flushes to the surface of a soil sample is an indicator of the soil's plasticity. High plasticity or pottery clay-like soils will not develop a shiny surface despite repeated striking. Silty soils will readily develop a shiny surface. Very fine beach sand is the classic example of a soil which responds well to the Dilatancy Test; shaking loose, moist, beach sand with your foot produces a readily apparent "flush" of water towards the ground surface. Pottery clay does not develop a shiny surface upon striking.

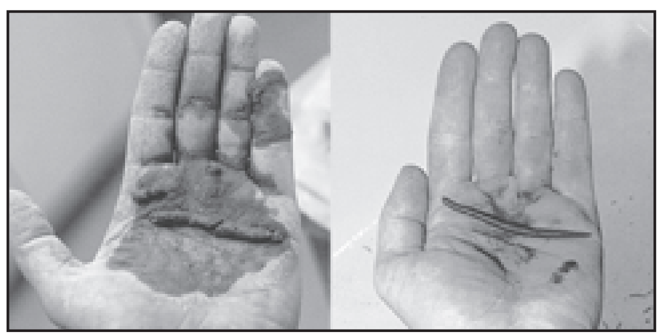

Figure 6. A silty and a clay-like tills response to the toughness test. The soil on the left is a silty or silt-like till. Soil on the right is the clay-like till collected from the sidewall of the largest slope failure shown in figure 1. At appropriate soil moisture content both soils can be rolled out to form thin (approximately 3-mm diameter) soil worms. The soil worm on the left (the silty soil) is very fragile; the soil worm on the right (the medium plastic or clay-like till) is quite durable. Clay-like soils can be rolled out into a soil worm and remolded many times before they refuse to form a coherent soil mass. Ideal granular (non-plastic) soils, such as gravel or sand can not be rolled out into a soil worm. Silty soils can generally be rolled out into weak, fragile, soil worms which quickly lose their ability to form a coherent soil mass with subsequent remolding and rolling.

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- Was quite resistant to crushing and powdering when thoroughly air-dried (Figure 7). Such a response to the Dry Strength Test suggests the till is a medium to high plasticity.

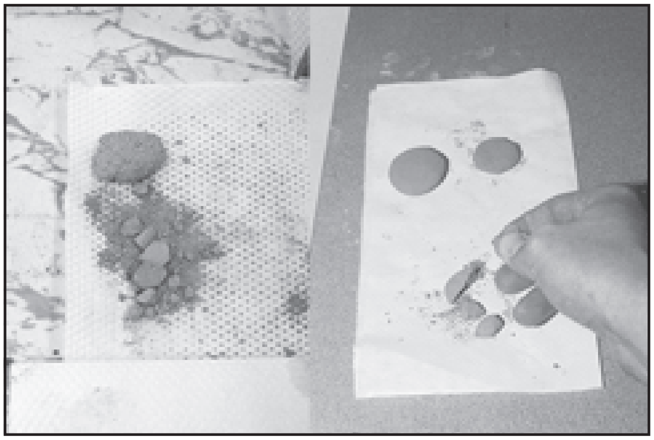

Figure 7.
A silty and the clay-like tills response to the dry strength test. The soil on the left is a silty till. The soil on the right is the medium plastic or clay-like till. The dry strength test is a crude measurement of a soil's unconfined compressive strength at the soil's lowest reasonable moisture content (thoroughly air-dried). The soil cakes on the left broke into many granular fragments under modest to substantial finger pressure; this is typical of a silty soil containing a modest quantity of a clay binder. The soil cakes on the right generally required two handed finger pressure to break; in some cases the soil cakes on the right could not be broken by crushing under intense, two handed, finger pressure. When the soil cakes on the right could be crushed they generally broke into sizeable fragments which were difficult to powder with finger pressure. Such difficult to crush and powder soil cakes are typical of a soil which possesses a moderate to high degree of soil plasticity (i.e. are significantly clay-like). Soil cakes formed from a high plasticity soil generally can not be broken or crushed under finger pressure.

What is the practical significance of soil plasticity?
Most coastal B.C. tills are granular or silty soils. However, some tills exhibit plastic or clay-like behaviour (Chatwin et al. 1994). In a laboratory setting, increasing the soil moisture content of the more plastic tills, by a modest 12 to 20% (Clague J.J. 1989) reduces the soils inherent shear resistance to sliding by ~99%. In other words adding a bit of water to significantly plastic or clay-like tills can induce slope failures on almost flat hillslopes. Chatwin et al. (1994), reports slope failures in such soils upon sideslopes as low as 5%. In reality such extreme, deep-seated, softening of clayey tills rarely occurs; unweathered clay-like tills are typically too impermeable for redirected surface water to penetrate without considerable, persistent human assistance. Forestry related slides upon clay-like terrain tend to occur within the near surface weathered till. Weathered clay-like tills typically fail long before they reach the levels of soil softening which can be created within a soils laboratory.

In contrast silty and granular soils lose very little, if any, of their inherent shear resistance to sliding by simply adding water to the soil mass. Gravel is an example of an ideal non-plastic soil. Adding water to gravel does not cause gravel to spontaneously soften or turn to mud and flow away. However, due to the flotation effects of water, all soils including gravel lose about 50% of their apparent shear resistance to sliding when fully saturated. In essence soil, like a person, has a tendency to be partially supported or float when placed in a swimming pool. It follows that terrain composed of silty or granular tills should only be able to lose a comparably modest 50% of its total (inherent plus apparent) shear resistance to sliding due to modifications of natural hillslope drainage. In contrast plastic soils, including clay-like tills, could lose 99.5% of their total shear resistance to sliding due to equally modest alterations of slope drainage. Terrain composed of clay-like soils should be more failure prone to modest changes in natural hillslope drainage than identical terrain composed of silty or granular soils.

As a consequence, cross ditches, culverts, flooded quarries or water ponded ditch lines should cause more slides on clay-like terrain than equivalent forestry practices on silty or granular terrain.

The Time Dependant Nature of Plastic Soil Behaviour
In general water softening (or hardening) of a plastic soil within a hillslope is a slow process. Turning a lump of dry pottery clay into mud, without the use of a

blender and a significant quantity of water, is a slow process. Conversely drying out a bowl full of fluidized pottery clay is best done with a great deal of patience. The installation of drain pipes into a clay-like soil can take months or years to dewater a slide mass (Chatwin et al., 1994), whereas the process of working excess surface water into a clay-like hillslope can take months or years to occur.

Abandoned, flooded, rock quarries (Figure 2) are a good method of injecting water into a clay-like hillslope. Naturally occurring tension, and sidecast road fill 'settlement', cracks have similar effects. Cross drains (culverts or cross ditches), which constantly moisten specific points upon a hillslope, can produce a similar, albeit, more localized softening effect. The water filled quarries associated with the slides in Figure 1 were probably flooded and softening the adjacent hillslope for about seven years before the largest of the slides occurred. This is in general accordance with the rules of thumb for water table fluctuations to soften, or harden, clay-like hillslopes (Chatwin et al.,1994).

Conclusions

Soil plasticity is a field indicator of slope stability. The engineering concept of soil plasticity has evolved to explain why some soils are more failure prone than others. Plastic soils exhibit clay-like behavior. Adding even modest quantities of water to such soils may cause unusually large and frequent slope failures. Forestry workers should:

- Know how to identify plastic or clay-like soils.
- Be extra diligent with their efforts to conserve natural hillslope drainage upon such terrain.

There are a number of field methods to detect such soils (see figures 3 to 7 above).

The nature of clay-like terrain creates opportunities for unusually cost effective forestry operations. Where terrain is composed of such soils there are opportunities to harvest potentially unstable terrain with fewer slope failures.

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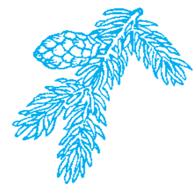

Technical Tip

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

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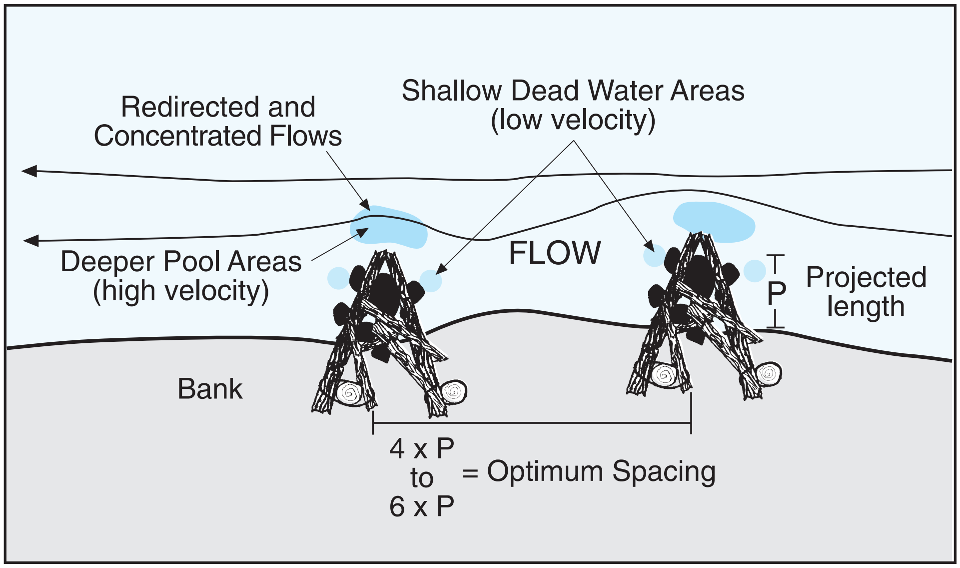

Figure 1. Large Woody Debris functioning as a spur.

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.

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.

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;

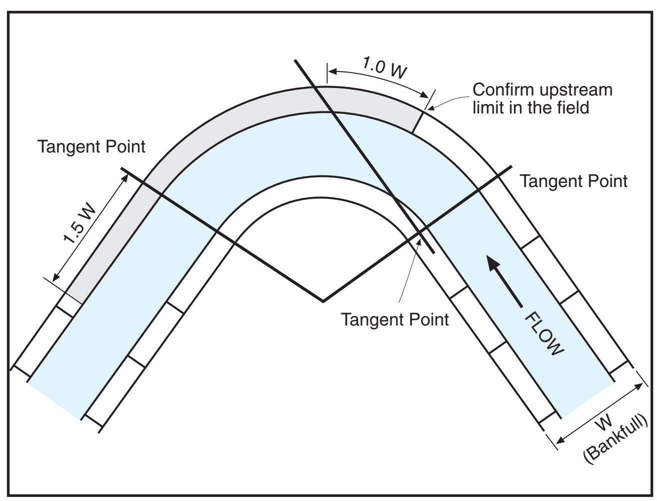

Figure 2. Extent of Protection required at a Channel Bend (U.S. Dept. of Transportation, 1991).

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- 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.

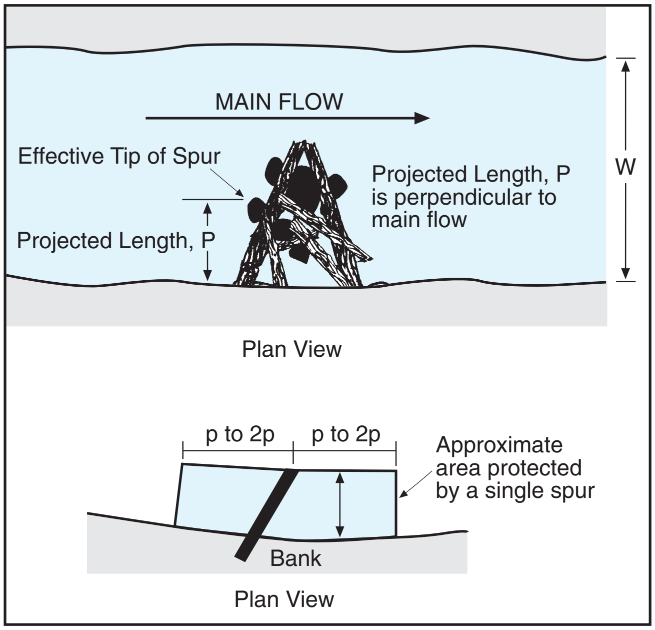

Figure 3. Projected length and spacing of spurs.

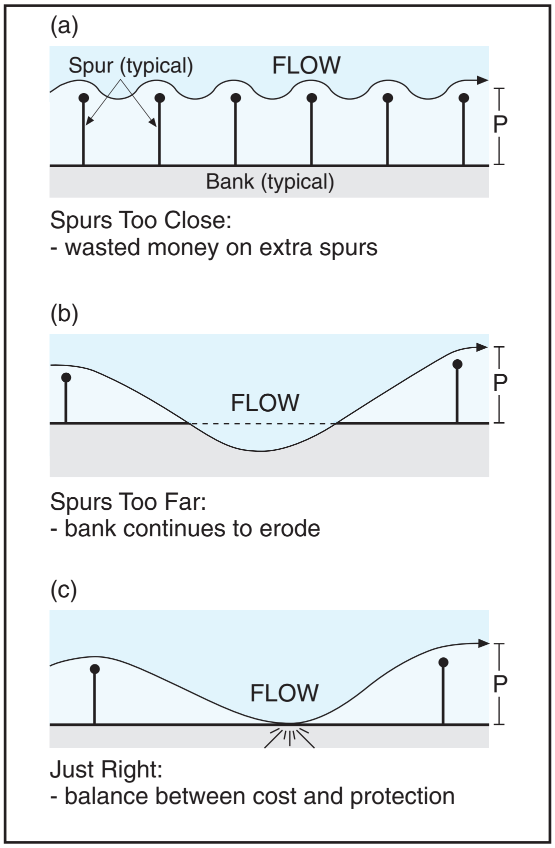

Figure 4. Examples of spur spacing.

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

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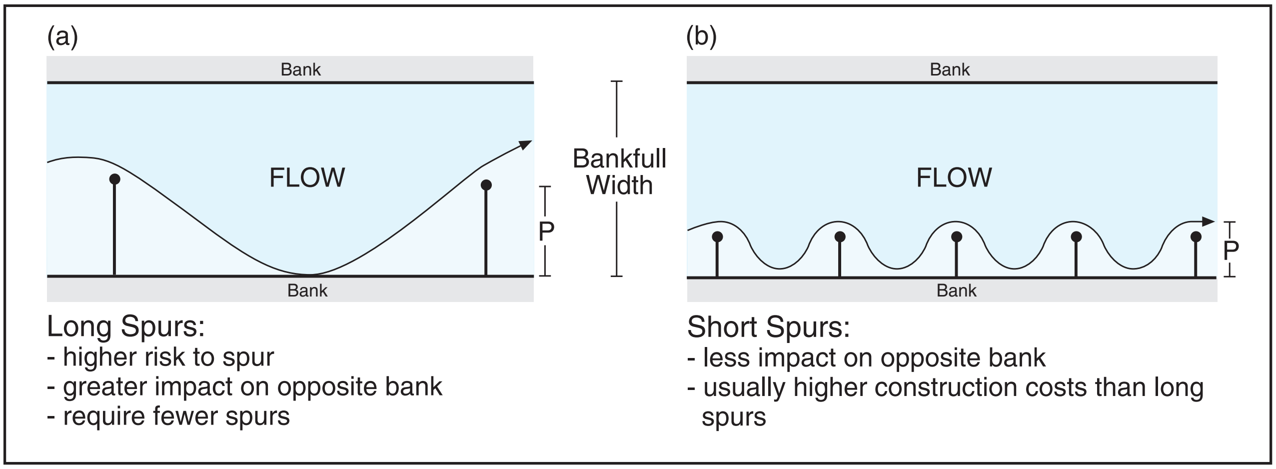

Figure 5. Examples of spur length.

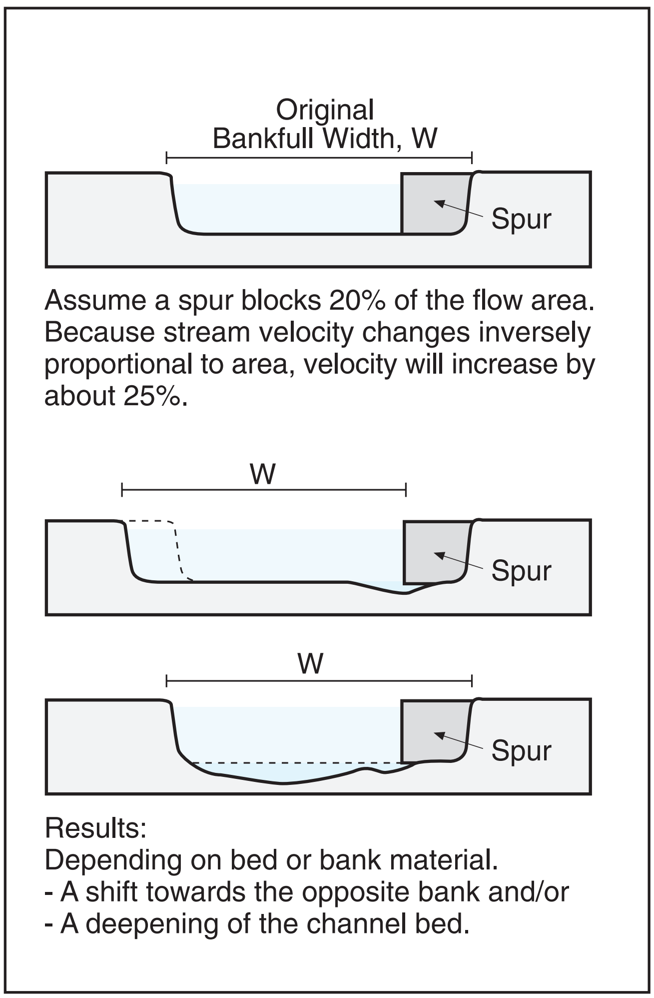

Figure 6. Effect of spurs on flow area and bankfull width.

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:

$P \leq (0.15 \text{ to } 0.20) \times W$ *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.

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(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.

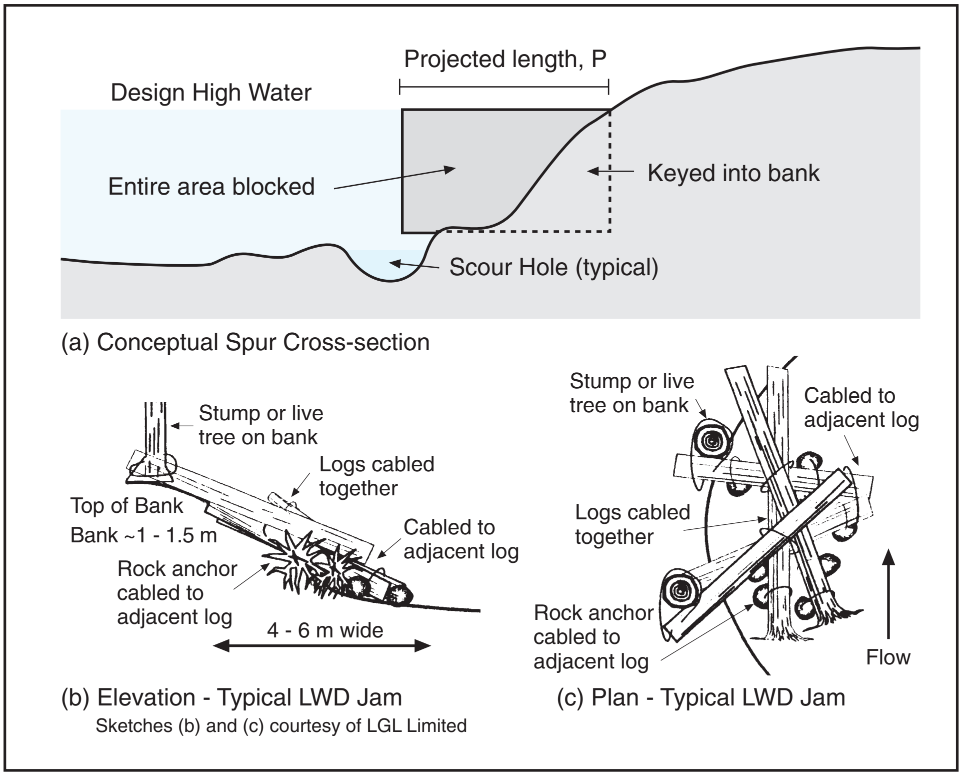

Figure 7. LWD Spur Layout.

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.

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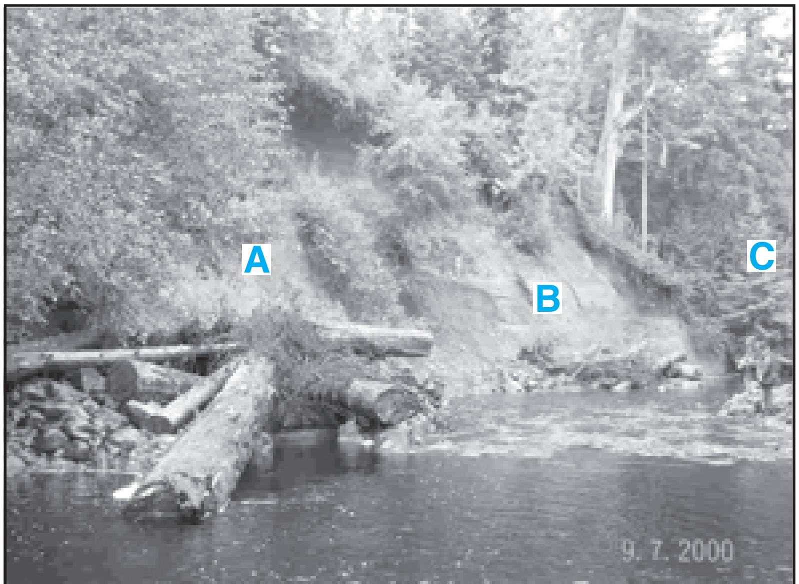
Providing fish habitat and evaluating an alternative bank protection scheme were secondary objectives.

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.



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.

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.

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

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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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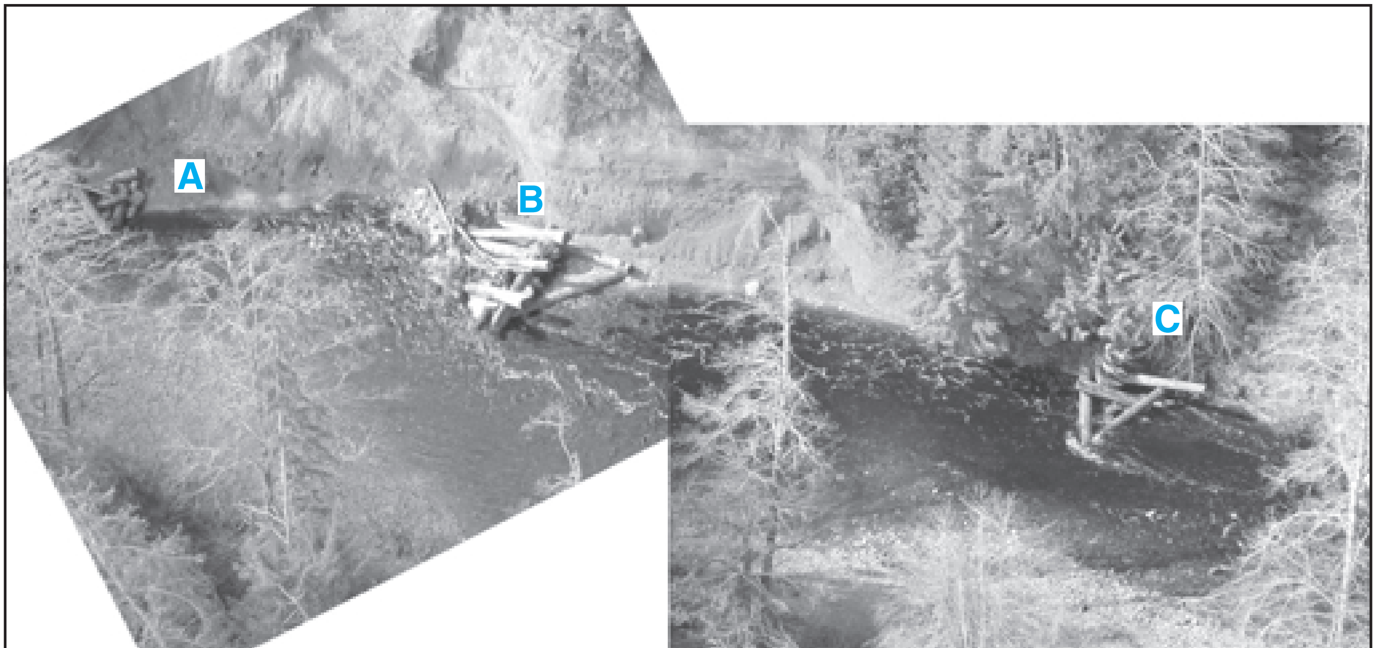

Hydraulic Comments and Observations

- 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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Update

Conferences

Coastal Forest Site Rehabilitation Conference (CFSR), Nanaimo B.C. Nov. 27 - 29, 2001. **A Decade of Accomplishments.** This conference will be located at the Port theatre. It is a two day event based around the themes of Upslope Rehabilitation (Day 1) and Riparian Rehabilitation (Day 2). The emphasis will be on the accomplishments we have seen in the WRP program during the last ten years. The conference is proceeded by a one-day series of workshops focusing on culverts, gully assessment and wind-throw management. Inquires can be directed to 604-222-9157. Registration forms are available on the website: www.fcsn.bc.ca

Canadian Conference for Fisheries Research, Vancouver, BC. Jan 3-5, 2002. The Empire Landmark Hotel. This conference includes sessions on climate change and the impacts on aquatic systems, fish biology, ecological research and productive capacity of systems. In 2003 this conference is in Ottawa; in 2004 in St. Johns. For further information, contact:_www.phys.ocean.dal.ca/ ccffr_main.html.

WATERSHED 2002, Feb 23–27,Fort Lauderdale, FL. Contact 703/684-2442, fax 703/684-2413.

Conference of Coastal Communities 2002. Port Alberni B.C. May 2 – 4, 2002. Co-hosted by the Alberni-Clayoquot Regional District and Nuu-chah-nulth Tribal Council. Call for presentation proposals and conference ideas. The goal of this conference is to network with local, first nations, federal and provincial government, and coastal community Leaders. Contact: Michael Torontow, Coastal Community Network Ph: (250) 383-1923 Fax: (250) 383-1903, coastcom@island.net, http://www.coastalcommunity.bc.ca/

IUFRO Mountain Forests: Conservation and Management. Vernon, B.C. July 29 - Aug. 2, 2002. Forest management in mountainous regions of the world is becoming increasingly challenging. For historical and ecological reasons, these regions contain extensive tracts of forests often adjacent to heavily developed and urbanized areas. The beauty and "natural" character of many such areas accentuates land use conflicts over timber and non-timber values. There has been a long history of human intervention in mountain forests but little is known about the effect increasing demands will have on mountain forest ecosystems. This international silviculture conference will explore these issues. It includes 5 days of practical forest conditions, silvicultural and ecosystem presentations and field trips. For further information contact Tom Rankin at 250-573-3092 or check the website: www.mountainforests.net

13th International Salmonid Habitat Enhancement Conference, Sept. 16-19, 2002. Westport, Co. Mayo, Ireland. Contact Don Duff, dduff@fs.fed.us. See www.cfb.ie.

Workshops

AFS Watershed Restoration Workshop 2001: Integrating Practical Approaches, Nov 13–15, Eugene, OR., Contact Richard Grost 541/496-4580, rgrost@compuserve.com. Also see www.osu.orst.edu/groups/orafs/wrw.

Websites

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Streamline

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Streamline's goals are to communicate information on practical approaches to watershed restoration including the rehabilitation of stream channels, riparian zones and hillslopes, and to act as a link between geographically separated WRP proponents and their contractors by facilitating the sharing of information and ideas between the regions of B.C.

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