

# Watershed Restoration Technical Bulletin

## Streamline

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## Analyzing the Effectiveness of Common Road Construction and Deactivation Techniques

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This study uses the finite planar slope stability model to analyze the road fill failure shown in Figure 1. The failure occurred near Pemberton B.C. within the Pacific Range of the Coastal Mountains. The model is an acceptable approximation of the local terrain, manner of road construction, and mechanics of the failure. For the failure in question, the model predicts:

- The road was stable when it was built by inexpensive sidecasting, about 20 years ago.
- It is unlikely that a mature regenerative forest growing on the road fill (i.e. natural road deactivation) would have prevented the slide.
- Inexpensive control of surface water (cross ditching) would have deferred the slide for an indefinite period. However, full pullback and sound water control would be required to assure the stability of the road fill during extreme groundwater/runoff conditions.
- Pullback, without sound water control, would have been an ineffective, potentially counterproductive, road deactivation strategy. Only full (P15) pullback would provide an immediate improvement to slope stability equivalent to sound management of surface water. P9 and P6 pullback, without adequate measures to control surface water, would have somewhat increased the slope's immediate probability of failure. See Figure 6 of this article for illustrations of P15, P9 and P6 pullback; the "P" system of prescribing pullback is defined in Advanced Road Deactivation Course Manual, 1997, drawing number 012013-00-02, TYPICAL SIDECAST PULLBACK.
- P9 pullback and sound water control measures substantially improved the stability of the road fill.
- Full (P15) pullback and sound water control provided the best, immediate, assurance of slope stability.
- The long-term effects of P6 or P9 pullback and reforestation are somewhat unclear. However, the greater the quantity of pullback (the thinner the

residual sidecast road fill) the better are the prospects for long-term slope stability. Tree roots must penetrate to at least the original forest floor or the road fill will be primed for failure.

The above predictions, made from the analysis of a single road fill failure, must be viewed with caution. Site-specific conditions will almost always take precedence over idealized analysis of an individual, historical, road fill failure. As discussed below had the failure occurred upon a side slope steeper than 32 degrees or a hillslope composed of less favorable (lower friction) soils analysis would have indicated pullback was a more beneficial road deactivation technique.

*continued*

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Figure 1. A southern coastal mainland road fill failure showing the workers for scale, the high cut tree stump supporting residual sidecast road fill, and the almost planar nature of the failure surface. The dashed white line highlights a layer of black, decomposed organics within the sidewall of the slide.

## The Fundamentals of Slope Stability Analysis:

Slope stability analysis expresses the stability of a slope in terms of the slope's factor of safety (F) (Chatwin *et al.* 1994, p. 6).

$$F = \frac{\text{the sum of the forces within a slope resisting failure}}{\text{the sum of forces within the slope promoting failure}}$$

In theory, a slope will only fail when its factor of safety is less than 1.0 (the forces resisting failure are less than the forces driving failure). In reality, however, the input parameters for slope stability analysis are uncertain; it is prudent to say that a slope with a factor of safety between 1.0 and 1.3 "may be stable" rather than to make strong (and potentially incorrect) statements that the slope will, or will not, fail.

The five factors that determine the driving and resisting forces in a slope are:

- **The frictional resistance of the slope material(s) to sliding.** Geotechnical engineers refer to this as a material's angle of internal friction ( $\phi$ ). Forestry workers tend to use the term angle of repose when discussing a material's resistance to sliding. High friction is good for slope stability. Granitic shot rock and unweathered, well graded, till are examples of high friction forestry materials ( $\sim 45^\circ$ ). Decomposed, "greasy", organics are an example of a low friction forest material ( $\sim 12$  to  $27^\circ$ ). Clay rich soils (tills containing  $\sim >16\%$  clay, glaciolacustrine and most marine clays) are examples of low to moderate friction materials ( $\sim 18$  to  $38^\circ$  depending upon the stress history, mineralogy and moisture content of the soil).

- **The slope angle of the potential failure surface ( $\psi$ ).** In general, the steeper the prospective failure surface, the less stable a slope will be.
- **The weight of material above the potential failure surface.** The weight of material above a potential failure surface can influence slope stability in several ways. If the slope angle of a potential failure surface ( $\psi$ ) is:
  - less than the soil's angle of internal friction ( $\phi$ ), then more weight on the failure surface will increase slope stability;
  - the same as the soil's angle of internal friction ( $\phi$ ), then the weight of material on the failure surface makes little or no difference to slope stability;
  - greater than the soil's angle of internal friction ( $\phi$ ), then extra weight on the failure surface will reduce slope stability.

To illustrate the above principles, place a coffee cup on the face of a hard cover book. Incline the book slightly; to initiate "failure" of the empty coffee cup (causing the coffee cup to slide down the face of the book) requires a significant push of your hand. Place a significant weight in the coffee cup (an office stapler works well) and repeat the experiment. The loaded coffee cup's greater weight requires even more of a push to initiate failure than the lighter, empty cup. In the language of geotechnical engineering, when ( $\psi$ ) (the angle of the prospective failure surface- the book's cover) is less than ( $\phi$ ) (the angle of internal friction for the coffee cup on the book cover), then adding weight to the coffee cup (our surrogate road fill) will improve slope stability.

Now gradually increase the tilt (angle of inclination) of the book; at a critical slope angle the coffee cup, whether empty or full, will slide down the book cover at your slightest touch. In engineering terms, when ( $\psi$ ) (the face angle of the book cover) is equal to ( $\phi$ ) (the angle of internal friction for the coffee cup on the book cover) the stability of the road fill (the coffee cup) does not depend on the weight of the prospective failure mass (the loading, or weight, of the coffee cup).

Next, increase the tilt of the book cover a little bit more; whenever the face angle of the book is steeper than the critical slope angle determined in the previous experiment, you must use your fingers to hold the coffee cup in place. Holding a coffee cup, loaded with a stapler, requires more stabilizing force from your

# Feature

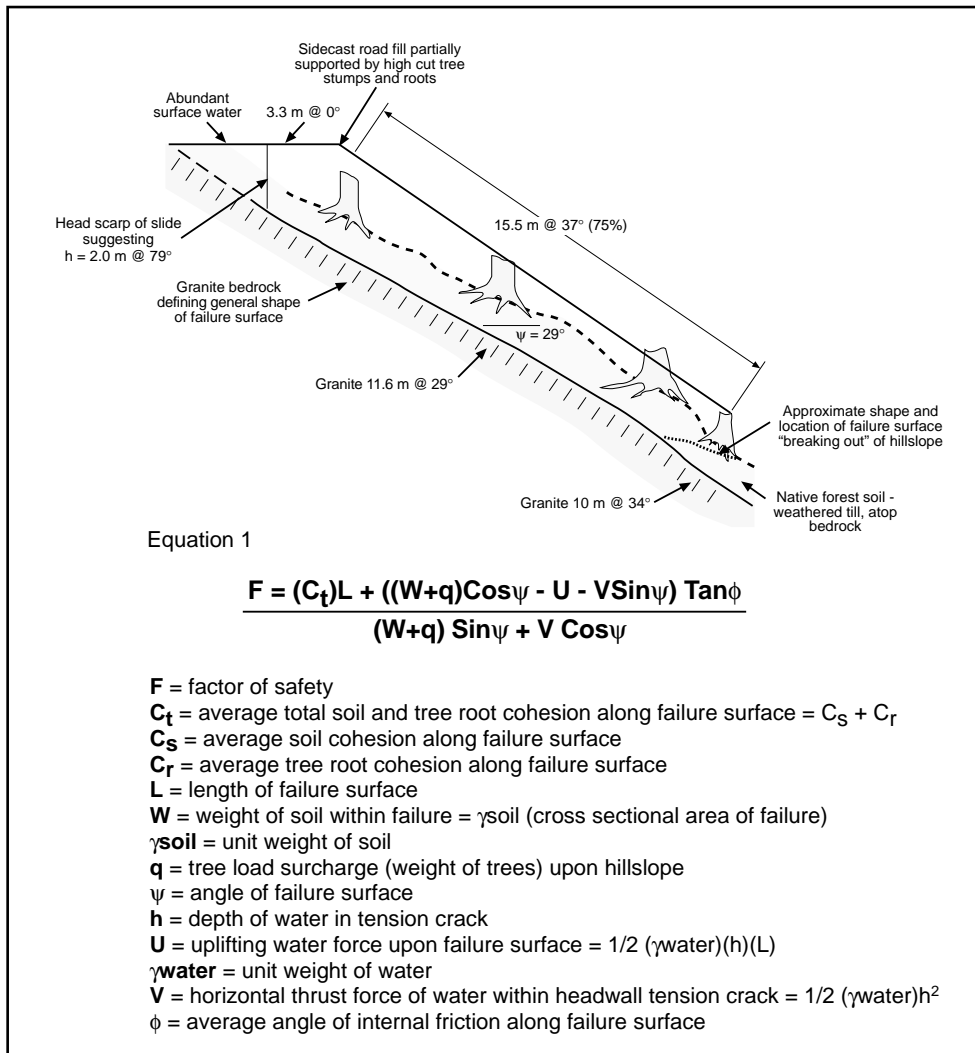


Figure 2. The Finite Planar Slope Stability Model.

fingers than holding the same, empty, coffee cup on the slope. In engineering terms, whenever (ψ) (the angle of the prospective failure surface- the book cover) is greater than (φ) adding weight to the coffee cup decreases slope stability. That is, you must apply more force from your fingers to hold the loaded versus the unloaded coffee cup on the book cover.

- The cohesion or “stickiness” of the material(s) in a slope. In forestry, there are two common sources of “stickiness” in a hillslope: soil and tree root cohesion.
  - Hardpan (unweathered till) is an excellent example of a forest material with high soil cohesion; hardpan is difficult to dig until the “stickiness” (cohesion) between adjacent chunks of soil is broken; once broken, hardpan is easy to dig.
  - The effects of tree roots upon shallow slope stability are complex; for simplicity, trees roots

are usually modeled as a thin (roughly one metre deep) veneer of “extra-sticky” soil.

- Total cohesion is the available soil cohesion plus the available tree root cohesion. High cohesion is good for slope stability. On steep hillslopes (slopes steeper than (φ) for the local soil) cohesion stabilizes the hillslope in much the same manner as peanut butter could be used to “glue” a coffee cup to the cover of a steeply inclined book.
- The magnitude and direction of water pressures in a slope. The role of water in slope stability merits special attention.

Water pressures less than atmospheric pressure are good for slope stability; a modest amount of water in soil causes “apparent” cohesion between soil particles, due to the capillary effects of water. Many soils are more resistant to sliding when slightly moist, rather than when completely dry. For example, moist sand makes better sand castles than dry

ple,

sand; a few drops of water around the base of a cup can “glue” it to a book cover.

Water pressures greater than atmospheric pressure push soil particles apart, decreasing slope stability. For example, turning on a garden hose buried in a sand castle will induce failure of previously stable sand castle walls; a garden hose can easily blow a coffee cup from a book cover. The higher the water pressures, the less stable the slope.

The direction and rate of water movement (the water pressure seepage vector) in a hillslope can have a profound effect on slope stability; the jet of water from a garden hose is far more effective at inducing failure of a sand castle’s walls than the same quantity (and driving pressure) of water dripping from a soaker hose. Because water has such negative effects on slope stability:

# Feature

- Failures are almost always triggered by intense rainfall, snowmelt, or concentrated ditch water.
- Failures frequently occur in areas of concentrated water flow such as gully headwalls, sidewalls, stream escarpments, zones of seepage-prone (fractured) bedrock, cross ditch, and culvert outlets.
- Failure surfaces are often located along the top of a “water trap” (an impermeable soil layer) such as hardpan (unweathered till), or bedrock.

All of the above generalities have to be analyzed and molded into a host of slope stability equations and models. There are dozens, possibly hundreds, of slope stability models. Each model is designed to approximate a specific style of slope failure. In general, the most complex, site specific models, supported by extensive field assessments and costly laboratory testing, are the best approximations of specific slope failures. Until and unless researchers focus such advanced analytical techniques on forestry road fills, simpler models, such as the one used in this paper, will have to suffice.

## Rationale and Limitations of the Two Dimensional Finite Planar Slope Stability Model

This model, adapted for use upon a typical sidecast road fill, is illustrated in Figure 2, equation 1; at the base of Figure 2 is the equation for calculating the factor of safety for a typical sidecast road fill. The model requires the prospective failure surface to be a straight line, but readily accommodates convoluted ground (fill slope) surfaces and tension cracking. The model is a useful approximation of road fill failures because:

- It is widely observed that road fill failures approximate planar failures (Gray and Leiser, 1982. pp 33-34).
- The core equations for numerical modeling of finite planar slope failures are well established (Hoek and Bray, 1981. pp 7.1-7.3) and can be readily modified to incorporate tree load surcharging, tree root cohesion and water pressures, which the US Forest Service (Hammond et al, 1992. pp 53-74 and 82-86) suggests are appropriate for coastal BC (Figure 2).
- Forested hillslopes are frequently primed to produce planar failures. Most tree roots penetrate about a metre into a hillslope before spreading out laterally along some manner of hardpan; and, eventually all trees die. Over hundreds, in some cases thousands, of years, thin layers of decomposed tree roots accumulate on specific layers of hardpan; it is reasonably common to find slickensided (sheared) plates of “greasy” (low friction) decomposed organics in the initiation zone of recent landslides (Baumann, 1997. p. 3).



Figure 3. Photograph of the slide's initiation zone. Note the planar nature of failure surface, high cut tree stumps supporting road fill and abundance of water flowing over the headwall of the slide.

- When buried in sidecast road fill, tree stumps approximate soil piles. Piles buttress the soil above them; soil will arch between closely spaced soil piles and tree stumps (Gray and Leiser, 1982. pp 55 and 59). The soil buttressing and arch effects are visible behind the tree stumps in Figures 1 and 3. Tree stumps transmit any sliding forces in the fill slope to the base of their root wad, where pockets of low friction, decomposed, tree roots are mostly likely to exist.
- Sidecast road fills held together by “sill” logs and tree stumps approximate low face angle retaining walls. There are four “classic” stability tests for retaining walls. All retaining walls should be analyzed for: rotational stability where the wall topples over due to the weight of soil and water it is attempting to support, bearing capacity failure (crushing the soils at the toe of the retaining wall), global stability (deep-seated slope failure potential) and rankine sliding (a style of planar failure). Because sidecast road fills are generally built with modest face angles, the likelihood of rotational and bearing capacity failure is very low. Hardpan or bedrock generally prevents deep-seated global failure of road fill. In effect, the nature of forest soils (low friction organics ~ one metre below the original forest floor), together with hardpan or bedrock concentrating groundwater near the zone of maximum root penetration and the buttressing effects of tree stumps, force road fills to fail in a form of rankine sliding. The planar slope stability model is a good approximation of rankine sliding.
- The finite planar model is simple yet robust; the factor of safety generated by the model is a respectable approximation of the more complex “method of slices”, rankine or translational slip models which a slope stability purist might apply to a road fill failure.

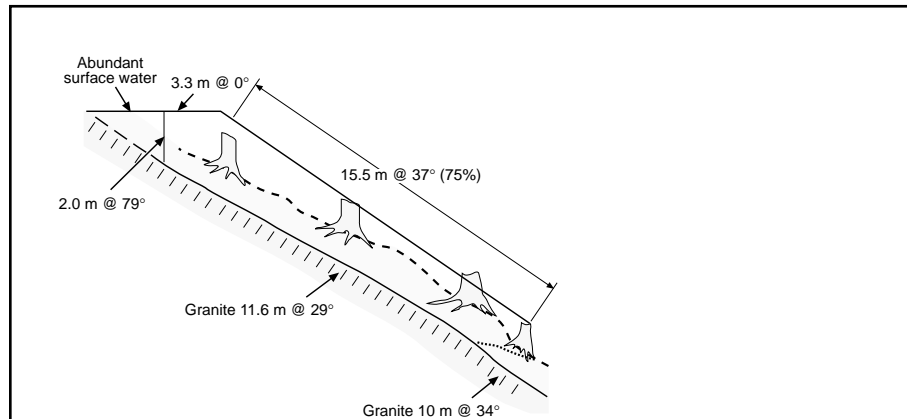
The model is especially well suited to the slope failure illustrated in Figure 1. The geometry of the site, woody debris in the fill slope, well defined headwall of the slide and shallow soil depth to the smooth, massive, underlying bedrock, make this slide an almost ideal example of a planar slope failure.

The analysis of very old (or poorly built) sidecast road fills is more complex. The decomposition of logs and stumps in very old road fills invalidates several of the model's assumptions; without the support of woody debris, steeper failure surfaces could develop in the unreinforced road fill. In addition the long-term effects of soil erosion upon the shape and weight of sidecast road fill are difficult to predict; a hundred years of soil erosion could easily reduce the weight and depth of a modern fill slope. In general, it is ill advised to project the long-term slope stability of a road fill, from the back analysis of a recent slope failure.

### An Illustrative Example

The site illustrated in Figures 1 and 3 was surveyed within 72 hours of failure. Figure 4 is a best estimate, cross-sectional reconstruction of the road fill moments before it slid from the hillslope. The failure was triggered by an abundance of surface water entering open tension cracks along the shoulder of the approximately 20-year-old, abandoned roadway. The road was built by sidecasting on an open, steep, uniform slope composed of a thin veneer of weathered, silty sand, non plastic (~<10% silt and clay) till upon massive, smooth, granitic bedrock. The weathered till and top of the bedrock were laced with thin, discontinuous, seams of decomposed organics.

The engineering characteristics of such heterogeneous (mixed) soils profiles, especially the organic lenses, is a complex function of soil moisture content, the void ratio of the soil, stress history, total magnitude and rate of pre-failure slope deformation and layering of the materials in the



### Road Fill Failed @ 20 yrs post harvest

- $\phi = 32^\circ$  on failure surface by back analysis
- $C_t = 4.4$  kPa on failure surface by back analysis
- $L = 17.7$  m length of failure surface by geometry
- $\gamma_{\text{soil dry}} = 16.0$  kN/m<sup>3</sup> by Lisa figure 5.11
- $\gamma_{\text{soil wet}} = 20.0$  kN/m<sup>3</sup> by Lisa figure 5.11
- $\psi = 29^\circ$  angle of failure surface by geometry
- $h = 2.0$  m by field measurement
- $V = 1/2 \gamma_{\text{water}} h^2 = 1/2(9.8 \text{ kN/m}^3)(2.0 \text{ m})^2 = 19.6$  kN/m
- $U = 1/2 \gamma_{\text{water}} hL = 1/2(9.8 \text{ kN/m}^3)(2.0 \text{ m})(17.7 \text{ m}) = 173$  kN/m
- $A =$  cross sectional area of failure =  $44 \text{ m}^2$
- $W_{\text{wet}} = A(\gamma_{\text{soil wet}}) = 44 \text{ m}^2(20.0 \text{ kN/m}^3) = 880$  kN/m
- $W_{\text{dry}} = A(\gamma_{\text{soil dry}}) = 44 \text{ m}^2(16.0 \text{ kN/m}^3) = 704$  kN/m
- $q = 0$  kPa

Sample calculation- Therefore, equation 1 at the moment of failure becomes:

$$F = \frac{(C_t)L + ((W+q)\cos\psi - U - V\sin\psi) \tan\phi}{(W+q) \sin\psi + V \cos\psi}$$

$$= \frac{(4.4 \text{ kPa})(17.7 \text{ m}) + [(880 \text{ kN/m} + 0) \cos 29^\circ - 173 \text{ kN/m} - (19.6 \text{ kN/m}) \sin 29^\circ] \tan 32^\circ}{(880 \text{ kN/m} + 0) \sin 29^\circ + 19.6 \text{ kN/m} \cos 29^\circ}$$

$$= \frac{77.9 \text{ kN/m} + [880 \text{ kN/m} \cos 29^\circ - 173 \text{ kN/m} - (19.6 \text{ kN/m}) \sin 29^\circ] \tan 32^\circ}{880 \text{ kN/m} \sin 29^\circ + 19.6 \text{ kN/m} \cos 29^\circ}$$

$$= \frac{77.9 \text{ kN/m} + [770 \text{ kN/m} - 173 \text{ kN/m} - 9.5 \text{ kN/m}] 0.625}{426.8 \text{ kN/m} + 17.2 \text{ kN/m}}$$

$$= \frac{77.9 \text{ kN/m} + [587.5 \text{ kN/m}] 0.625}{444 \text{ kN/m}}$$

$$= \frac{77.9 \text{ kN/m} + 367.1 \text{ kN/m}}{444 \text{ kN/m}} = \frac{445 \text{ kN/m}}{444 \text{ kN/m}} = 1.002$$

Figure 4. Back analysis of the failure illustrated in the two photographs.

hillslope. It is well established that other soil types, such as a weathered high fines (plastic) till, may exhibit inferior engineering characteristics. Conversely an unweathered, slightly cemented, low fines, till may exhibit substantially superior engineering characteristics.

# Feature

A comprehensive discussion of the soil mechanics and groundwater hydrology for all conceivable soil types is beyond the scope of this paper. For further information, interested readers are directed to reference books such as: An Introduction to Geotechnical Engineering by R.D. Holtz and W.D. Kovacs 1981 and Hammond *et al.* 1992.

From the abundance of water at the site (see Figures 1 and 3) it is possible to infer that the tension cracks at the headwall of the slide were completely full of water at the moment of failure. Using iterative calculations, the average angle of internal friction and average total cohesion along the failure surface at the moment of failure can be estimated. The text portion of Figure 4 summarizes the slope stability input parameters derived from iterative back analysis of the failure, engineering judgement, and experience.

## The slope stability “life cycle” of the road fill failure

Using the data in Figure 4, the factor of safety for the road fill can be calculated using the infinite (not presented in this paper) and finite slope stability models (Figure 2). Specifically, this is accomplished by adding:  $q_0$  (tree load surcharge) prior to harvesting, or

upon full reforestation, for the slope as estimated from the LISA manual (Hammond *et al.*, 1992) table 5.1 as 2.0 kPa.  $C_r$  (average tree root cohesion across the failure surface) was estimated from the LISA manual figures 5.6 and 5.7. Average root cohesion, anchored into the underlying granite, was estimated to be 2.5 kPa immediately before and after road construction. Root cohesion across the “breakout” portion of the fully reforested road fill was estimated to be 10 kPa (assuming a maximum rooting depth of roughly one metre). The slope’s factor of safety was calculated for fully saturated and dry conditions. Given the abundance of surface water runoff and climate of the site, such extreme groundwater conditions were deemed a reasonable approximation of field conditions.

Figure 5 is a plot of the slope’s factor of safety versus various slope treatments which loosely correspond to the age of the sidecast road fill. Along the y axis of the graph is the factor of safety ( $F$ ); plotted on the x axis is slope treatment. The horizontal lines at  $F = 1.0$  and  $F = 1.3$  illustrate the range of uncertain slope stability due to foreseeable errors in the back analysis of slope stability input parameters and site geometry. Open

squares on the plot are the calculated dry (completely unsaturated) factor of safety for the slope treatment described along the bottom of the graph. Black squares are the calculated wet (fully saturated) factor of safety ( $F$ ) for each slope treatment. The dashed lines between open and black squares illustrate the relative change in  $F$  between the various slope treatments. The analysis of the fully regenerated road fill is speculative due to the potential for long term erosion of sidecast road fill and decomposition of woody debris in the fill slope. The key conclusions from Figure 5 are:

- The road fill was quite stable when built; however, stability of the road fill decreased with decay of the supporting tree roots. The abundance of water flowing into open tension cracks eventually floated the road fill from the hillslope.
- The failure would not have occurred had there been sound water control measures at the site.
- If the road fill had not failed it would have remained potentially unstable, in severe groundwater/runoff conditions, into the indefinite future. Even fully reforested, it is possible that some future storm or snowmelt event could have induced failure of the road fill. Because  $(\phi) > (\psi)$ , the weight of the regenerative forest on the road fill would have modestly improved the stability of the road fill. However, reforestation would not have significantly

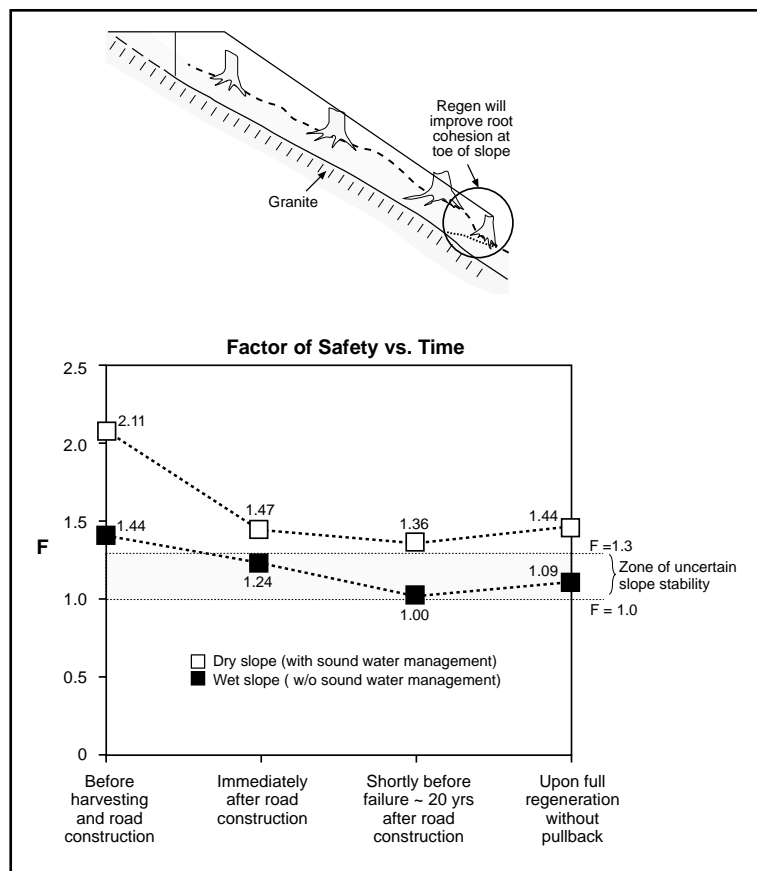


Figure 5. The slope stability “life cycle” of the road fill.

# Feature

improved stability of the road fill because few of the regenerative tree roots would have grown across the most probable failure surface in the fill slope (the zone of historical maximum rooting depth).

## Stabilization options:

Figure 6 illustrates the four most practical stabilization options for the site. The slope's factor of safety (**F**) response to each of the stabilization options was calculated by making appropriate modifications to the weight (cross-sectional area) of the prospective road fill failure and water pressures in the fill slope.

## The immediate slope stability effects of road deactivation:

Figure 7 is a factor of safety plot (**F**) for each of the stabilization options illustrated in Figure 6. The key conclusions from Figure 7 are:

- Water control accounts for most of the slope stability improvement in all of the analyzed stabilization options.
- P6 and P9 pullback decrease the stability of the road fill in fully saturated (wet) conditions. P6 and P9 decrease the stability of the road fill by reducing the weight of the potential failure mass; since  $(\phi) > (\psi)$  removing weight on the potential failure surface decreases slope stability. Therefore, directing surface water on a partially pulled back, previously dry sidecast road fill is a calculated risk. As cross ditches are the leading cause of "road deactivation related landslides (Advanced Road Deactivation Course Manual, 1997. p 11)," there is an excellent correlation between the conclusions derived from slope stability analysis and field observations of actual road deactivation works.
- None of the analyzed stabilization options immediately assured the stability of the road fill. Poor control of surface water could easily defeat P6 and P9 pullback and might even defeat full (P15) pullback. (Please note that water-induced failure of the P15 pulled back road fill would require there to be significant errors in the back calculated slope stability parameters of the road fill.) Only sound water control and P15 gave substantial, immediate, assurance of stabilizing the residual road fill.
- P15 contributes more to slope stability by water control (see the equations for water-induced forces V and U in Figures 2 and 4) than by removal of excessive weight of sidecast road fill. Pullback reduces the water pressures in the fill slope by reducing the maximum possible depth of a tension crack (and therefore the water column and pressures) in the fill slope.

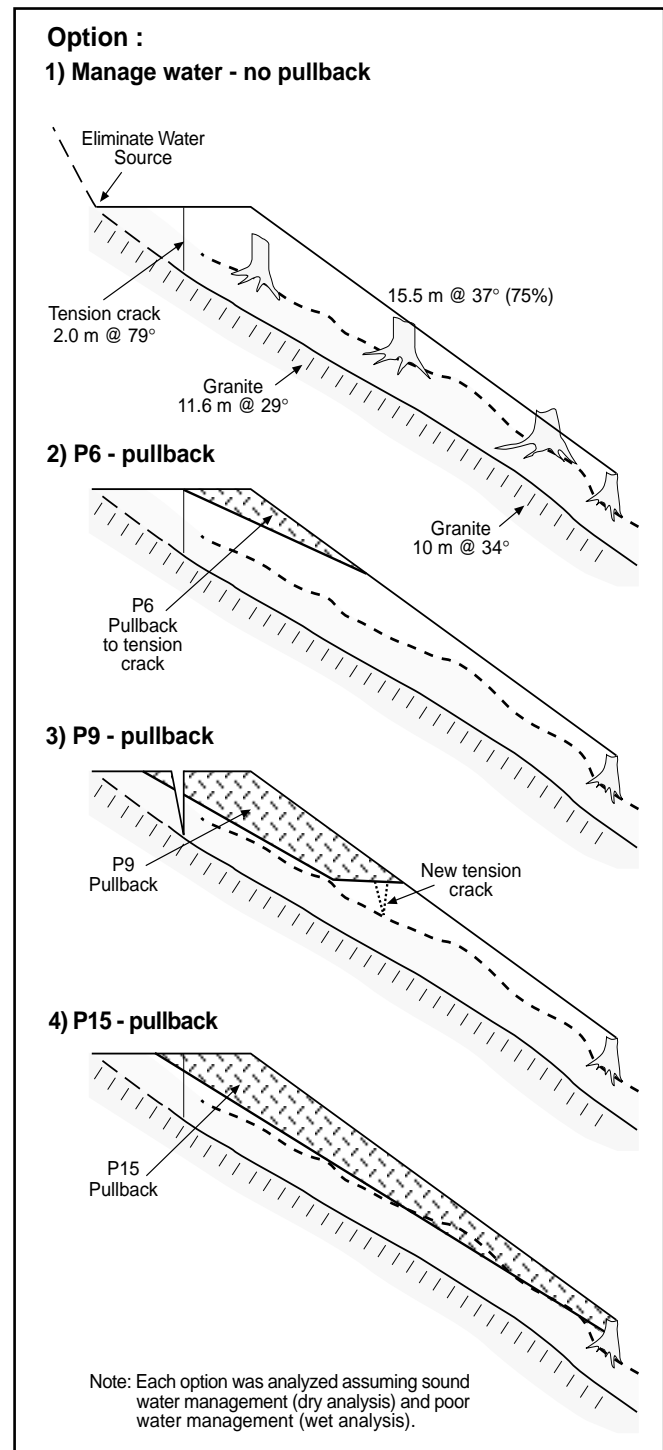


Figure 6. Stabilization Options - the most probable deactivation treatments.

## The long term effects of road deactivation:

The long term effects of road deactivation work and reforestation are difficult to assess from the back analysis of a modern road fill failure. However, a few specific

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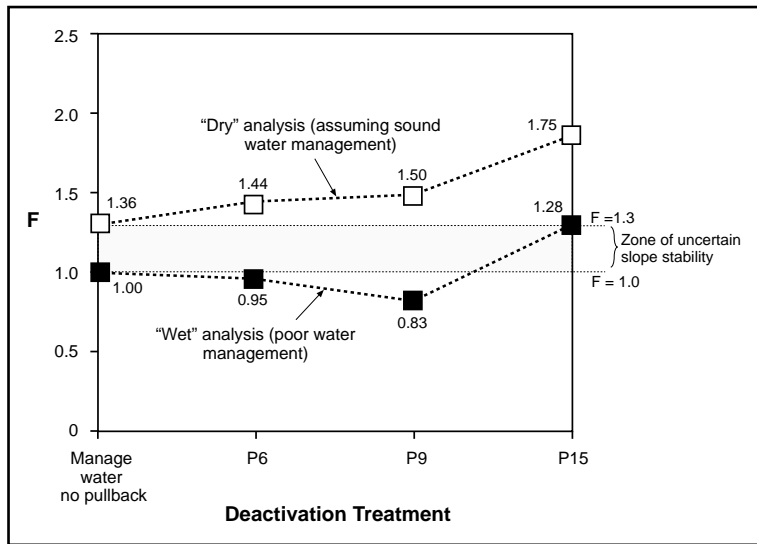


Figure 7. The Road Fill's Immediate Factor of Safety Response to Deactivation.

observations on the long-term effects of road deactivation and reforestation are possible:

- The stability of sidecast road fills generally decreases with time due to the decomposition of woody debris within the fill slope. The resulting loss of shear strength within the fill slope may be seriously compounded, or generously offset, by natural deactivation/deterioration of a site's water control measures.
- It is hard to go wrong with sound control of surface water. Control of surface water is an inexpensive and effective investment to improve the stability of sidecast road fill.
- The less residual fill on a hillslope, the better. Tree roots will not significantly improve the stability of the residual road fill unless they can reach beneath the prospective failure surface(s) in the fill slope.
- Reforestation will add tree load surcharge to the residual road fill. Whenever  $(\phi) > (\psi)$  the weight of the regenerative forest on the residual (or undisturbed) road fill will very modestly improve slope stability. Conversely, wherever  $(\phi) < (\psi)$ , reforestation will very modestly reduce the stability of a road fill.

## Conclusion

The general principles of slope stability analysis are always more robust than the details of a specific slope stability analysis. The key principals from the above analysis are: sidecast road fills can be remarkably stable when built, but quickly become potentially unstable with decay of the supporting tree roots and woody debris; and water control is the most effective

(and least costly) short-term road deactivation technique. However, long-term stability of a deep sidecast fill slope can only be assured by extensive pullback, sound water management, together with reforestation.

Slope stability analysis is a tool to explore the landslide hazard reduction potential of road deactivation work. Selecting the "right" road deactivation prescription requires broader based knowledge of landslide consequences and, ultimately, acceptable risk.

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# A Discussion of Fish Passage at Culverts in the Cariboo Region, British Columbia

Michael Parker

Issues related to fish passage at culvert crossings have long been an underlying concern of fisheries managers in the Cariboo Region. Some documentation of crossing problems has occurred through fish inventories, but obvious sites are usually known to field personnel from the Ministry of Environment, Lands and Parks, the Department of Fisheries and Oceans, and community groups. The magnitude of the problem of culvert barriers, however, has not been fully appreciated.

With the development of the Watershed Restoration Program (WRP), an informal evaluation of culvert crossings was occasionally conducted during a field assessment. This would occur if the road crossing happened to be within the portion of stream reach from which data was being collected during a Fish Habitat Assessment Procedure (FHAP) - Level 1 Field Assessment (Johnston and Slaney 1996). In such cases, however, there was no formal evaluation of the culvert, or specific data collection required, to evaluate passage. Nor would any culverts above or below the site necessarily be assessed, and certainly not all culverts in the watershed were assessed. Similarly, the Sediment Source Surveys (Moore, G. D. 1994) funded by FRBC do not assess fish passage, although designed to evaluate every culvert crossing in a watershed for sediment concerns.

Since 1997, a number of Fish Passage Culvert Inspections (FPCI) (Parker 1998) have been conducted around the Cariboo Region under the auspices of the Forest Renewal BC via the Watershed Restoration Program. FPCI draft procedures, now available on the web at <http://www.elp.gov.bc.ca/car>, have been developed to identify road crossings at which the culvert may be a barrier to fish passage.

To prioritize the sites for works, the intention of the FPCI is that the assessments be done on 100% of the crossings in a basin, that meet the four basic criteria listed below:

- The stream is known fish-bearing, or linked by a gradient not in excess of 20% (25% for bull trout) to a known fish-bearing reach.
- The crossing is on a first or second order stream based on current 1:50,000 scale maps of the watershed. (All others are assumed to have bridges.)
- The stream is an actual culvert crossing, confirmed by a field visit. (Note that locations at which culverts are expected are often found, upon inspection, to be fords, bridges, or deactivated.)
- The stream is not an undefined channel through a draw, or a dry channel, at time of evaluation.

A variety of measurements are taken at the culvert crossing to determine whether a fish passage problem exists. Measurements include culvert slope and water velocity, outfall drop, plunge pool depth, stream gradient, and bankfull width. A minimum of fish sampling effort and habitat evaluation is also required above and below each culvert assessed, according to the FPCI methods. This allows for more accurate determination of priority for works at an identified barrier site. The priority is determined by a weighted score based on: whether an additional culvert barrier exists upstream; the length of stream habitat upstream of the barrier; the degree of barrier; the fish species present; and a subjective score for the value of the physical fish habitat to be gained (Figure 1).

In reviewing the summary of culvert assessments conducted to date (Figure 2), the magnitude of fish access issues in the Cariboo Region becomes somewhat clearer. First, the number of culverts that met all four criteria for an assessment, as noted above, was only 35% of those that met the first two selection criteria of gradient and stream order. The

	Fish Species	Habitat Value		Barrier		Length of New Habitat		Limiting to Upstream Barrier	
		H	10	Full	10	≥ 1 km	10	Yes	5
Multiple or Significant	10	H	10	Full	10	≥ 1 km	10	Yes	5
Single	6	M	6	Partial	6	< 1 km ≥ 500 m	6	No	0
Other	3	L	3	Undeter.	3	< 500 m	3		

Figure 1. FPCI Scoring Matrix (0 - 10) to prioritize culvert barriers for works.

# Feature

Project Location	Total crossings considered	Total number of culverts assessed <sup>2</sup>	Crossings assessed as full or partial barriers	Culverts assessed as barriers (%)	Total km of stream barred	Avg. Stream Length (km) to be gained per high priority crossing
Woodjam Cr.	43	8	7	87	4	3.6
Little River	NA	6	3	50	4.1	1.4
Eagle / Bradley <sup>1</sup>	167	66	26	39	52	2
Jim / Windy <sup>1</sup>	81	30	18	60	36	2
Upper Cariboo	70	9	6	67	11.7	1.7
Boss	-	33	13	39	8.3	1.4
Upper Bowron	NA	36	9	25	12.9	1.5
Cottonwood	NA	27	22	81	55.8	1.7
Nazko	244	49	22	45	217	7.2
<b>Regional Average</b>	<b>NA</b>	<b>NA</b>	<b>NA</b>	<b>55</b>	<b>NA</b>	<b>2.5</b>
<b>Regional Total</b>	<b>NA</b>	<b>264</b>	<b>126</b>	<b>NA</b>	<b>402</b>	<b>NA</b>

<sup>1</sup> report only specified > 2 km upstream of barrier, therefore, results are understated.

<sup>2</sup> these are crossings that meet the four basic requirements for a culvert assessment.

Figure 2. Summary of Cariboo Region FPCI Reports.

benefits of field visits is clear, given that this may reduce the anticipated number of culvert crossings to be assessed by approximately 65%. Upon inspection, many expected culverts turned out to be ephemeral streams, deactivated crossings, or ford and bridge crossings. Field visits allow for better planning and budgeting of works. However, until the field visit, it is not apparent whether a crossing will meet the eligibility criteria, and therefore the number of sites visited will remain well in excess of those proven to be in need of assessment.

Of those culverts that met all four criteria and were subsequently assessed using the procedures outlined in the FPCI guide, 48% of the crossings were identified as being either a full or partial barrier. A full barrier is a barrier to all species present at all life stages, whereas a partial barrier is a barrier to passage of a given target species or life stage of a target species. There is, then, a significant number of culverts that need some attention to ensure fish access to upstream reaches. Through the nine assessments completed in the Cariboo Region, over 400 kilometers of stream were identified as not being fully accessible. As these nine projects cover only a small portion of the region, the poor fish passage at culvert crossings in the Cariboo Region is expected to have a significant impact on the migratory behaviour of anadromous and resident populations.

There also appears to be a correlation between the length of stream habitat to be gained and the topography of the land. The Nazko River watershed is significantly different than the other project areas. In this flat area

where there are fewer, but longer, drainages, the average length of stream to be gained per high-priority crossing is much greater than the other basins (7.2km/crossing, as compared to an average 1.9 km/crossing for all others). This compares to the average result of three culvert assessments in the Fort St. John area, where an average of 5.9km/crossing was found (MacMahon 1999).

### Management Considerations:

Of particular note is the fact that current FPCI assessments do not identify the length of the fish-bearing stream that is barred by a known culvert barrier. This does not allow us to evaluate the relative importance of what may otherwise seem to be a small habitat gain to a system. On the coastal and more mountainous systems of British Columbia, it has been common practice to run mainline roads parallel and close to the mainstem of the river systems. Barrier crossings on such a road are often not perceived to have a significant impact on the fish productivity of a system, as such short lengths of moderate gradient stream typically lie above these crossings. However, since this stable rearing and refuge habitat is such a small proportion of the system, it could very well be the limiting habitat feature, and therefore highly important to the long-term survival of local fish populations. For example, a study on the Skagit River in the Puget Sound area of Washington estimated culvert barriers to decrease summer and winter coho smolt production by 13% and 6%, respectively, on a basin-wide scale. However, in tributary-type habitats, the production losses increased drastically, to 44% and 58%, respectively (Beechie *et al.* 1994).

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Participants at the BC - US Technical Exchange visiting a recent rip-rap and LWD treatment of an eroding bank at the West Kettle River near Beaverdell. (Work completed by Attrill Woodworking Services.)

## INTEGRATED WATERSHED PROJECTS

### Upper Grande Ronde River Watershed Restoration: Past, Present, And Future

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#### **Purpose**

This paper examines a case example of a watershed planning effort in the upper Grande Ronde River drainage, and describes how it can be used as insight for current large scale efforts. Having been both criticized and acclaimed, the plan is worthy of review; more important, it has survived to become an active restoration vehicle. More than 10 years of continuous effort have been put into the plan, and it served as a blueprint for several million dollars in restoration effort on public and private lands.

Wallowa-Whitman National Forest experienced a series of drought years in the late 1980's and early 1990's. The loss of two year classes of spring/summer chinook salmon and steelhead that belong to the Snake River stock was caused by the Tanner fire in the watershed, which burned 3,900 acres (1580 hectares) and adversely affecting the majority of the main-stem anadromous fish habitat. There was a period of controversy (1989 to 1995) between the multi-discipline, multi-stakeholder agencies that sponsored the development of a plan, and the Forest Service group. In 1992, the Upper Grande Ronde River Anadromous Habitat Protection, Restoration and Monitoring Plan (UGRR Plan) was presented. Over an eight year period, the US Forest Service gave various reasons why the UGRR Plan could not be officially implemented. This was a classic example of unsatisfactory linkages between scientific, social, political, and management levels. Certain stakeholders were disappointed that the plan that they had spent time and effort to develop, was not implemented officially.

In 1995, the UGRR Plan was converted into a working paper called the Upper Grande Conservation Strategy for Endangered Snake River Spring Chinook Salmon. It covered the strategy until October 1, 1999. Although it had not been implemented officially, the personnel of the La Grande Ranger District used personal initiative to conduct an extensive watershed restoration based on the working paper. Several million dollars have been spent to close roads, change grazing practices, work

with landowners, conduct timber salvage, reduce fire hazard, restore streams, and change recreation sites and practices, in an effort to improve the watershed. Much of the funding was acquired through partnership funds, and the plan enabled partners to understand the need and priorities for projects proposed by the district. Extensive road, forest, fire hazard and stream inventories have also been conducted to design new projects to improve baseline conditions.

Based on what we have learned from the UGRR Plan, a model for watershed restoration implementation has emerged. It is necessary first to develop a plan with clear purpose and objectives. Second, a description of the watershed needs must be written in enough detail to provide understanding of its relationship to the natural resources and their uses. Projection of desired future conditions can be developed based on baseline resource condition inventories and the best scientific information available. The plan should be officially supported and endorsed by the forest leadership, and shared with tribal, state, and public participants whose input, support, and matching dollars can greatly enhance the project's success. The period following the end of Fiscal Year 1999 may bring substantial changes in the way funds are allocated to the US Forest Service to do its work. The national directions for management emphasize watershed and water quality restoration instead of only traditional commodity values including timber. ▲

### San Juan Integrated Restoration

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The San Juan Watershed Agreement establishes a cooperative and jointly managed program with the objectives of protecting, improving, and replacing fish habitat and fisheries-related recreational opportunities. This agreement concerns the 665 km<sup>2</sup> drainage of the San Juan River, located on the southwest coast of Vancouver Island approximately 80 km west of Victoria. The main valley lies east-west and has been eroded along a major fault line with different terrain and geology to the north and south. The south side of the drainage is composed of easily erodible sedimentary rock, while the north side is composed of more stable intrusive and volcanic rock. The length of the San Juan River is just over 50 km and is composed of two

distinct types of stream channel morphology. Most of the streams, particularly the headwater reaches, are steep bedrock/boulder-controlled channels. The other channel morphology type is a 1-2 km wide floodplain found in the lower 10 km of the San Juan mainstem.

The agreement for the San Juan Watershed recognizes both the economic and social values provided by forest management, and also that fulfillment of private property rights includes protection of publicly-owned environmental values such as fisheries, water quality, and water quantity. It was signed on August 1, 1995, and will terminate on December 31, 2001.

The parties to the agreement recognize that there has been significant improvement in forest practices, especially during the last three years. The agreement builds on this positive change by developing a comprehensive fisheries restoration and enhancement plan for the entire San Juan watershed. The plan has been adequately funded, professionally implemented, and cooperatively managed by the parties.

The ownership in the San Juan watershed is approximately 44% Crown. The remaining 56% is privately held, of which 11% is managed within a Tree Farm License (TFL) by TimberWest Forest Limited. TimberWest holds 86% ownership interest in the non-Crown watershed lands, and MacMillan Bloedel holds the remaining 14%.

To meet FRBC objectives, it was necessary to obtain input and develop a cooperative planning process that included other interests in the San Juan Watershed. As a result, the FRBC Steering Committee was created to advise and make recommendations regarding the projects to be carried out on the Crown land portions of the watershed.

Representatives on the committee include:

- Pacheedaht Band
- Sooke Renfrew Forestry Society
- San Juan Enhancement Society
- Cowichan Lake Forest Coop
- Renfrew Community Association
- IWA

The San Juan integrated restoration work has involved the preparation of base maps and terrain mapping, stream enhancement activities, slide restoration assessment, road deactivation, gully and slide rehabilitation, riparian plantings, and construction of instream habitat rehabilitation works.

To provide an excellent workforce that was able to work on this and other projects in a safe and productive manner, a training proposal was developed by the FRBC Steering Committee. The training, completed during the fall of 1997, involved native and non-native individuals from the Port Renfrew area. The course had 16 components, covering a variety of subjects such as first aid, basic forestry, vehicle and helicopter

safety, power saw operation, basic mapping, fish habitat assessment, fire suppression, supervisory skills, and other related topics. A total of 26 individuals took part in one or more of the individual course components for a total of approximately 1,832 hours of training. The individuals who participated in the training have been involved in a variety of projects in the San Juan Watershed as employees of the Pacheedaht Development Corporation.

The cooperative and jointly-managed program in the San Juan Watershed is, and has been, successful in protecting, improving, and replacing fish habitat and fisheries-related recreation opportunities. The watershed restoration plan has been adequately funded, professionally implemented and cooperatively managed by the parties. The work-to-date has created employment, and the working partnership has resulted in increased stewardship for fisheries resources throughout the San Juan watershed. ▲

## Windermere Creek Restoration

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The restoration efforts for Windermere Creek owe their success, in part, to area residents and a multitude of vested stakeholders who are dedicated participants in these local initiatives. The various partners remain committed to the successful management of the Windermere Creek Watershed.

Windermere Creek is a fifth order tributary of the Columbia River. The lower reaches of the creek flow directly through the community of Windermere, located in the East Kootenays of southeastern BC. The mainstem flows 27 km from its origin in the Stanford Range of the Columbia Mountains to its confluence with Lake Windermere. Windermere Creek is the largest tributary to the lake, and is a regionally important fish stream. Extensive human land use activity in the Windermere Creek Watershed includes crown land forest harvesting of 16 percent of the total watershed area, access development (highway, secondary and forest roads), two open pit gypsum mines (one active), gravel pits, agriculture, recreational (golf course, camp grounds), and residential development. Windermere Creek is under review for "Community Watershed" status, as it provides water for agricultural use and for local native communities (it incorporates a portion of Columbia Lake Indian Reservation #3).

The watershed is within licensed guide-outfitter and

trapper territories; it provides important wildlife movement corridors for a number of species. (See multiple stakeholders, Figure 1.) Backcountry recreation activities in the Windermere Creek Watershed, such as hiking, fishing and hunting, are popular pursuits for local community members. The area offers berry picking sites close to local communities. Karst topography features provide unique swimming opportunities at a “bottomless” sinkhole. The watershed is of spiritual significance to the native community of the Columbia Lake Band.

Resource extraction and developments have resulted in considerable adverse impacts to the water, habitat, and channel conditions of Windermere Creek. A watershed prioritization completed by Ministry of Environment, Lands and Parks recognized the uniqueness of Windermere Creek due to its importance to a broad range of concerns and interests. The need for restoration was considered high at both the local and regional levels. Restoration strategies were developed to ensure a watershed restoration process that was integrated overall, and which incorporated the interests of multiple stakeholders. Restoration was funded through Forest Renewal BC, in partnership with Slocan Forest Products, Radium Division, and Ministry of Environment, Lands, and Parks.

Overview Interior Watershed and Fish Habitat Assessment Procedures (IWAP and FHAPs) were conducted in 1997 to provide a preliminary assessment of the location, nature, and extent of the effects of human impacts on the watershed and affected habitat. Based on the results of the overview studies, a Level 1 FHAP commenced in late 1997/early 1998, concurrently with a Channel Condition and Assessment Procedure (CCPA), to provide more detailed information on the watershed, and to identify specific restoration opportunities. A multitude of associated plans and reports were reviewed by the BC Environment, the licensee, and the consultant, to ensure coordination with other initiatives and existing data. These included timber resource plans, access management plans (development and deactivation), lake studies, historic stream discharge information, fish population information, water quality studies, and community plans. Ultimately, a coordinated effort among biologists, foresters, engineers, and hydrologists was used to develop high priority restoration prescriptions for Windermere Creek.

Restoration activities have been completed at seven high-priority sites. These includes stream bank stabilizations and revegetation applying bioengineering techniques; stream bank revetment and sediment controls; fish passage barrier removals and gradient controls; and construction of an inlet catch basin and drain system for diversion of a spring-fed discharge. The project employed ‘standard’ restoration techniques, including v-log weirs, large woody debris placement and tree revetment, boulder cluster armoring, live

cutting placement, revegetation techniques, and construction of an inlet catch basin/drain system. Stakeholder support of these prescriptions and activities was due, in part, to the time and effort taken to provide education and to disseminate information in the planning stages. An important aspect of the Windermere Creek restoration was that in all possible cases, the project employed displaced forest workers, who also received new skills training.

Readers should refer to Streamline Vol. 3 No. 4, page 1, for further information, including technical details of restoration work on Windermere Creek. ▲

## FOLLOW-UP CASE STUDIES

### Kingfisher Creek Restoration for Endangered Middle-Shuswap Coho

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The Kingfisher Creek Watershed includes both Danforth and Hunter’s Creeks in addition to the mainstem river. It drains an area approximately 750 km<sup>2</sup>. The watershed lies within the Interior Cedar-Hemlock biogeoclimatic zone. The drainage flows from north to south and enters the Shuswap river east of Enderby, B.C., near the outflow from Mabel Lake. This area is heavily used for recreation, tourism and timber harvesting.

Both rainbow and bull trout populations are resident in the watershed, and there is evidence that adfluvial rainbow trout from Mabel and Mara Lakes use all three creeks for spawning. Anadromous salmonids in the watershed include a threatened population of coho salmon, as well as small numbers of chinook and sockeye salmon that periodically use the lower reaches for spawning.

Kingfisher Creek was chosen as the representative (demonstration) watershed for the northern portion of the region because of its salmon population. Future WRP projects are likely to use the structures and techniques established here as templates for other works related to interior coho salmon. The partners

involved in this project were: Riverside Forest Products Ltd., Lumby Division, Ministry of Forests, Kingfisher Environmental Interpretive Centre Society, and Spallumcheen First Nations.

The objectives of this project were to:

- provide off-channel spawning, over-wintering, and rearing habitat for resident rainbow trout and coho salmon;
- provide instream spawning and rearing habitat through the re-establishment of large woody debris-boulder structures;
- provide stream channel and floodplain stability to reduce the input of sediment and prevent channel avulsions; and
- provide template structures and techniques to be used in other restoration projects throughout the Kamloops Forest Region.

Preliminary feasibility studies indicated species presence and distribution and provided potential areas for restoration projects. Due to fisheries work window timing restrictions, prescriptions were refined in the field with assistance from P. Slaney, R. Finningan, B. Symonds and B. Franz, and then implemented in 1998.

The rehabilitation work included:

- Development of off-channel spawning and rearing habitat within the floodplain of the lower reach of the Kingfisher Creek mainstem. Using a combination of groundwater sources (0.05 m<sup>3</sup>/s) and a controlled surface water diversion (maximum of 0.85 m<sup>3</sup>/s), 1,200 m of channel and 6,000m<sup>2</sup> of pond habitat were restored. Habitat complexing within this channel included the development of riffle, run, and pool sequences using a variety of rock and woody debris structures. The techniques used were chosen for their applicability to the specific hydraulic conditions of each reach, and to the creation of diversity, and for demonstration purposes. Groundwater sources were natural, perennial springs. The surface water diversion included a 1000 m<sup>2</sup> settling pond and head-gate protected by a 3.5 m berm from freshet flows.
- Upgrading of fish access throughout the groundwater channel adjacent to Hunter's Creek at 10.5 km on the Forest Service Road. This included the hand-placement of rock, minor excavation of the channel, and the addition of 75 discarded pole saplings as cover for the rearing ponds. Trails were also upgraded and 5,000 willow whips were planted throughout the site.
- Stabilization of 200 m of Danforth Creek's eroding channel bank under the BC Hydro right-of-way at 12 km on the F.S.R. There were 1,500 m<sup>3</sup> of overhanging and under cutting bank removed, 500 m<sup>3</sup> of rip-rap (>0.5 m diameter) placed, 24 pieces of LWD (>0.5 m diameter X 10 m length) and 5 rootwads (>2 m diameter) placed within this reach. This

created 3 triangular debris catchers, 1 Newbury riffle, 50 m of lateral debris jam and 75 m of protected streambank. Intensive bioengineering revegetated 1 ha of riparian zone with low-growing willow species (BC Hydro requirement).

- Restoration of instream fish habitat throughout a 250 m length adjacent to a bridge crossing of Danforth Creek. Work included the construction of 2 Newbury riffle structures, 4 triangular debris catchers, and 25 m of lateral debris jam.
- Excavation of three (50 m<sup>2</sup> by 1 m deep) off-channel ponds in a spring-fed side channel to Danforth Creek under the BC Hydro right-of-way. Habitat complexing in these ponds includes the addition of woody debris (40% surface area cover) and grade controls to maintain pond depth. Sixty-five pieces of LWD were added to 450 m of the mainstem channel to provide instream fish habitat features and bank and floodplain stability. These were used to augment the few remnant LWD remaining from right-of-way construction 25 years ago.

The total project costs were \$155,500. In all, it restored 1,500 m and 6,125 m<sup>2</sup> of off-channel and 1,000 m of instream spawning, rearing, and over-wintering fish habitat; It also created 356 person-days of employment. This project has the potential to produce an estimated 12,910 coho smolts and 1,633 rainbow trout juveniles annually, if recruited to capacity. To determine the success of the restored habitat, long-term monitoring should be implemented to assess habitat use, and thus refine fish habitat restoration prescriptions for southern interior watersheds. ▲

## Various Thompson Restoration and Enhancement Projects

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There has been a sharp decline in the numbers of the Thompson River coho over the past several years, due to historic over-harvesting, changing ocean conditions, and cumulative habitat loss. Unfortunately, ocean conditions are uncontrollable, but freshwater habitat conditions can be restored and protected. The Department of Fisheries and Oceans (DFO) uses a variety of techniques to improve freshwater fish habitat conditions. Riparian restoration is one of the key techniques used. This includes not only bank stabilization and erosion

control, but also planting and setback fencing to re-establish a riparian corridor. As well, side-channel work provides extremely productive habitat and is used to aid in naturally maintaining stocks where the mainstem is in poor condition or is under recovery. Another component of the DFO strategy is to undertake strategic fry and smolt release programs in areas of grave conservation concern. ▲

## **Marchant Riparian Restoration Project in Harris Creek, Lumby, B.C.**

The Harris Creek system is subject to urban/industrial, forestry and agricultural impacts. As a result, much of the riparian has been lost and the stream banks have become unstable.

As a trial of the North American Green P300 geotextile technique, a 130 meter site was selected on Bloom Road Farm immediately downstream of the confluence of Brett Creek and Harris Creek.

The bank, composed mainly of top soil, clay, and sand, was nearly vertical, and in some cases had a negative slope. It was pulled back at approximately 1:3 slope and a setback trench was dug at the toe to key in the rock. Due to the March/April timing of the project's construction, there was a requirement for zero sediment discharge from the work site. To address this, a small berm was left between the river and the trench so that the rock could be placed in isolation from the main stream flow. A 3 hp. gas pump was used to drain water from the trench to allow for displacement when the rock was placed. Logs with rootwads were buried into the bank at approximately 15 meter intervals to add habitat value to the rock used at the toe of the slope.

Partners in this project include the Department of Fisheries and Oceans, Forest Renewal BC/Watershed Restoration Program, Bloom Road Farm, and River-side Forest Products. ▲

## **Avola Creek Pond Project in Avola Creek, Avola, B.C.**

Historically, the Avola Creek Pond was used as a log sort until the mid-1970's. Since then, the community has made use of it as a swimming area. Due to its previous use for log sorting, excavation to increase the pond's depth was not a feasible option. However, it was possible to raise the pond's level to increase water depth. A berm constructed of pit run material was armoured and planted with native plant species. This

increased spawning and rearing habitat by an additional 60 meters. In the fall of 1998, six pairs of coho were observed to be spawning in the expanded habitat; the total run for the creek was approximately 25 pairs.

The CN Rail tracks are adjacent to the project and there were several thousand concrete rail ties stacked for disposal. Approximately 300 of these ties were sandblasted to clean them, and used to construct a variety of structures, including islands and uncut banks. The ties also provided excellent anchor for the woody material that was placed in the pond.

Partners in this project include the Department of Fisheries and Oceans, Weyerhaeuser, CN Rail, and the Community of Avola. ▲

## **Salmon River Smolt Pond Project in Salmon River, Falkland, B.C.**

Coho stock status on the Salmon River is extremely depressed; historically escapements were in the tens of thousands of fish, however, in 1998 returns were less than one hundred. Smolt release programs increase the number of fish that normally migrate to the ocean. Salmon River coho are reared in the Spius Creek Hatchery in the Nicola system. To maximize hatchery adult returns to the natal stream, the fish are transported from the Spius facility to the Salmon River and held for a four to six week period for imprinting prior to downstream migration.

The project itself consists of a river intake leading to a settling pond. A small spring that fed into the channel was diverted to enter further upstream. This ensures that as much water as possible will flow through the two ponds that have been constructed in sequence. Typically, one pond will be used for chinook, and the other for coho. As the project was constructed in March, there was a requirement for zero sediment discharge from the work site. This was accomplished using a variety of means. For the intake, an Aquadam and bulk bag diverted the flow, and a pump ensured that there was a net inflow of clean water into the site. At the confluence of the channel and the river, a silt curtain acted as a buffer. On the channel side of the curtain, a diesel-driven pump was used to pump dirty water onto an adjacent field, thereby maintaining an inflow of clean water. As part of site reclamation, disturbed areas were seeded and a straw mulch layer was spread. Planting of both whips and rooted stock has been carried out in the disturbed areas as well.

Partners in this project include the Department of Fisheries and Oceans, Dennis Lapierre (Habitat Farms), and the Salmon River Roundtable. ▲

## NEW CASE STUDIES

**Deschutes Restoration Projects****Beth Sanchez***Fisheries Biologist**USDA Forest Service, Crescent Ranger District**Deschutes National Forest**P.O. Box 208 Crescent OR 97733**Tel: 541-433-3236**e-mail: bsanchez/r6pnw\_deschutes@fs.fed.us*

The Big Marsh and Soda Creek restoration projects were implemented on the Deschutes National Forest in the Fall of 1997. Both systems had been altered by past management; both systems had been used for cattle and sheep grazing in the past; and the channels had been modified for road protection and drainage of Big Marsh for increased livestock forage. The method used to recreate the original stream characteristics was developed by hydrologist Dave Rosgen. This technique was used by the forest hydrologist and fisheries biologists to redesign Soda and Big Marsh Creeks.

Soda Creek was realigned from a bermed, straight, wide and shallow channel to a meandering channel with pools. The restored section of Soda Creek is now 2,000 feet (610m) long, nearly double its former length. Willows were planted, and grass, rush, and sedge seed was collected locally and spread on the disturbed areas.

Big Marsh was privately owned from 1906 until it came under public ownership in 1982. At that time, there were efforts made to remove the ditches that drained the marsh and allowed it to return to a wetland. Three pieces of legislation guided the direction of land management activities in the marsh: the 1984 Oregon Wilderness Act made Big Marsh part of the Oregon Cascades Recreation Area, and the 1988 Omnibus Oregon Wild and Scenic Rivers Act designated fifteen miles of Big Marsh Creek as a recreational river. In 1988, a progressive reversion in the east ditch was accomplished using a water control head-gate. After nine years, plans were made to totally block off the east ditch. The head-gate was removed, and a permanent dam was built in its place to maintain water flow into the original stream channel. Several dirt berms and side-channels were also constructed to restore connectivity of the floodplain.

Pre-project monitoring included stream surveys, photo points, low elevation aerial photos, Wolman pebble counts, a longitudinal profile, cross-sectional profiles, and electrofishing. Ongoing, post-project monitoring is repeating these surveys. ▲

## Trapping Creek Routine Monitoring of Structures Built in 1997: Background for Field Visit

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The project proponent for this restoration work was Pope and Talbot, Boundary Timber Division, Midway, BC. In 1997, 550 large woody debris (LWD) structures were built in Trapping Creek, based on ten different designs. The structures were placed over 8 km of stream in order to restore pools and instream cover in areas affected by previous riparian logging. Following the freshet in 1998, routine monitoring was conducted to evaluate the performance of the structures built in 1997. Structure stability varied with crew experience, runoff conditions at the time of installation, and also with structure type.

Structure stability improved as the crew became more experienced with anchoring procedures, over a six week installation period. This finding emphasizes the importance of proper crew training prior to instream work.

Higher rates of failure had occurred in structures that were built during an unusually rainy period in September. Increased streamflow from the rainy period created difficult conditions for the anchoring crew. Baseflow conditions were found to be ideal for building stable structures.

Stability also varied by structure type ranging from 65% to 100%, with an overall rate of 82% stable structures. Multiple log structures, including log wing deflectors, log V-weirs, and lateral log jams. The last had the highest rates of stability. From a biological standpoint, the lateral log jams created the greatest benefits, and were associated with scour pool development and substantial increases in instream cover. Log wing deflectors and log v-weirs promoted scour pool development, but did little to increase instream cover. Single log structures, such as cover logs and sediment traps, also had high rates of stability. However, logs that ended up parallel to the direction of flow created minimal hydraulic disturbance and were sometimes associated with additional scour and erosion of streambanks. Cross-stream structures such as diagonal log weirs, were the least stable structures, particularly in the wide upper reach that had lacked riparian vegetation. Failures were due to insufficient ballast, log breakage, and insufficient keying of the log back into the bank. A learning point from the field visit was to avoid use of cross-stream sill logs in widened, unstable channels because they exacerbate instability by reducing channel depth.

In 1998, only three multiple log designs were used: lateral log jams; log spurs placed along outside bends with eroding banks; and meander jams placed on top of existing gravel bars. Anchoring techniques were upgraded to include the use of sufficient ballast, tighter cables, and more connections between the individual components within a jam.



Figure 1. Participants at the BC - US Technical Exchange visiting the Trapping Creek Watershed Restoration Project. ▲

## West Kettle Watershed Restoration Project: Background for Field Visit

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Fish habitat restoration work is being carried out in a 2 km section of the West Kettle River, as part of a larger effort to restore this watershed to a more natural and stable condition. At this site, rainbow trout, mountain whitefish, and red-sided shiners are commonly present fish species. Work will eventually include bankside planting of willows, and riparian planting of conifers and cottonwood trees. The risks associated with fish habitat rehabilitation on larger interior streams made the West Kettle project a good choice as a demonstration site.

### **Triangular Log Jams:**

Eight lateral triangular log jam structures at this site were installed in 1997 to create deep pools and provide overhead cover for fish habitat. They emulate what would naturally be present in this river before human impacts of land clearing for forest harvest and agriculture, Highway 33, and the old rail bed from the now defunct Kettle Valley Railroad. Each log structure was fixed on-shore to a tree base, or deadhead. Then it was

ballasted with 1 cubic meter of boulder per log to provide extra stability to allow for debris accumulation. It was anticipated that each structure would, over time, develop into a lateral log jam. The surface armouring layer beside the structure was removed to ensure rapid scour, which effectively emulates one flood event.

### **Box Groins and Bank Stabilization Structures:**

We installed four box groins in 1998, to provide refuge cover for fish (mainly for resident rainbow trout and mountain whitefish). These consisted of 4 logs secured in a slot near the top of the streambank, sloping downward at an upstream angle to the streamflow. The logs generate pool scour and provide cover for adult fish. Care must be taken to ensure adequate ballasting plus boulder revetment on the upsides of the structure to prevent infilling from scour at the upstream log.

Bank stabilization structures consist of logs secured to the bank, with boulder ballasting to prevent flotation. The logs are designed as a ramp to catch woody debris and armour the bank, similar to natural templates. They are meant to be a softer solution for bank erosion protection, replacing the more conventional rock rip-rap. There are two sets of three bank stabilization structures located near the midsection of the treatment area (installed in 1998).

Additional triangular log jam, bank stabilization and debris reef structures will be constructed to augment fish habitat complexity while reducing bankside erosion. The structures consist of hemlock and larch logs, using rounded river boulders for ballast. In particular, the bank stabilization structures will provide an example to private landowners of the positive benefits of these for reducing erosion along their riverfront farm land. Our work will be followed with increased riparian planting of willows, cottonwoods, and conifers.

### **Evaluating our Success:**

We have installed a total of 20 structures since 1996 and are currently evaluating the success of our work, based on fish counts in this section of the river and compared to an upstream control (untreated) section. To assist evaluation, we have posted signs and have requested that people fill out fishing record cards and drop them into boxes. Initial results from underwater counts of fish have indicated about a seven-fold greater abundance of age >1 yr rainbow colonizing the structures, thus augmenting trout numbers and angler opportunities. (Only one structure, a box groin, failed up to spring 1999, as a result of inadequate ballast on shore.)

For further information contact Phil Epp at Tel: (250) 490-8274, Watershed Restoration Program, Ministry of Environment, Lands and Parks, Penticton. ▲

## Central and Northern Interior Fish Access

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The interior of British Columbia experiences relatively low amounts of rainfall per watershed area and thus the stream widths are generally smaller. This may lead to greater use of culverts for crossing streams. Fish species such as bull trout and grayling are at risk because they tend to use the smaller streams (1<sup>st</sup> to 3<sup>rd</sup> order streams), where culverts have been installed.

Re-establishing the fish passage can be a cost-effective means of increasing the productive capacity of the system. In this discussion (summarized on pages 9 to 12 of this issue of Streamline), there are criteria suggested for prioritizing restoration of culverts and fish barriers based on the FPCI (Fish Passage Culvert Inspections). Habitat gain is the most significant advantage of addressing barriers at culvert crossings. A study on the Skagit River in the Puget Sound area of Washington estimated culvert barriers to decrease summer and winter smolt production by 13% and 6% on a basin-wide scale, however this increased to 44% and 58% production losses in tributary type habitats (Beechie *et al.* 1994).

For further information, please see pages 9-14 this issue of Streamline. ▲



## INNOVATIONS/EFFECTIVENESS MONITORING

### Aquatic and Riparian Effectiveness Monitoring for the Northwest Forest Plan

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The Aquatic and Riparian Effectiveness Monitoring Program for the Northwest Forest Plan is presently being developed by an inter-agency team of scientists and technical staff. It is intended to evaluate how successful the Aquatic Conservation Strategy (ACS) is in restoring the ecological health of watersheds and their aquatic ecosystems. It will determine, based on a rotating panel sampling design, present watershed condition, track trends in this condition over time, and report on the ACS's effectiveness across the region. A conceptual model provides a framework for selection of indicators that, considered in aggregate, describe watershed condition. Indicator information for in-channel, riparian/floodplain, and upslope processes will be evaluated using a knowledge-based decision support system, of which the physical, biological and chemical components and relations are developed by provincial expert panels with local knowledge of system functions. The advantages of the system are that it is a transparent procedure (regarding the data used, assumed relationships between data elements, and the analysis performed), is repeatable, and can be updated easily as better information on relationships becomes available. The product will be a histogram of watershed conditions defined as a probability of each watershed being in a functional state, and, by tracking individual indicator values and representing them as a function of a reference condition. An initial pilot test of these concepts has been completed and results of this approach show promise. This program proposal is in preparation for scientific and agency peer review. Once completed, it will be presented to agency executives for their consideration. ▲

## Breaking New Ground in Riparian Restoration

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Functioning riparian ecosystems are needed for long-term restoration of fish habitat, water quality and channel stability. In watersheds where logging has removed timber to stream edges, riparian attributes critical for creating and maintaining fish habitat and protecting water quality are lost or significantly impaired. Although natural re-vegetation and efforts by logging companies to re-establish vegetation in most watersheds has been successful, it is only the beginning of a complex and very long process of restoring the ecological characteristics required for riparian areas to function properly and for fish habitats to recover.

Riparian restoration is new to British Columbia. Unlike in the Pacific Northwest, where the past 10 years has seen advancements in testing and assessing restoration techniques, B.C. is just breaking ground. Our report provides a brief overview of methods developed in B.C. for assessing riparian stands, and shares with you some of our ideas on restoring these stands.

### Assessment Methodology

- a detailed description of the methodology used in B.C. is given in Koning (1999) *Riparian Assessment and Prescription Procedures (RAPP) Watershed Restoration Technical Circular No. 6*.
- assessments are intended to provide governmental agencies with all of the necessary information for approval to undertake work in the riparian area.
- a brief overview is completed using large-scale aerial photography (1:2,500 – 1:5,000). Riparian polygons in the area of interest are mapped on overlays.
- riparian polygons are stratified into riparian vegetation types (RVT's) with similar riparian restoration opportunities.
- field information is collected to determine the degree of riparian dysfunction and stand condition such as vegetation composition of the overstory and understory, number of stems/ha, heights and diameters of trees, year of harvest, and soils.
- riparian restoration prescriptions are prepared and sites prioritized for treatment.

### Riparian Restoration in Coastal Forests of BC

- overstocked conifer forests and mixed deciduous-conifer forests are two common stand conditions that occur in coastal watersheds.

- these conditions can slow or prevent the long-term recovery of fish habitat, water quality, and channel stability.
- restoration prescriptions are being applied to the riparian reserve zone of logged streams
- the primary restoration goal is to improve the growth and survival of conifer trees, and to achieve the largest size of trees (diameter) in the shortest possible time.
- biodiversity and wildlife objectives influence prescriptions, as stand modifications intended to achieve large wood are those that accelerate the return of mature or old growth forest characteristics.
- target stand conditions include: low-conifer stocking densities, variable density retention, gaps, clusters, largest and most windfirm trees, ecologically preferred tree species, multiple canopy layers, and a component of dead and dying trees.
- prescriptions include: thinning overstocked conifer stands, topping or girdling to create dead and dying trees (wildlife trees and LWD), fertilizing nutrient-poor sites, releasing understory conifers by total or partial canopy removal, and managing for large alder by thinning and planting conifers, willow and cottonwood. ▲

## South Fork Coquille River Wood Placement Project

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This project was completed with an equipment rental contract that pulled over-large diameter conifers from the Powers-Glendale Bike Path route and hauled them about 4 miles, to the upper South Fork of the Coquille River, for instream placement. Rootwads were essential for weight and stability concerns and as natural ballasting. The stream is low gradient, 1% or less, and the tributary watershed above the site is about 8,000 acres. Six standing green trees and numerous downed trees were used. All trees were placed using a mobile yarder with a 1 inch mainline and 5/8 inch haulback line. Numerous straps, blocks and different-sized chokers were used during placement. No fastening cables were used to attach these wood pieces and whole trees. Twenty brush bundles (using damaged tree branches and pieces) were tied with hemp rope after completion of the structures.

Two control and treatment reaches were set up prior to project implementation. Both reaches were physically similar in appearance. During the winter of 1996, a 75-year flood event occurred. Only 4 of 51 marked

and tagged structures were displaced from the treatment area. The rest of the structures piled up and created log jams where the lining tree structures were located. These log jams have provided abundant cover for native cutthroat trout. Results from Level III monitoring efforts indicate treated areas have increased P:R ratio, increased pool depth, increased pool volume, while decreasing surface area. In addition, gravel recruitment covered bedrock and re-attached the flood plain. ▲

rehabilitation for juvenile salmonids in streams may partly counteract recent dramatic and persistent declines in survival observed in freshwater and marine life stages.

For more information, please see: Stream rehabilitation in British Columbia's watershed restoration program: juvenile salmonid response in the Keogh and Waukwaas rivers, 1998. Province of British Columbia, Ministry of Environment, Lands and Parks, Watershed Restoration Project Report No. 12. ▲

## Steelhead and Coho Responses to Habitat Structure Setting

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The effectiveness of stream habitat rehabilitation was evaluated in year two of a five-year program in the treated (logged and rehabilitated) watershed, the Keogh River, compared to the neighbouring and untreated (logged, no rehabilitation) watershed, the Waukwaas River.

Anadromous salmonid density and growth were compared in untreated and treated reaches of the Keogh River, which contained a variety of stream habitat structures as well as fertilized and unfertilized sections. Treatments were added annually to previously untreated reaches, starting upstream and working downstream with various placements of structures, and starting downstream and working upstream with an annual addition of slow-release fertilizer, incrementally from 1997 to 1999.

Significant increases were found overall in steelhead parr and fry abundance and coho fry abundance, at the watershed level, and in reaches treated with rehabilitation structures, compared to untreated controls both within and between watersheds, despite low levels of adult escapement.

Detailed analyses of structure usage by species indicated variation from year to year; climatic factors (stream discharge) may have influenced annual variations in species and age-class distributions. A diversity of structural types appears to provide an optimum strategy for habitat rehabilitation, rather than singular types. Analysis of salmonid growth in-stream continued to indicate that significantly larger salmonids were found in fertilized sections. Results indicate that habitat



An example of fish barriers caused by road construction: Central and Northern Interior Fish Access by Michael Parker (see page 9A).



## Feature

Therefore, careful identification of potentially limiting habitat on a watershed scale, not just on length to be gained, could provide more accurate cost-benefit analysis to determine in which coastal streams attention to fish passage at culverts is particularly warranted.

The problem of culverts is an issue that needs to be addressed around the province, as the example above indicates. Those FPCI assessments that have been completed throughout the Northern Interior show that there are many improvements to be made. A compilation of 16 culvert assessment projects through the Cariboo Region and Omenica/Peace sub-regions have shown that an average of 36% of the culverts assessed are barriers to fish passage (438 in total). To address these barriers would improve access to almost 2000 km of stream habitat (not including off-channel, pond, and lake habitats). FRBC Interior/Coastal Watershed Assessments Procedures (Province of British Columbia, Ministry of Environment Lands and Parks and Ministry of Forests 1995) identifies the number of crossings per kilometer of stream. This can serve as an indicator of systems in which crossings might be a primary focus, where the implementation of culvert assessments is needed, and where re-establishing fish access is a priority.

Finally, there is an important cost-comparison exercise to be considered, that may recommend culvert crossing restoration over other restoration efforts. In 1998, 19 high-priority culvert crossings in the Cariboo Region were addressed by WRP culvert replacement, bridge installation, or weir construction. This work will provide fish access to all life stages of target species to an estimated 67 kilometers of stream habitat (pond and lake habitat has not been calculated), or an average of 3.5 km per crossing. This is in excess of the 2.5 kilometer average identified for all high-priority crossings in the completed Cariboo Region FPCI assessments. These works were completed for an average cost of \$10,300/km habitat gained, varying from less than \$1,000/km for weir structures in the Cottonwood River drainage to approximately \$26,000/km for a bridge installation on Canimred Creek. The first cost-comparison to be made is a direct comparison of these activities to stream restoration activities that may be as much as \$50,000/km for pond excavation, LWD placement, channel excavation, and other complexing activities. Second, there is a need to consider what the productivity gain will be for a given investment, regardless of the amount. For example, we might estimate that impacts have reduced the productive capacity of an 0.5 ha off-channel by 30-50%. In restoring such a system, therefore, that same percentage is the most we can hope to gain back for our investment. If access is the issue, a full barrier to an 0.5 ha

off channel is a 100% reduction in its productive capacity, and we can expect to get a 100% production increase out of that habitat by restoring fish access. If both of these projects cost \$10,000, a culvert restoration providing a 100% productivity gain is a better investment than a project costing the same amount, but in which we expect a 30-50% gain. The degree of barriers to fish passage at culvert crossings is therefore an important one to consider for fish managers in all regions of the province.



Figure 3. Before and after pictures of a culvert crossing on the a tributary to the Cottonwood River, near Quesnel B.C., for which a weir was constructed to backflood the culverts to provide fish passage.

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## Cottonwood Culverts Post-Flood Assessment August 1999

Michael Parker

In the fall of 1998, West Fraser Mills - Quesnel undertook Forest Renewal BC funded Watershed Restoration Program activities in the Cottonwood River drainage, Quesnel Forest District, Cariboo Region of British Columbia. Part of these activities was to restore fish passage at four culvert road crossings on the 1300 Road. Scour of the stream bed below all four of these sites had left the outlet with drops between 25 and 60 centimeters (Figures 1 and 2). The four separate systems all had a bankfull width of approximately 3 meters. Rainbow trout were the primary target species

of these works, although bull trout have been found in the watershed at other locations. Although the outlet drops alone were not definitive barriers to fish passage, in combination with culvert water velocities, lack of

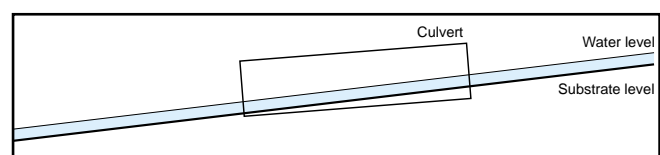


Figure 1. Initial placement - culvert near stream gradient, substrate throughout.

# Feature

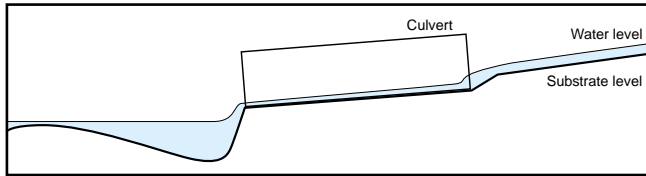


Figure 2. Placement after x years - outlet scour has led to a drop into a plunge pool, substrate no longer holds in culvert so velocity increases, substrate back-cuts to culvert entrance or beyond.

substrate within a culvert, and lack of an outlet plunge pool, passage was at best limited to adult fish.

Two different techniques were implemented to improve fish passage at the four sites. At three sites, a riffle weir was constructed a few meters downstream of the culvert outlet. The crest of the weir was constructed at an elevation that caused water to backflow to slightly above the bottom lip of the culvert outlet (Figure 3). These structures provided a pool between the culvert outlet and the crest of the riffle. One such structure required two weirs in order to achieve the necessary elevation gain to backflow the culvert. Weir design and substrate sizing was conducted according to need (Technical Circular 9).

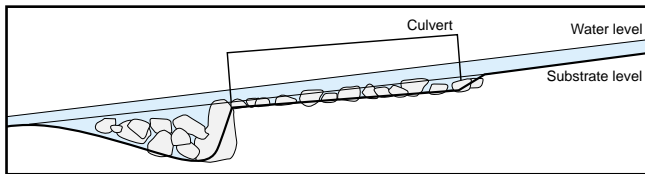


Figure 3. A backflow weir built at the tail of the plunge pool eliminates the drop, but creates a steep slope riffle.

The second technique, employed at one site, was to construct a riffle from the outlet of the culvert to the stream bed at a moderate gradient over approximately 7 meters (Figure 4). This did not provide any pool habitat at the outlet, but did ensure water flowed along a stream substrate from above the culvert, through the culvert, and down the constructed riffle, all at very moderate gradients.

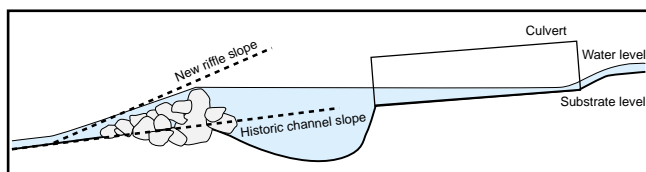


Figure 4. Restored outlet. Assume culvert size is adequate, a large key stone at outlet extends to height of historic bed to hold material in culvert, and reestablish outlet riffle. Assorted angular rock is used to build riffle and line culvert. Small gravels used to fill interstitial spaces. Reduces water velocity and eliminates outlet drop to improve fish passage. Note: evaluate if loss of pool habitat significant to the system.

Seven months after construction, elevations of the four riffle/weir structures were measured. It was considered that this would provide good baseline data, as the structures had time to settle after installation, but had not gone through a high flow event. For the three structures that had backflow weirs installed, the residual pool depths at the culvert outlets were measured at between 0.5 m and 1.13 m. There was no pool associated with the fourth site, but the riffle crest and end elevations were measured to determine if the riffle would shift over time.

During the spring of 1999, the Cottonwood River area received an estimated 2-year return flood. As waters receded a second set of elevation data was collected to determine how much shift had occurred in the four riffle/weir structures. Evaluation of the elevation data shows that the greatest post-flood change was the reduction in residual depth of the three primary pools created by the weirs backflooding the culverts. On average, the pools filled in with fine bedload, reducing residual depths by between 60-89% of the pre-flood measure. In one case, this meant that more than 95 cm in depth was lost. In all cases, the bedload was of fines to gravel size, and cobble-to-boulder material remained in place. The bedload movement of these small materials was not evident in the pre-work assessment of the sites. The other change, one appears related to the fines movement, is that two of the weir crests actually were slightly higher than the original installation. The smaller material filled in the tail of the outlet pool, effectively filling the interstitial spaces at the weir crest and causing the crest to be slightly higher than the original construction. Significant changes were observed on the face of these riffle weir structures, as flood waters had created step pool morphology on the face of the riffles. However, this change was anticipated; it is what allows for effective fish passage up the riffle face at lower flows. During August 1999, sampling rainbow trout were found in every constructed riffle, pool, and culvert. Seventeen fish between 68-141 mm were sampled during 892 seconds of electrofishing.

### Expectations:

Over the long term, the extended riffle structure from the lip of the culvert will be more durable and more likely to maintain an elevation close to design specifications than the other three backflow weir riffles.

The backflow pools below the three culverts with downstream weir riffles will not be further infilled. It is expected that a point of stability has been reached and that spring freshet will help maintain the minimal pools that now exist.

## Feature



Figure 5. Rock riffle from culvert outlet that formerly had a 0.54 m drop.

Over the long term, the weir riffle structures may be less stable and the relative elevations will drop slightly. However, the large angular material prescribed and used in construction is expected to keep the structures functional.

Bed material in the weir riffle structures will, at least partially, wash out of the inside of the culverts at the downstream ends, while the one riffle structure will maintain all substrate within the culvert due to key

riffle boulders at the outlet holding material in place.

#### Recommendations:

Based on observations of this limited test site, we recommend installing a riffle from the lip of a culvert, instead of a backflow weir, whenever feasible. This may not be possible in some situations where culvert capacity is inadequate or the outlet pool is considered an essential habitat feature to be maintained. The benefits of this type of application is that construction is closer to the road surface, so bed material in the culvert is more stable, and riffle slope is less than a downstream weir. It is anticipated that the long-term stability of this technique is better than a downstream weir. The work at the four sites described included hauling 192 cubic yards of angular rock some 50 km, and yet the cost per site was just over \$2,300; thus, it is an economical alternative to culvert replacement, if the existing structure is in good condition and is adequately sized.

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## Technical Tip

## Watersheds BC: Strategic Information About BC's Watersheds

*Malcolm Gray*

### Introduction

Geographic Data BC's objective for the Watersheds BC project is to provide decision-makers with comprehensive and easy-to-use information about the land and water resources of British Columbia. These summaries of province-wide GIS databases, containing many measurements that pertain to the cumulative effects of forest practices, are available in highly accessible formats.

We produce two standard products: *Environmental Statistics*, a database that contains 435 relevant statistics for each of the 18,481 watersheds identified in the BC Ministry of Fisheries' Watershed Atlas; and *Map*

*Folios*, a composite map derived from those input maps most important to the summarization process.

These products can be updated readily when new data become available, as the process for creating them is highly streamlined. The products are also compatible with such office software as Word, Excel, Access, and by map viewing packages including Arc/View.

### Product Description

The *Watersheds BC - Environmental Statistics* provides extensive summary information on many relevant land and resource indicators. This information is summarized in a number of categories for each of the province's

# Technical Tip

watersheds. For example, statistics on roads in a given watershed include the total length of roads in the specific area (Figure 1). The database is available in the common and widely used "dbf" format. All statistics are reported as a direct measurement of area, length, or count, and also as a percentage or density. This allows a meaningful comparison between watersheds of different sizes. Information is available in the following categories:

- **Roads:** length, density, on forest land, by 3 elevation ranges, on steep slopes, within 100 m of a stream, road-stream crossings.
- **Rivers** (both 1:20 000 and 1:50 000 scale): length, on forest land, mainstem, headwaters, by gradient, length logged.
- **Fish:** known salmon, sport and other fish distributions, 6 salmon species and bull trout, distribution on forest land, urban land, agricultural land.
- **Riparian:** area summaries for land use and land cover for all land within 30 metres of a stream.
- **Forest Land Use:** area summaries for forest land use, also characterized by slope classes.
- **Non-forest Land Use:** area summaries of 15 land use classes.
- **Ecology:** summaries of biogeoclimatic and ecoregion classifications.
- **Terrain:** elevation - min, max, mean, standard deviation:
  - slope - summary by 8 categories
  - aspect - summary by 9 categories.

## Product Description

The *Watersheds BC - Map Folios* composite maps indicate some of the most important input map features based on the data used to calculate the Environmental

Statistics. These 1:100 000 scale maps are available in the widely used "JPEG" image format. Spiral bound 11" x 17" books of maps covering 12 regions of B.C. are also available. A portion of an individual map for the Howe Sound area is shown in Figure 2.

## Input GIS Databases

Data from the input maps were summarized to produce the *Environmental Statistics* and the composite maps in the *Map Folios*.

### • Watershed Atlas

The atlas contains the basic units (18,481 watersheds) used for summarizing and presenting the information. It also allows for aggregation from small to medium to major watersheds based on the watershed code. The size of the basic watershed units varies from 50 to 35,000 hectares (5,000 ha. average), with 1600 watersheds covering Vancouver Island, for example.

### • 1:20 000 Base Mapping (TRIM)

Standard base mapping including detailed information on roads, streams and topography (slope, aspect, elevation).

### • 1:250 000 Land Use Mapping (BTM)

Land use and land cover information down to units 15 hectare in size. It identifies 20 broad classes, including such features as Old Growth forest, logging (approx. the last 20 years), urban and agricultural areas, and wetlands.

### • FISS (Fish Information Summary System)

Fish distribution and fish habitat information.

### • Community Watersheds

The location of all community watersheds as defined under the Forest Practices Code.

### • Biogeoclimatic / Ecoregion

Ecological classification information.

### • MinFile

Information on producing mines and other activities related to mining.

### • Crown Land

An overview-level determination of Crown versus private land.

## Applications

These new information products will be useful for a wide range of applications, particularly at the strategic and planning levels. The relevance of these products for a range of diverse applications combines with their comprehensive, easy-to-use format to produce a powerful

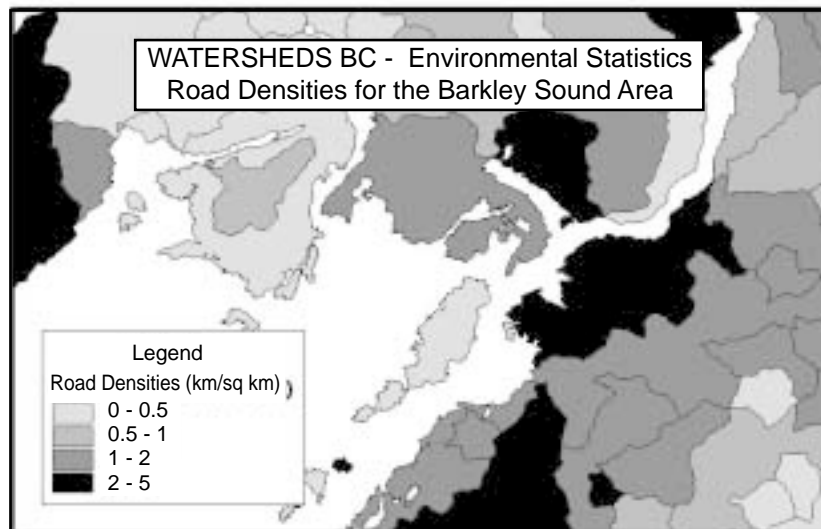


Figure 1. An example of road density information.

# Technical Tip

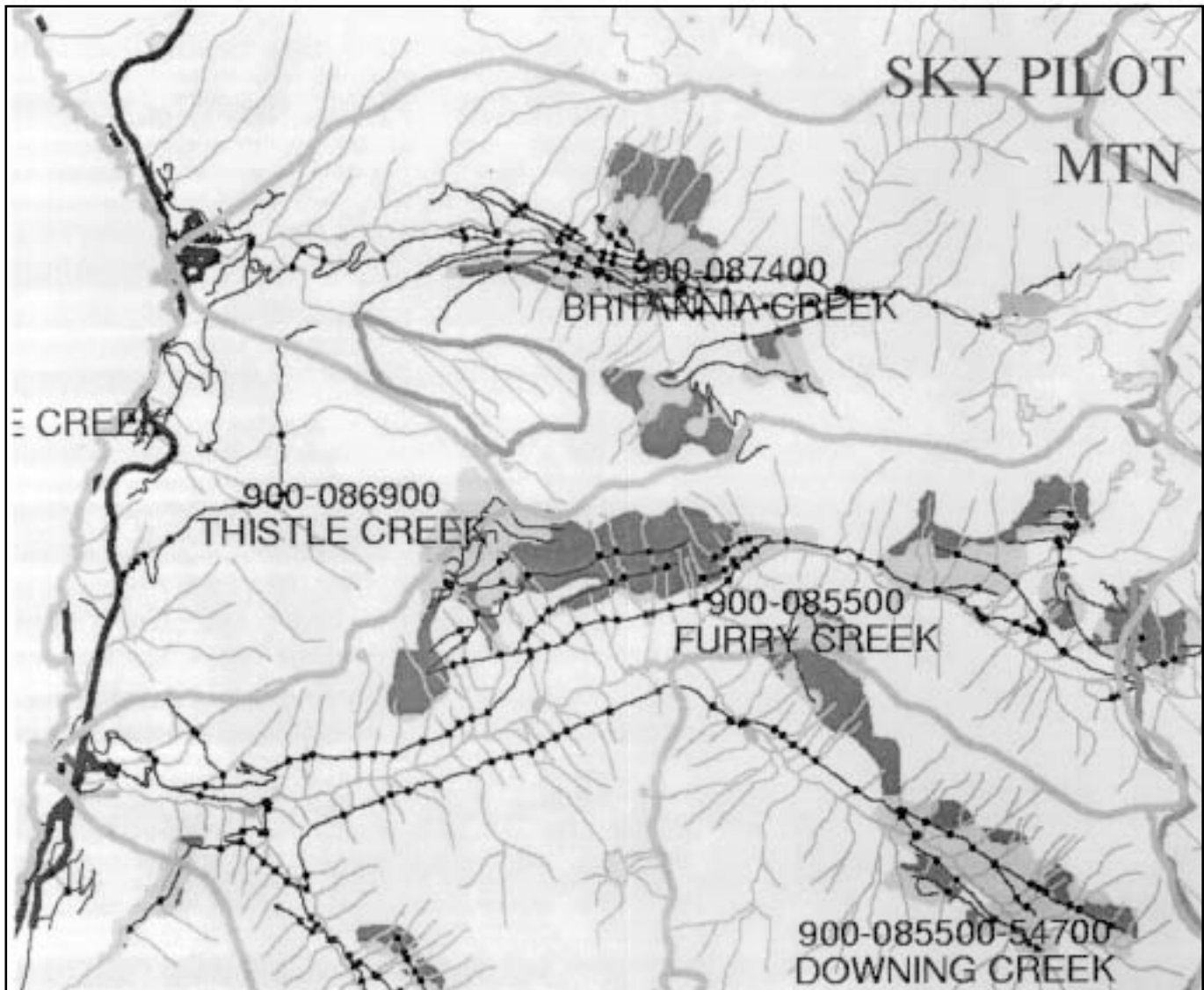


Figure 2. Enlarged view of a portion of the Watersheds BC map of Howe Sound (original in colour).

information tool. Applications include:

- strategic overviews of areas ranging in size from Forest Districts to all of BC,
- comparative analyses of watersheds,
- ranking and prioritizing watersheds based on a wide range of parameters,
- provision of a quantitative basis for expert opinion,
- creation of an extensive (and repeatable) environmental baseline, and
- monitoring, when the input data sets are updated.

The Watersheds BC product will be complete for all of B.C. by November 1999. For further information, please visit the WATERSHEDS BC web site: [www.env.gov.bc.ca/gdbc/Watersheds\\_BC](http://www.env.gov.bc.ca/gdbc/Watersheds_BC)

Please check the website first. Then, if you require further information, contact:

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## Technical Tip

# Channel Rehabilitation: Debris Groins as a Bank Stabilization Option

*Rheal Finnigan and Pat Slaney*

Changes in natural stream channels and banks are only perceptible over a period of years if riparian areas are undisturbed. Past practices of logging or land clearing to streambanks can shift the “dynamic” equilibrium of streams. The resulting effects on some sites, include widening of channels, expansion of bars, and eroding of streambanks. Where widespread, these conditions in a watershed have serious aquatic resource implications, including degraded water quality, reduced fish survivals (or stock productivity), and depressed fish habitat capacity. Such conditions will persist for several decades, at least until mature riparian trees have re-established, or the supply and transport of sediments have stabilized, or both.

In considering restorative measures to accelerate natural recovery, there have been two common approaches. One of these has been to walk away; this should be the first option to consider, based on an appraisal of the following questions:

- are the hillslopes relatively stable, particularly road crossings of gullies?
- does revegetation (e.g. willow growth on bars) indicate that the natural recovery process is in progress?
- what is the steepness of the channel gradient relative to debris-flow risks from upstream?

If there is evidence of an improving trend, or if channel disturbances are localized, there is a second option to consider. B.C.'s Watershed Restoration Program has recently utilized debris groins as a mechanism for stabilizing and even narrowing channels.

Conventional prescriptions for eroding banks have typically been the rip-rap armouring treatments commonly observed along highways and dikes. These treatments are largely unnatural and expensive — as much as \$1000 per lineal meter of streambank. In addition, they frequently feature smooth streamline alignments that efficiently pass water hydraulically but are depleted of fish habitat. Large boulders installed along the toe of armoured banks can dissipate energy and greatly improve habitat capacity. This is often all that can be done to mitigate the aquatic habitat losses that rip-rap treatments may produce. However, debris groins are viable alternatives to rip-rap. Not only do they more closely resemble natural fluvial templates, but they are also more effective in shifting the thalweg sufficiently

to allow sediment deposition and re-vegetation.

### Natural Debris Groin Templates

In mature forested streams, log jams of varying sizes and locations are common stabilizing features. Lateral jams in natural river systems may be up to a kilometer in length. Occasionally, a large jam may span the entire channel. Until recently, this typically has led people to urge their removal. Some of these large jams became the focus of stream restoration endeavors or log salvage revenue: the prevailing view seems to have been, “the only good jam is a removed jam.” While we are all familiar with the large apex jams at the upstream end of bars on split channels, lateral jams at bends often go unnoticed unless they are large. A closer look indicates that there are many types of jams. A common type is one that originates directly from trees that fall into a stream, with their large rootmasses acting as anchors. Some such jams are swept laterally to the stream and provide a natural type of armouring. Others fall upstream or lodge next to other logs or large boulders; these act as “key logs,” producing log matrices that accumulate small and large woody debris. These form lateral jams that deflect the flow away from banks, causing sediment deposition and re-invasion of riparian vegetation. These provide the natural template for “debris groins.” It is important to note that such jams are often associated with lateral scour pools, providing prime fish-holding and rearing sites in all sizes of streams, but especially in medium or larger streams.



Figure 1. Debris groin at the West Kettle River, ballasted to hold ramp-logs against the channel bed.

# Technical Tip

## Applications to Channel Restoration

Over recent years, with the expansion of aquatic restoration efforts, certain limitations were evident. Although we have improved our capability of restoring and rehabilitating fish habitat with reasonable success in stable channels, we have been limited in our effectiveness in accelerating the recovery of logging-distabilized channels. We have frequently walked away from eroding banks, although they were known to be large sources of fine sediments.

Logistically we had been constrained by limited access to very large mature whole trees. Alternatively, we have relied on large boulders for ballast, either those already present in the channel or transported to the site. For debris groins, we prefer to ballast logs to overcome buoyancy by sloping them downward into the bed of the channel. In this way we can transfer the current's frontal drag forces downward towards the bed, as in natural templates for this treatment (Figure 1). Ballasting must be sufficient to counteract buoyancy of logs (see Chapter 9 in

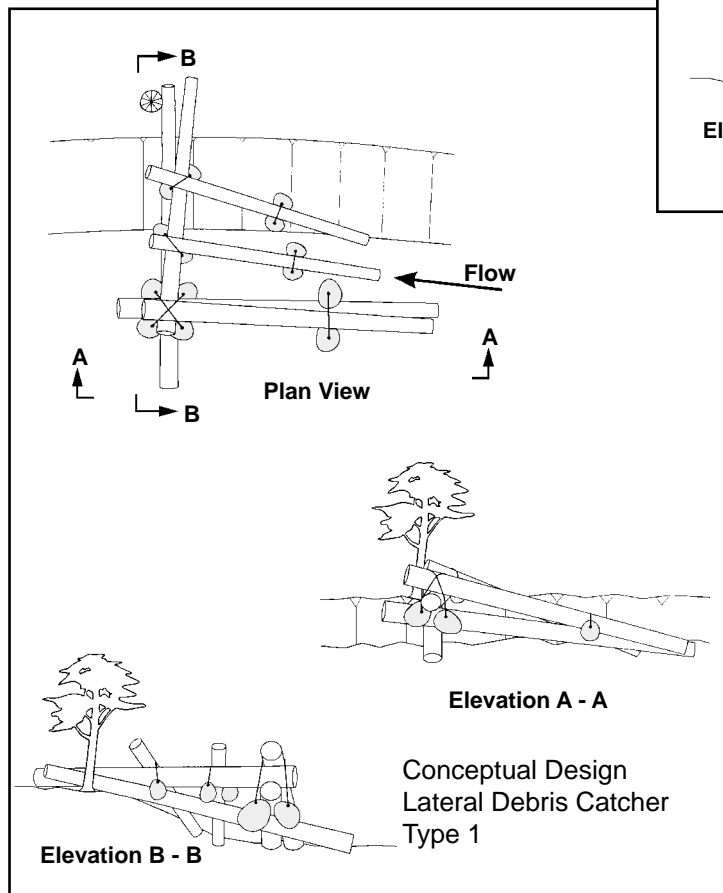


Figure 2. Debris groin type 1 for sites where there are no boulders in the channel to attach logs (Boulders are slung over logs using expoxied solid core 1/2" galvanized cable).

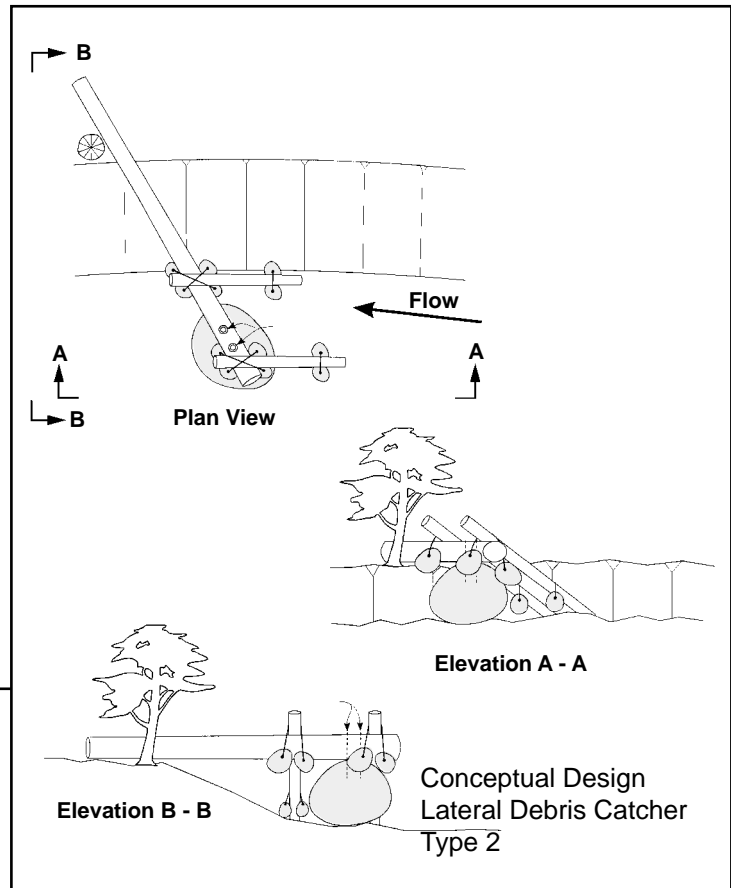


Figure 3. Debris groin type 2 for sites where a large boulder is available in the channel for epoxy cable attachments (Boulders are slung over logs using expoxied solid core).

WRP T.C. No.9). In templates, large rootwads of such trees act as natural anchors so that the smaller ends of the trees are weighted into the substrate. This creates wedges or rakes to capture drifting woody debris. Also, we can strategically place such debris groins in series to stabilize entire eroding bends.

Now, what can we do about fish habitat? The key would be to create some roughness and lateral pool habitat. Following the pattern of certain lateral jams, we could attach whole trees that would then trail downstream. However, this may cause excessive sediment deposition behind the tree, promoting in-filling of habitat. It is therefore not a desirable design feature, unless bank erosion has been excessive and extends for a significant distance. A beneficial alternative is to scrape away the armour layer beside the groin to accelerate the creation of a lateral scour pool that might otherwise take several years to scour naturally. There is no need to excavate below the coarse cobble layer because the substrate

# Technical Tip

is often sandy gravel under the amour. Immediately adjacent and downstream of debris groins, we have observed that scour creates prime habitat.

## Design Features

Figures 2, 3 and 4 show the design features of debris groins. Specifications for materials will vary with stream power, as indicated by channel width and gradient. The width of the debris groin should be adjusted according to the amount the channel has been widened. At Narrowlake Creek, where the stream was widened by 2-3 times, the debris groins were 6 m wide. Structures installed for demonstration in the more constricted channel at Keogh River were only 3 m wide. Height is another important design feature. Debris groins should extend just above bankfull flood levels to prevent trapped woody debris from being washed away at a peak event, as occurred at the Coquitlam River (Figure 5). Some variations in design will also be needed to take advantage of large instream boulders for attachment, or to provide an elevated support for the structural members of the debris groins if the site is along a steep bank. Use of opposing rootwads to provide in-channel height is an option that also creates prime rearing habitat

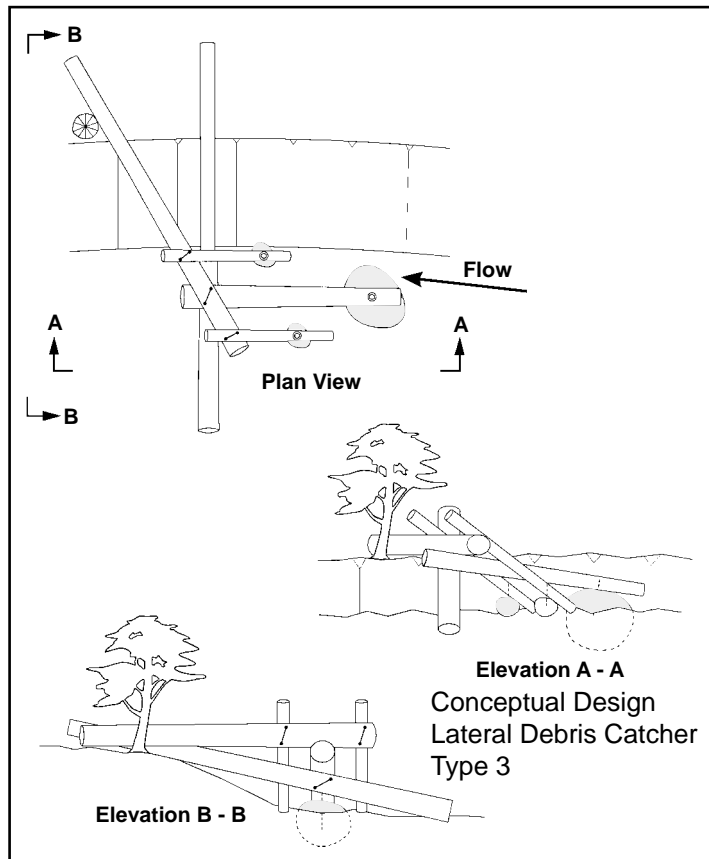


Figure 4. Debris groin type 3 for use at a site where a large boulder is unavailable for the main support log, but are available for ramp logs.



Figure 5. Debris groin at Coquitlam River in winter, 1999. The height of the groin should be just above floodplain height to prevent debris washout.



Figure 6. Debris groin located at a large steep eroding bank. Rootwads are used to gain elevation for the wide ramp of logs constructed at Narrowlake Creek.

(Figure 6). Machine-planted willow clumps to a depth that roots are wetted will also accelerate bank recovery.

## Expanded Applications and Limitations

We are still uncertain about the maximum gradients at which debris groins remain functional, although it is clear that these will vary according to the stability of the watershed and its channels. As we gain more experience, we may find that steep channels (5%), with unraveling banks due to past streambank logging, may be suitable sites, but only if the watershed is relatively stable. However, debris groins are unlikely to remain stable during a debris torrent.

For more information, contact:

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## Conferences

**Where Land Meets Water: Riparian Challenges for the New Millennium.** Oct. 19 - 21, 1999. The Capri Hotel, Red Deer Alberta. For further information, contact <http://www.tucanada.org/riparian99/>.

**Wetlands and Remediation.** Nov. 16, 17, 1999. Salt Lake City, Utah. Hilton Hotel. Sponsored by Battelle, based in Columbus, Ohio.

## Workshops

**Coastal Forest Site Rehabilitation Workshop.** Nov. 16, 17, and 18, 1999 Nanaimo, BC. This year's conference-style workshop will again be a two-day event held at Nanaimo's Port Theatre, 125 Front Street. In addition to the conference, a topical one-day course will be held on November 16 that will be of great interest to conference participants. Conference registration/check-in, complimentary wine and cheese reception, poster session and the opening of the trade show begins at 7:00 pm on November 16, 1999. This workshop is jointly managed by Malaspina University College, Forestry Extension Program and the Forestry Continuing Studies Network. Accommodation: A block of rooms has been reserved for conference participants at the Coast Bastion Inn in Nanaimo. These rooms will be held until October 16, 1999 at which time remaining rooms will be released to the general public on a first come, first served basis. When reserving your guest room, please identify yourself as a Coastal Forest Site Rehabilitation Workshop participant. The hotel phone number is (250)753-6601 or toll free 1-800-6631144.

**Who Should Attend:** If you are an equipment operator, forestry worker, technical or professional involved in watershed restoration, site rehabilitation, reclamation, road deactivation, soil

conservation, stream and fish habitat enhancement and restoration, you will not want to miss this year's workshop! If you wish to exhibit in the Trade Show reserve now by calling Tom Hedekar (see info below).

**Registration and Information:** Registration fees and detailed program information will be available soon. Watch our web page <http://www.mala.bc.ca/ForestEx/index.htm> for more information, or call Tom Hedekar, Forestry Extension Program, Malaspina University College or Jim Rodney, Forestry Continuing Studies Network, at the numbers above.

**Call For Nominations:** Nominations for the annual "Watershed Restoration Award" are now being accepted. If you would like to nominate someone for this prestigious award, please contact Tom Hedekar or Jim Rodney.

## Courses

**Watershed Restoration Program Courses.** Coordinated by the Ministry of Environment and delivered by Forestry Continuing Studies Network, the Watershed Restoration Program (WRP) is an initiative of Forest Renewal BC designed to restore watersheds impacted by past timber harvest activities. In order to meet the mandate of stream restoration, WRP must ensure that appropriate training and skills development is available for those people involved in restoration. This training will provide a series of short courses and workshops on topics relevant to stream restoration. The FCS Network will offer these courses and workshops in multiple locations around the province. Please see the FCSN Website for further information and/or course descriptions: [www.fcsn.bc.ca](http://www.fcsn.bc.ca). To register: See [www.fcsn.bc.ca](http://www.fcsn.bc.ca) for a registration form. For further information, call Jennifer Smith - Executive Assistant 604-222-9157, Fax: 604-222-1730 E-mail: [jdwsmith@interchange.ubc.ca](mailto:jdwsmith@interchange.ubc.ca).

### Introductory Courses:

The following courses are appropriate for those working, or preparing to work, at all levels of watershed restoration projects.

**Riparian Assessment & Prescriptions Procedures.** October 12 - 14, 1999 Chilliwack. October 18 - 20, 1999 Prince George.

### Advanced Courses:

**Channel Conditions and Prescriptions Workshop.** October 6 & 7, 1999 Chilliwack. October 13 and 14, 1999 Prince George.

**Advanced Fish Habitat Rehabilitation Procedures.** In-Stream Structures & Large Woody Debris October 18 - 20, 1999 Port Hardy.

**Advanced Fish Habitat Rehabilitation Procedures.** Off-Channel Habitat, October 26-27, 1999 Chilliwack.

The following courses are offered through Malaspina College and the Forestry Continuing Studies Network. For further information contact Tom Hedekar at (250)741-2597 or <http://www.mala.bc.ca/www/ForestEx/index.html>.

**Integrated Resources Management.** Alternate weekends: Oct. 2 - Dec. 18 Nanaimo.

**Introduction to Ecoforestry.** Oct. 7, 14, 16, 23, Nanaimo.

**Urban Tree Management-Reducing Risk & Liability.** Oct. 21 & 22 Nanaimo.

**Helicopter Logging Project Management.** Oct. 28 & 29 Nanaimo

**Distance Education in Forestry and Range.** The following university credit courses are offered in the years 1999 and 2000, through Distance Education in conjunction with the Continuing Education Coordinating Committee for Forestry and Range (Oregon and Washington).

Program: **Rangeland Resources**  
University: OSU-DRR  
Telephone: 541-737-3341

# Update

## Natural Resource Economics

WSU-EDP  
800-222-4978

## Forest Insects

WSU-EDP  
800-222-4978

## Forest Pest Management

WSU-EDP  
800-222-4978

## Natural Resources and Society

WSU-EDP  
800-222-4978

WEBSITES for more up-to-date information: OSU-DRR: <http://www.osu.orst.edu/dept/range>  
WSU-EDP: <http://www.eus.wsu.edu/edp/>

The following short courses are offered through Distance Education in conjunction with the Continuing Education Coordinating Committee for Forestry and Range (Oregon and Washington).

Nov. 2-4, 1999 **Views from the Ridgetop: Considerations for Planning at the Landscape Scale.** Vancouver Washington, PNW, USDA Forest Service. Pacific Northwest Research Station. Tel: (503) 808-2599

Mar 6 - 15, 2000 **Decision Making and Systems Thinking for Natural Resource Professionals.** Corvallis, Oregon. Tel: 541-737-2329

June 5 -14, 2000 **Integrated Problem Solving for Natural Resource Professionals.** Eatonville, Washington. Tel: 206-543-0867

## Publications

The following new publications are now available through Queen's Printer (please refer to sidebar for information about ordering):

D.O. Zaldokas (Editor.) 1999. *Annual Compendium of Aquatic Rehabilitation Projects for the Watershed Restoration Program 1998-1999.* Province of B.C., Ministry of Environment, Lands and

Parks, and Ministry of Forests. Watershed Restoration Project Report No. 13. 378 pp.

M.A. Parker. 1999. *Fish Passage - Culvert Inspection Procedures.* Watershed Restoration Technical Circular No.11. 51 pp.

C.N.Blackwell, C.R.Picard, M.Foy. 1999. *Smolt Productivity of Off-channel Habitat in the Chilliwack River Watershed.* Watershed Restoration Project Report No. 14. 46 pp.

## Magazine

In Australia there is a magazine with very similar objectives to Streamline. This magazine is called RipRap, and focuses on Riparian Lands Management. The latest issue of RipRap features articles on Managing and rehabilitating riparian vegetation, managing floodplain vegetation in Cooper Creek, and fire management on tropical savannas. There is a comparative chart summarizing and comparing natural regeneration to direct seeding to planting seedlings. There is also an article on a publication on Virtual Fencing, which compares on-animal devices with a virtual exclusion zone that signals pre-conditioned animals as they approach the radio wire to turn around and walk in the opposite direction. Apparently two North American companies have intentions to develop similar devices. RipRap is produced by the Land & Water Resources, Research and Development Corporation, edited by Dr. Siwan Lovett, Program Coordinator of River Restoration and Riparian Lands. For more information, or to contribute to this publication, please direct your enquiries to: LWRRDC, GPO Box 2182, Canberra ACT 2601, Tel:02-6257-3379 Fax: 02-6257-3420 e-mail: [public@lwrrdc.gov.au](mailto:public@lwrrdc.gov.au) or check their website: [www.rivers.gov.au](http://www.rivers.gov.au). ▲

WRP's new motto:  
"Healthy Watersheds for Healthy Communities"

## Streamline

Published and Produced by:  
**Watershed Restoration Program**

B.C. Ministry of Environment,  
2204 Main Mall, Vancouver, B.C.  
V6T 1Z4 Fax: 604-660-1849

Editor: Donna Underhill  
Fax: 604-224-6880  
E-mail: [dbuirinc@axion.net](mailto:dbuirinc@axion.net)  
Design: Diana McPhail

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. We rely on our readers' participation. Please send articles and project descriptions (with relevant photos and drawings), as well as information for our "Update" section. We reserve the right to edit submissions for appropriate content, style, and relevance to the Technical Bulletin.

WRP Publications, Technical Circulars and Videos may be ordered from:

**Queens Printer**  
PO Box 9452 Stn Prov Govt  
Victoria B.C. V8W 9V7  
Tel: 1-800-663-6105; or 250-387-6409  
Fax: 250-387-0388

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Forest Renewal BC

