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Predicting Channel Change in Narrowlake Creek in the Central Interior: A Tool for Watershed Protection and Restoration.

Andrew Wilson

Introduction

The interaction of stream channel morphology and riparian vegetation is of fundamental interest to aquatic and terrestrial resource managers and the Watershed Restoration Program (WRP). While the biological consequences of riparian logging along fish-bearing streams are well documented (e.g. Meehan 1991, Murphy 1995), the longer-term morphological changes that occur in stream channels following streamside harvesting are less well understood. Hydrological models that predict channel change may provide tools for understanding this linkage and may aid in protecting watersheds and developing watershed restoration prescriptions. As a result of complex and extensive channel changes that have occurred at Narrowlake Creek following floodplain forest harvesting (Soto et al. 1997), stream restoration there has involved three treatments. These included bar stabilization and revegetation, streambank stabilization, riparian restoration, bridge replacement of culverts, and instream habitat rehabilitation.

Morphological change in stream channels may be a result of streamside forest harvesting. Millar (2000) developed a model to predict stream channel morphology based on the condition of riparian vegetation. This model was tested on a portion of Slesse Creek (a tributary to the Chilliwack River) downstream of an old-growth area in the headwaters. The riparian area was extensively logged in the 1950s and 1960s, and has subsequently become parkland. The model predicted that in the presence of dense riparian vegetation, Slesse Creek would form a meandering channel morphology, and that in the absence of dense riparian vegetation it would form a braided channel. These predictions were then confirmed using pre- and post-logging air photos.

The predictive model developed by Millar is useful for natural resource managers and watershed restoration practitioners interested in determining the sensitivity of stream channels to upslope activities or for developing restorative prescriptions. While the model was found to apply to south-coastal watersheds such as Slesse Creek, there was no similar example of streamside forest harvesting affecting stream morphology in the Central Interior of British Columbia. This analysis seeks to confirm that Millar's model applies to watersheds in the Central Interior by applying it to Narrowlake Creek, a WRP demonstration watershed located 80 km south-east of Prince George.

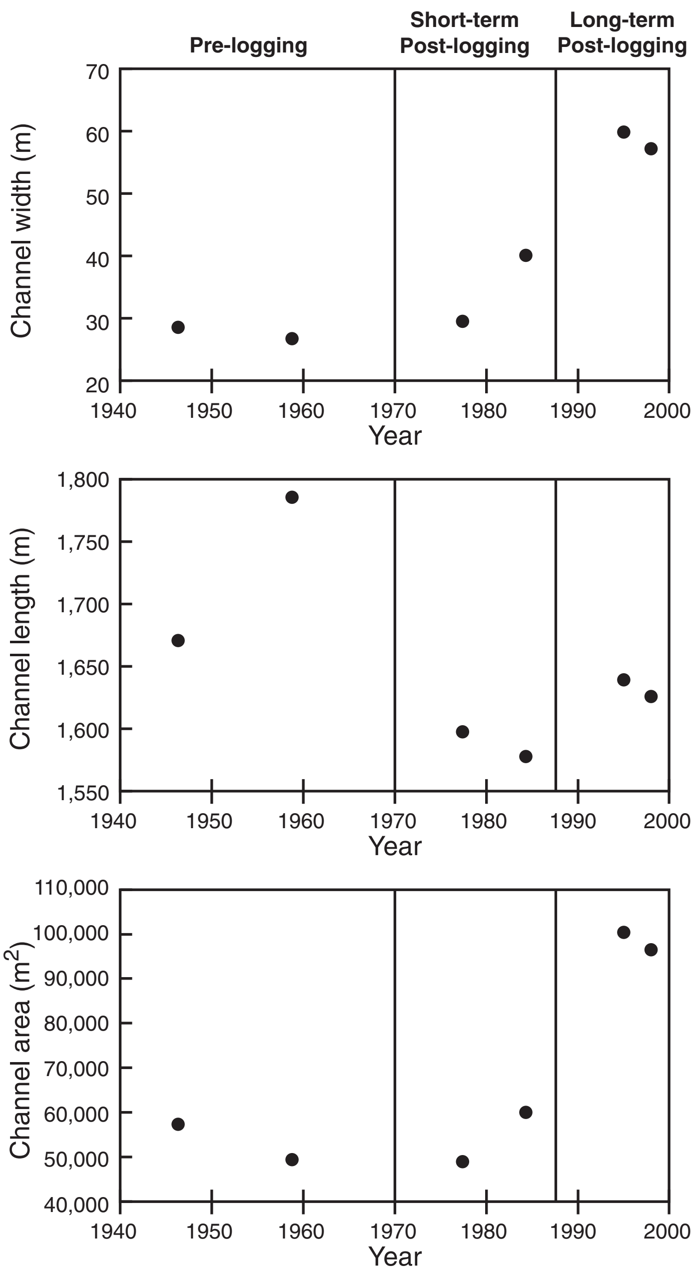

Figure 1. Narrowlake Creek treatment reach 3: measures of channel change over time.

Narrowlake Creek

Narrowlake Creek, a tributary to the Willow River, was extensively logged in the 1960s and 70s. Streamside vegetation was removed from much of the lower watershed, with 80% of the fish-bearing reaches harvested of timber without adequate riparian buffers (Berry, 1996). The majority of early logging was conducted with ground skidders, which resulted in high levels of floodplain disturbance in the form of road development, stream crossings, and landing construction.

The active channel of Narrowlake Creek has changed following streamside forest harvesting. Analysis of six sets of historical airphotos from 1946 to 1997 indicates that measures of bankfull width, channel length and area have all changed over time (Figure 1). Pre- and post-streamside logging air photos of Narrowlake Creek from 1946 and 1997 definitively illustrate the widening that has occurred over time (Figure 2). Thus, it would appear that the channel morphology of Narrowlake Creek has changed from a pre-logging *meandering* stream channel to a post-logging morphology better classified as a *braided* channel.

The pre- and post-logging change in channel morphology for Narrowlake Creek is similar to that of Slesse Creek. Millar (2000) identifies Slesse Creek's pre-logging channel morphology as meandering, while the post-logging morphology is braided. Thus, visual inspection suggests that the type of channel response to removal of streamside vegetation is consistent in both central interior and south coastal watersheds .

The Millar Model

Millar (2000) refined the transition slope equation initially developed by Leopold and Wolman (1957) by including the effect of riparian vegetation condition on transition slope. The removal of streamside vegetation decreases the bank vegetation friction angle, as roots decay and soil cohesion is lost. The decrease in friction angle may lower the transition slope, thus shifting morphology from a meandering to a braided state. Millar's modified equation for calculating transition slope (S*) is expressed as:

$$S^* = 0.0002 \cdot (D_{50})^{0.61} \cdot (\phi')^{1.75} \cdot (Q)^{-0.25}$$

where Q is bankfull discharge, D_{50} is median streambank and streambed substrate diameter, and ϕ' is bank sheer angle. If the actual channel slope (S) is greater than the transition slope (S*), the model predicts that the stream channel will have a *braided* morphology. If it is less than the transition slope, the model predicts a *meandering* morphology.

Millar's (2000) predictive model of channel morphology based on riparian vegetation condition can be applied

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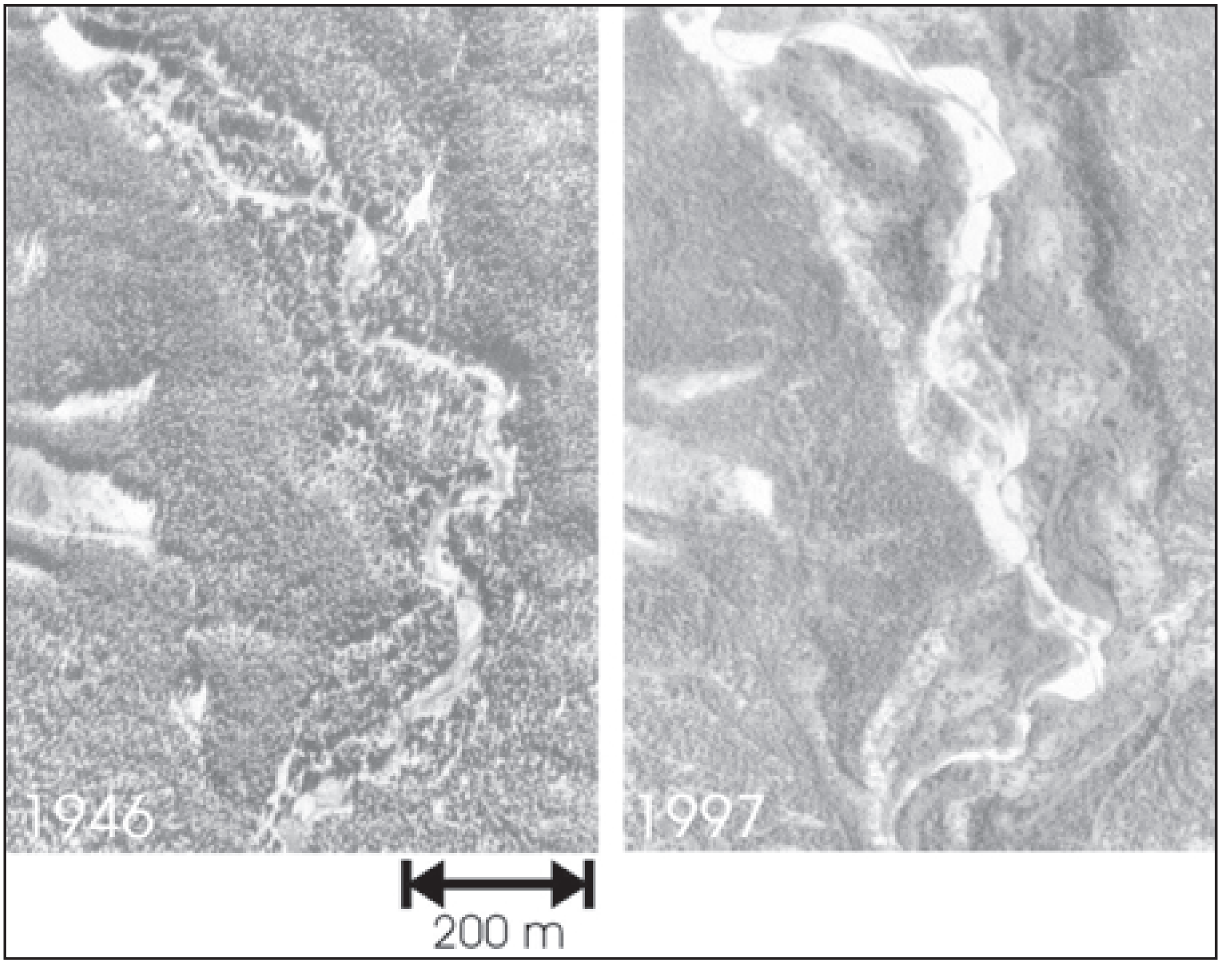

Figure 2. A comparison of aerial photographs taken in 1946 and 1997 of Narrowlake Creek treatment reach 3 indicates the change in channel morphology following removal of riparian vegetation through streamside logging.

Year	Bank shear angle (O') degrees	Channel slope (S)	Bankfull discharge (Q) m^3s^{-1}	Median substrate (D_{50}) m	Transition slope (S*)	Predicted	Observed
1946	70	0.007	31.1	0.058	0.025	M	M
1997	40	0.007	31.1	0.058	0.009	M	B

Figure 3. Variables used to determine the pre– and post–streamside logging transition slope for Narrowlake Creek (M is for meandering, B is for braided morphology).

to Narrowlake Creek. Data required to calculate transition slope (S*) are included in Figure 3. Transition slope analysis for Narrowlake Creek was completed for two values of riparian vegetation condition using bank sheer angles of 70° for pre-logging and 40° for post-logging conditions. These values are derived from values in the literature of bank sheer angles for braided and meandering rivers (Millar, 2000).

Model Output

The channel morphology prediction model successfully predicted channel conditions for Slesse Creek, as in Millar (2000), but less successfully for Narrowlake Creek (Figure 3). Millar (2000) indicates that streams can be classified into three planform stability categories:

- Region I streams are predicted to meander regardless of riparian condition;

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- Region II streams are predicted to change morphology depending on riparian vegetation;
- Region III streams are predicted to braid regardless of riparian condition.

Transition areas exist around the margins of these classifications where streams have somewhat unpredictable responses to altered riparian vegetation condition. Thus Slesse Creek clearly represents a Region II stream susceptible to morphologic change following removal of streamside vegetation, whereas Narrowlake Creek represents a Region I stream, but within a morphology transition area between the two regions (Figure 4). However, the development of large expanses of gravel bar, multiple channels and eroding streambanks visible on post-logging air photos (Figure 2) suggests that Narrowlake Creek has changed from a meandering to a braided channel morphology, contrary to the model prediction.

Cumulative impacts within the Narrowlake Creek watershed may account for the discrepancy between the model output and the observations from air photos. Road development throughout the floodplain, numerous stream crossings, construction of landings within the stream flood channel, large scale removal of riparian vegetation, channel avulsions, high flows and localised forest fires have combined to alter conditions within the floodplain. For example, a mainline road crossing has repeatedly failed owing to infilling of four culverts with bedload sediment. Sediment supply rates in the pre- and post-logging air photos appear to have changed as conditions upstream have been altered by forest

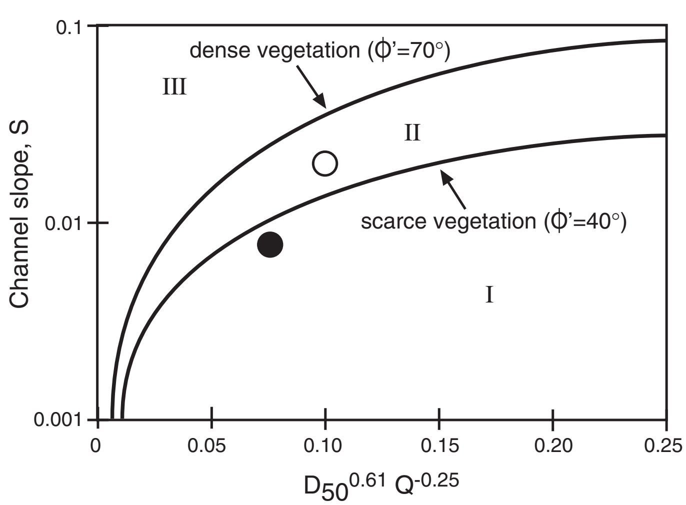

Figure 4. Planform stability diagram adapted from Millar (2000) indicating the position of Slesse Creek (○) and Narrowlake Creek (●) relative to the three stability regions.

harvesting and natural disturbances. These conditions are the opposite of those in Slesse Creek, which has been maintained in a pristine old-growth condition upstream of the logged area studied by Millar (2000). The lack of change in sediment supply, avulsions, or upstream conditions in Slesse Creek may have altered the channel response to streamside forest harvesting as compared to Narrowlake Creek.

While a portion of the channel change in Narrowlake Creek may be due to altered bank friction angle, as hypothesised by Millar (2000), the exact proportion of change attributable to riparian logging versus any other impact is impossible to determine. The effects of floodplain impacts on the Narrowlake stream channel are confounding and, to some degree, synergistic. For example, further historical air photo study has revealed that channel avulsions have occurred in the vicinity of old logging roads and skid trails, and removal of riparian vegetation has compromised the capability of the stream channel to recover to pre-disturbance conditions following these avulsions. The lack of floodplain roughness resulting from lost mature vegetation hinders channel recovery and promotes the long-term maintenance of braided channel conditions, unless aggressive restoration treatments are successful at replacing or supplementing these fluvial-resistive structuring elements.

Slesse Creek may not have undergone the level of disturbance over as great an area of floodplain as Narrowlake Creek. As such, successfully predicting channel change expressly due to changing riparian condition is likely much more straightforward for Slesse Creek than Narrowlake Creek. However, the tendency of the model to not predict channel change for a transitional watershed, is an indication that from a watershed restoration or management perspective, additional variables need to be considered to account for cumulative impacts to the floodplain.

A cursory analysis of the model predictions for transitional watersheds such as Narrowlake Creek, indicates the need for cautionary interpretation either for watershed protection or restoration. If the watershed were under consideration for timber harvest, the output of the model might imply lesser restrictions on floodplain logging for protection of the stream channel because its prediction is for maintenance of meandering morphology. However, the results of a liberal approach would be the prediction of a widened channel as confirmed in Figure 1 and visible on air photos of the channel (Figure 2). Furthermore, the prediction from the model suggests that channel rehabilitation prescriptions should be focused at a

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meandering stream morphology. These are not appropriate for the recovery of braided sections of the creek that require a long-term process approach to prescriptions that emphasise floodplain restoration, as has in fact been undertaken (see Soto et al. 1997 for a description of treatments). As excessive braiding reduces significant fish holding pools and can lead to excessive stream temperatures (Narrowlake Creek summer temperatures can exceed 25°C as opposed to a target of 20°C), focusing only on restoration of meandering portions of streams may have serious consequences for the achievement of restoration objectives.

Conclusions

The model for predicting morphologic change developed by Millar (2000) indicated that Narrowlake Creek is a *transitional* watershed, but it was not sensitive enough to accurately predict the apparent shift from a *meandering* to a *braided* morphology. This reinforces the notion that streamside forest harvesting does affect stream channels in the Central Interior, though not necessarily in a way that can be readily predicted from hydrology models or empirical analysis. While it is impossible to quantify the exact amount of channel widening in Narrowlake Creek directly associated with forest harvesting, the cumulative effects of logging and natural disturbance have led to channel change throughout the logged portions of the watershed. The predictive model Millar (2000) developed is an excellent tool for Slesse Creek, and will be important for future prescription development in watersheds that clearly fall within the Region II planform stability category. However, for *transitional* systems like Narrowlake Creek, model predictions should indicate that cautionary measures for either floodplain protection or restoration must be undertaken.

The linkages between logging activity and channel morphology are complicated. Predictive models have great value as tools that can be used to assist in successful watershed protection and restoration, but it will be important that they not be used without watershed analyses, particularly in the case of transitional systems. The biological implications of the Millar (2000) model, as indicated by the Narrowlake Creek and Slesse Creek case studies, are profound and worth the effort of further analyses and adjustment to provide a useful tool for both watershed protection and restoration.

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