Assessing impacts of a new flow regime along the lower Duncan River, British Columbia

Presenter: **Dr. Mary Louise Polzin**, Senior Ecologist/Riparian Specialist, VAST Resource Solutions Inc., Cranbrook, BC
Email: MaryLouise.Polzin@vastresources.com

Co-Author: **Dr. Stewart B. Rood,** Department of Biological Sciences, University of Lethbridge, AB
Email: rood@uleth.ca

Introduction

The Duncan River flows into Kootenay Lake and was dammed in 1967 as part of the transboundary Columbia River Treaty. The Duncan Dam has no hydroelectric facility therefore allows for greater flexibility for downstream flow management. Following a Water Use Planning (WUP) process, a new environmental flow regime was implemented in 2008 with Alternative S73 (Alt S73) that is intended to benefit black cottonwoods (*Populus trichocarpa* Torrey & Gray) and riparian woodlands, as well as Gerrard rainbow trout and Kokanee salmon. To assess responses to river damming and flow regulation with Alt 73, we undertook field studies from 2009 through 2018 to investigate channel and riparian responses. We applied a paired-comparison study design to contrast hydrology, channel form, bank profiles, surface sediments and vegetation along the regulated reach of the lower Duncan River with the unregulated Lardeau River (the reference reach) which joins the Duncan River downstream of Duncan Dam.

Following damming, substantial accumulation of cobbles, gravels, sands, and large woody debris has occurred along the lower Duncan River. This contrasts with the physical processes downstream from most dams, where alluvial sediments and woody debris are depleted due to trapping in the slack-water reservoir. For the lower Duncan River, extensive sediment and woody debris inputs persist from the free-flowing Lardeau River. The attenuation of high flows from the upper Duncan River has diminished the transport capacity below the Duncan Dam and downstream to Kootenay Lake.

Location

The lower Duncan River is located in the Columbia Mountains region in southeastern British Columbia. It flows south out of the 45 km-long Duncan Reservoir (includes the former Duncan Lake which was 15 km long), which was impounded by the Duncan Dam in 1967. Approximately 300 m downstream from the Dam, the lower Duncan River is joined by the free-flowing Lardeau River and the combined rivers continue south for approximately 11 km to Kootenay Lake, where a broad delta is formed. Midway along, in Segment 4, the lower Duncan River channel is joined by three free-flowing tributaries: Meadow, Hamill and Cooper creeks. Meadow Creek includes an artificial channel producing a low gradient stream, contributing small amounts of sediment and woody debris during spring high water. At their confluence, the Duncan River flows into Meadow Creek creating a back-water effect during high water. This backup of water into the Meadow Creek channel has been documented to occur past the second meander point bar upstream of the confluence since 2009 and earlier by Miles (2002). In contrast to Meadow Creek, Hamill and Cooper creeks are high gradient streams that contribute substantial sediment and large woody debris to the lower Duncan River (Figure 1).

The Lardeau River was selected as the reference reach due to its proximity to the lower Duncan River and its similar channel reaches. The Lardeau River flows out of a nearly parallel watershed with a higher gradient and lower discharge volume compared to the Duncan River. The Lardeau River study reach starts approximately 3 km upstream of the confluence with the lower Duncan River and extends upstream for approximately 11 km (Figure 1).

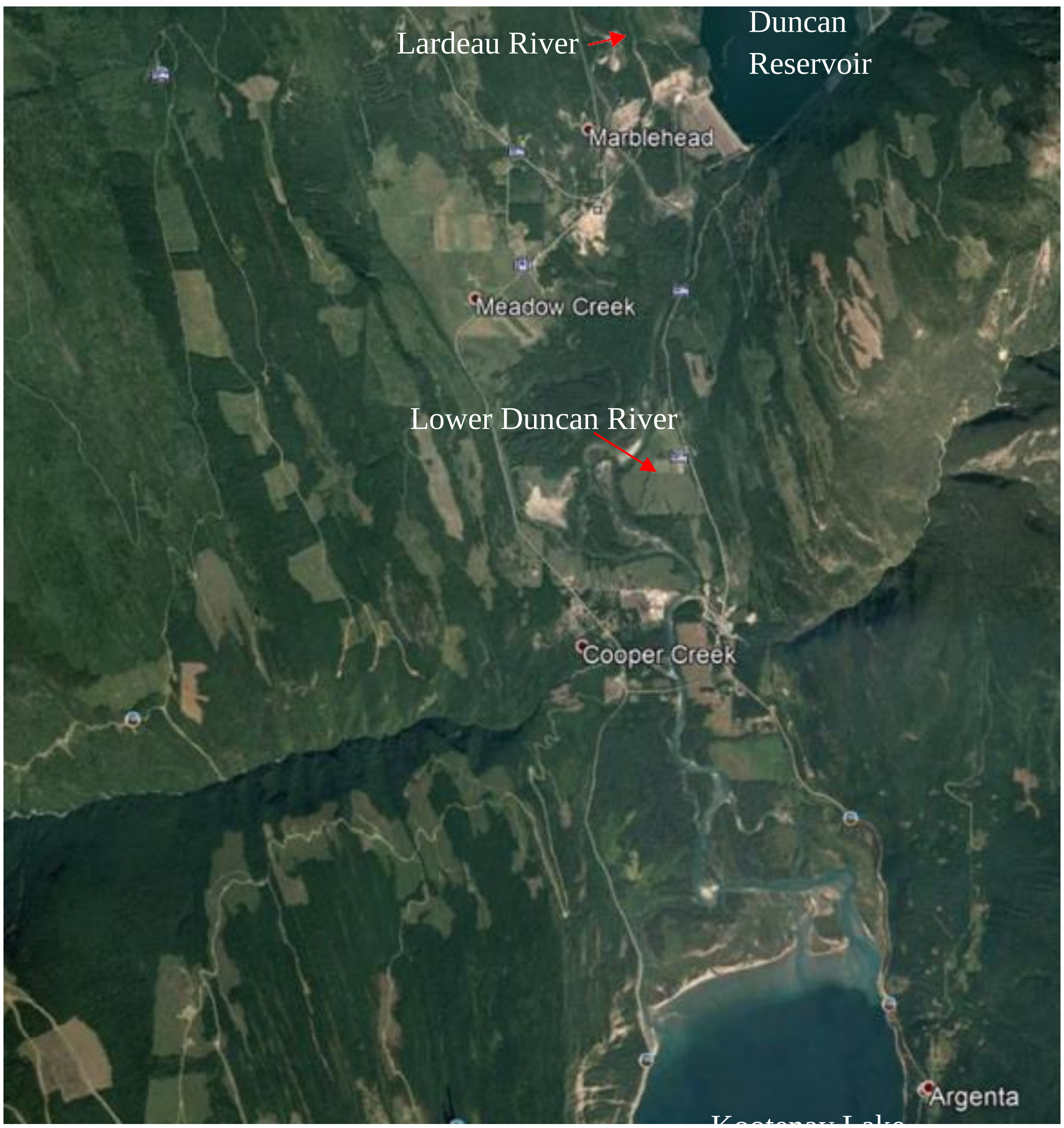

Figure 1: Location of the lower Duncan River and the lower Lardeau River (Google Maps).

Methods

To monitor the effects of the new flow regime Alt S73 on vegetation colonization dynamics, we used three methods of data collection.

1. Established belt transects with three quadrat sizes to assess plant occurrences and abundance.
   - Large quadrats (50 m^2 area) were used for woody vegetation greater than 2 m tall (referred to as Tree quadrats).
   - Medium quadrats (10 m^2 area) were used for woody vegetation less than or equal to 2 m tall (referred to as Shrub quadrats).
   - Small quadrats (1 m^2 area) were used for graminoids, forbs, moss, ferns, and cottonwood seedlings.

   Transects were permanent and re-established in the same place every year of monitoring.
2. Aerial photography of the lower Duncan and Lardeau reaches (100 m on either side of the channel)
   - Aerial photograph occurred every third year – 2009, 2012, 2015, and 2018.
3. Pre-Alt S73 sampling within delineated sites.
   - A ½ inch increment borer was used to sample black cottonwood trees within random generated 100 m^2 plots in 2016.

Three hypotheses were assessed:

H$_{01}$: There is no change in black cottonwood establishment or survival resulting from the implementation of Alt S73;

H$_{02}$: Black cottonwood establishment and survival along the lower Duncan River are not affected by the river flow regime; and

H$_{03}$: The river flow regime is the primary driver of black cottonwood establishment and survival along the lower Duncan River;

Results

We have provided the detailed results and analyses in yearly reports during the decade long study (Polzin and others, 2010 to 2018), and the following summarizes the findings relative to the specific hypotheses.

H$_{01}$: There is no change in black cottonwood establishment or survival resulting from the implementation of Alt S73.

The null hypothesis was rejected. There was a significant decline in black cottonwood survival compared to 10 and 20 years previous to Alt S73 during the previous flow regime. There was no data for establishment pre-Alt S73 so it was dropped from the null hypothesis.

Survival pre-Alt S73 data was collected through the extensive sampling and results of tree core data for pre-Alt S73 which gives cottonwood recruitment stems per hectare for pre-Alt S73 flow regime. However, we do not know what the pre-Alt S73 flow regime impact to survival would have been if it was applied from 2008 to 2018. Tree core data for the pre-Alt S73 results confirms that the H_{O1} as written is rejected. We are not comparing the previous flow on the current recruitment area.

An alternate hypothesis would relate to the DDMMON#8-1 study design, with the paired comparison of the regulated lower Duncan versus free flowing Lardeau River reaches. With this comparison, revisions to the null Hypothesis 1 would be:

H_{O1}: There is no difference in black cottonwood establishment or survival between the lower Duncan River with Alt S73 and the free flow Lardeau River.

This hypothesis is testable with DDMON#8-1 and the null hypothesis, H_{O1} is rejected. Generally, the patterns and dynamics of cottonwood seedling establishment and survival were very similar along the Duncan and Lardeau Rivers. This was a favorable outcome because the reference reach of the Lardeau is free flowing and with the natural flow paradigm it would thus be generally assessed as ecologically healthy.

However, there were some significant differences between the two river reaches. With the artificially prolonged high flow of 2012, there was complete mortality of second and third year seedlings and extremely low establishment. There was substantial seedling recruitment in the following three years resulting from the benefit of the extensive, barren colonization surfaces created by the high flow events.

A second difference arose with the drought interval and especially the more severe drought year of 2017. During the drought stress through August, some flow augmentation was provided by release from the Duncan Dam and this increased the survival of established second and third year cottonwood seedlings, relative to the lower flow along the Lardeau River.

Thus, the study indicates that cottonwood seedling establishment and survival were quite similar along the regulated and free flowing river reaches but there were some significant differences in particular years and these were both negative and positive with respect to both establishment and survival.

H$_{02}$: Black cottonwood establishment and survival along the lower Duncan River are not affected by the river flow regime

The H_{02} was rejected as there has been a significant decrease in the establishment and survival of black cottonwood correlated to the river flow regime. Particularly for the 2012 flow regime over the growing season. There have been moderate increases in survival rates compared to the reference reach for some years with low precipitation and high daily temperatures during the summer months. When the regulated flow regime was high enough it offset some drought mortality during dry, hot summers and not so high as to induce inundation mortality. When the regulated flows were low during dry, hot summers, survival was similar along the low Duncan River to the Lardeau River.

H$_{03}$: The river flow regime is the primary driver of black cottonwood establishment and survival along the lower Duncan River.

The results from DDMON#8-1 indicate that rivers are primary drivers of cottonwood establishment and survival but establishment and survival are also substantially influenced by weather. Therefore, H_{03} was accepted recognizing that while the river is the primary driver, weather plays an important influence.

In drier, semi-arid or arid regions such as the American southwest or the Great Plains, there are tighter associations between river flows and cottonwood recruitment. In the wetter Pacific Northwest, rain is more abundant and this can promote seed dispersal and enable seedling establishment even in positions that were not saturated with water from the receding river or from the capillary fringe above the alluvial groundwater table. Rains through the summer provide alternate water sources for riparian cottonwoods, including seedlings. As well, temperature and humidity, and subsequently the dryness or vapor pressure deficient, largely determines the extent of drought stress, which provides a major influence on seedling survival.

Conclusion

Over the study decade, there was extensive interannual variation and seasonal patterns were strongly influenced by rainfall patterns; this contrasts to some observations along rivers in drier regions (Williams and Wolman 1984, Dunne 1988, Debano and Schmidt 1990, Rood and Mahoney 1995, Polzin 1998). We observed that seedling survival was strongly impacted by sediment deposition and scour, emphasizing the importance of fluvial geomorphic processes. Moreover, there was a very close correspondence between the alluvial groundwater level and river stage, demonstrating a high degree of connectivity within the riparian colonization zones. From the decade long study, the results reveal mechanistic relationships between river flow regime, sediment dynamics, seedling colonization, and the persistence of riparian vegetation along the lower Duncan River. The study also revealed that during drought intervals, when weather is especially influential, river flow augmentation can be especially beneficial.

The Duncan River study provides useful insights towards the development of environmental flow regimes for other regulated rivers of the North American Pacific Northwest especially in humid reaches. It may be relevant for semi-arid systems but that was not tested during this study.

References

Debano, L.F., and L.J. Schmidt. 1990. Potential for enhancing riparian habitat in the southwestern United States with watershed practices, *Forest Ecology and Management*, **33**: 385-403.

Dunne, T. 1988. Geomorphological contributions to flood-control planning, *Flood Geomorphology*, V.R. Baler, R.C. Kochel, and P.C. Patton, (eds). John Wiley & Sons, New York, pp. 421-437.

Miles, M. and Associates. 2002. Channel stability assessment, Lower Duncan River. Report for project 0207 prepared for BC Hydro and Power Authority, Castlegar.

Polzin, M.L. 1998. *River and Riparian Dynamics and Black Cottonwoods in the Kootenay River Basin, British Columbia and Montana.* M.Sc. thesis, University of Lethbridge, Alberta, 224 pp.

Polzin, M.L., and others (one or more of: S.B. Rood, B. Herbison, K.M. Gill) (2010), (2011), (2013), (2014), (2015), (2016), (2017), (2018) DDMMON-8-1 Lower Duncan River Riparian Cottonwood Monitoring.

These reports for BC Hydro are posted on their website:

https://www.bchydro.com/about/sustainability/conservation/water_use_planning/southern_interior/duncan_dam.html

Rood, S.B., and J.M. Mahoney, 1995. River damming and riparian cottonwoods along the Marias River, Montana. *Rivers* **5**:195-205.

Williams G.P., and M.G. Wolman. 1984. Downstream effects of dams on alluvial rivers, Geological Survey Professional Paper 1286, United States Government Printing Office, Washington, PP-83.

Regulated Rivers II: Science, Restoration, and Management of Altered Riverine Environments

May 8-9, 2019
Nelson, British Columbia
Canada

Columbia Mountains Institute of Applied Ecology