Duhamel Creek Hydrogeomorphic Risk Assessment

APEX FILE HA-14-KL-01

Duhamel Creek at beaver-dam wetland complex (Site 14-12)

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1. Introduction

Mr. Tyler Hodgkinson R.P.F., Woodlands Manager for Kalesnikoff Lumber Co. Ltd., Thrums, BC, requested that Kim Green P.Geo., PhD of Apex Geoscience Consultants Ltd. (Apex) Undertake a hydrogeomorphic assessment of the Duhamel watershed to provide guidance for forest management. Duhamel Creek is designated as a community watershed for the Six-Mile Water Users Association. The objectives set by government for water in community watersheds (From; Forest and Range Practices Act: FOREST PLANNING AND PRACTICES REGULATION B.C. Reg. 14/2004, O.C. 17/2004) state that forest activities must not cause cumulative hydrological effects that result in a material adverse impact on the quantity of water or the timing of the flow of the water to the waterworks, or a material adverse impact on human health (i.e., water quality) that cannot be addressed by water treatment.

This report is intended to assess the likelihood of adverse material impacts to water quality and quantity of flows at the intake associated with harvesting in the Duhamel Creek Watershed. The report includes an analysis of the forestry related changes in flood frequency that could negatively impact water quality and quantity at the intake on the fan of Duhamel Creek. The risk assessment procedure outlined in B.C. MFLNR Land Management Handbook 61 *Managing Forested Watersheds for Hydrogeomorphic Risk on Fans* provides the framework for the analysis presented in this report.

2. Background

Past Studies

Previous watershed level studies undertaken in Duhamel Creek include:

- Duhamel Creek Channel and Slide Assessment October 2013 Summary of Findings (Apex 2013)
- Duhamel Creek Hydro-geomorphological Assessment (Apex, 2004)
- Duhamel Creek IWAP (Deverney, 1999),
- Water quality and quantity reports for Duhamel Creek (Cybele Consulting, 1999, Westcott, 1999, 2000, 2001),
- Terrain and terrain stability mapping (Wehr and Salway, 1995)

In addition to these watershed level studies there have been several site level terrain stability studies done as part of specific development permits over the past decade. DTSFA reports prepared by Apex have been reviewed prior to or as part of this study but are not listed here.

Consumptive water use

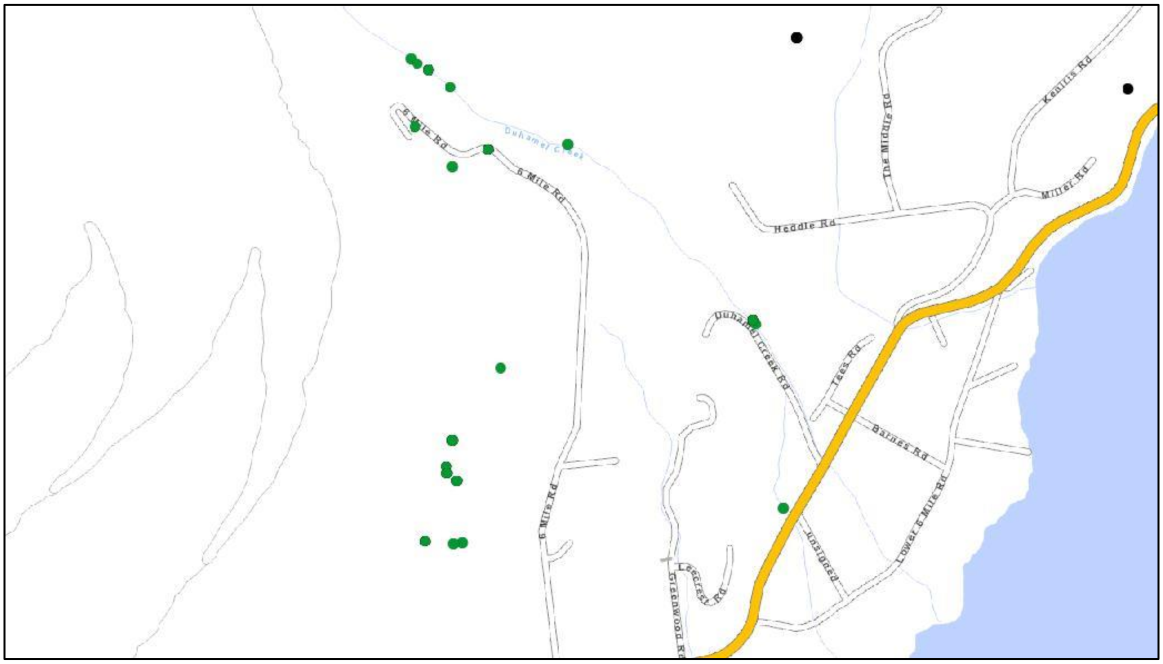


Figure 1. Points of diversion for domestic water licenses in Duhamel Creek (Downloaded from imapbc, Sept 2014).

As of September 2014 there are 151 registered active water licenses in Duhamel Creek (Appendix 1). Of these, 92 licenses are registered as domestic use and 3 are registered as water works. Figure 1 shows the points of diversion (POD) for the active (green dots) domestic water licenses in Duhamel Creek.

Development history

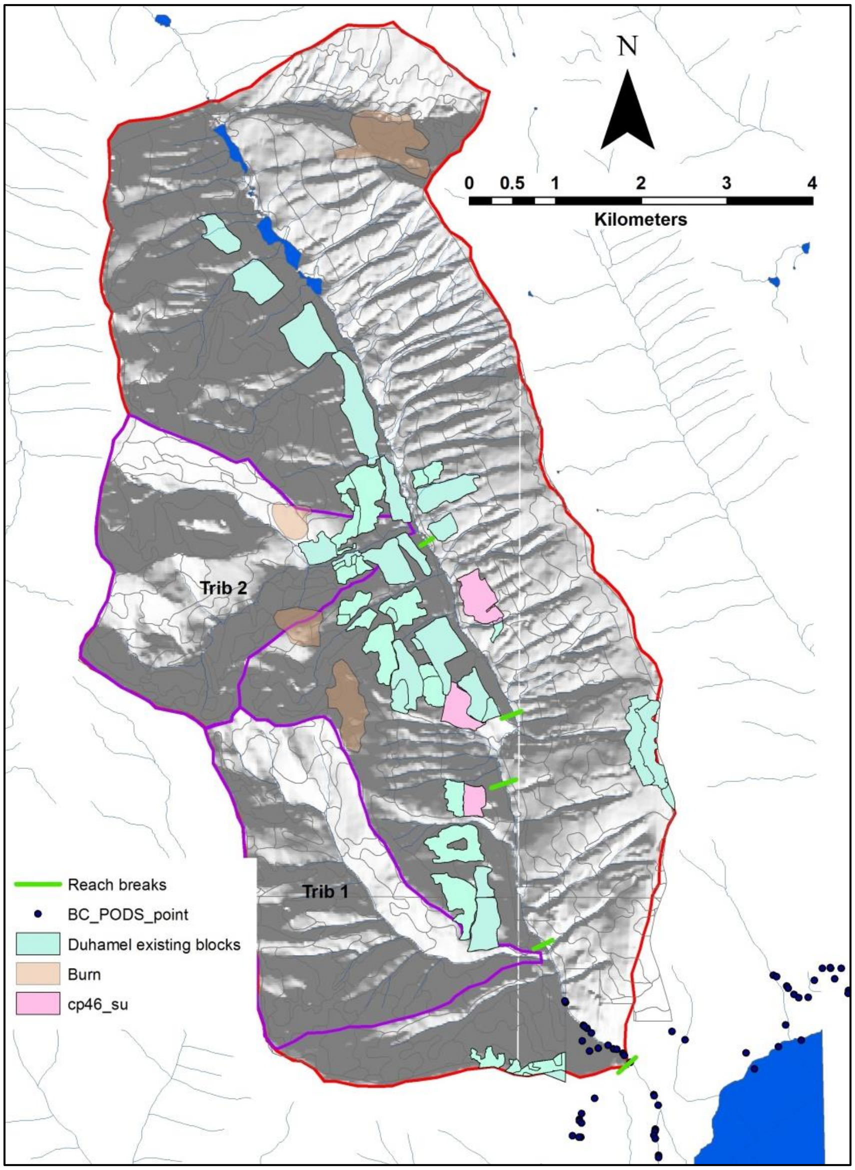


Figure 2. Existing (green) and proposed (pink) blocks as well as recently burnt areas (brown) in the Duhamel watershed. Note, proposed harvesting was formerly designated as CP 46 as shown in legend but has been changed to CP 53.

Duhamel Creek has experienced a long history of logging activities. In the early 1900's much of the riparian area and lower slopes of Duhamel Creek in the vicinity of Six-Mile Lakes were logged. During this earliest logging, logs were transported down Duhamel Creek by log-drives (https://upthelakehistory.wordpress.com/). The forest stand has, for the most part recovered from this earliest logging although much of the old cut wood currently in Duhamel Creek likely entered the channel during the early 1900's log driving or riparian logging activities. The earliest logging activities in Duhamel Creek recorded in the forest inventory (VRI) database occurred in the 1960's and 1970's. Since the 1960's about 483 hectares of logging (8.5% of the watershed area) has occurred in Duhamel Creek (Table 1). Kalesnikoff has logged 205.5 hectares of this total. In addition to the logging two wildfires (2004 and 2011) have resulted in an additional 112 hectares of disturbance to the watershed area. The current total of disturbed area (logged + burned) is estimated at 595 hectares or just over 10% of the total watershed area above the uppermost intake (5570 ha). According to the forest inventory data base some of the earlier blocks (pre-2000's) are beginning to show some hydrological recovery. By applying a recovery factor to the oldest blocks that considers recovery of stand-level processes of snow accumulation and snowmelt (See Appendix 2) the current equivalent clear-cut area (ECA) in Duhamel Creek is estimated at 534 hectares or just over 9% of the total watershed area (Table 1).

Table 1. Forest Development/disturbance to 2014

Harvest date	Area of disturbance (ha)	ECA (ha)
1960's to 1970's	106.6	56.8
1980's	40.2	27.8
1990's	88.1	89.1
2000's (not Kalesnikoff)	42.8	42.8
Kalesnikoff (CP 1, 21, 30 and 40)	205.5	205.5
Burned area (2004, 2011)	112	112
Total	**595.2 (10.7%)**	**534 (9.6%)**

3. Physical characteristics of Duhamel Creek watershed

Physiography (in part from Apex, 2004)

Duhamel Creek above the fan as delineated by the red line in Figure 2 is a 57 km^2 watershed that drains southward into the west arm of Kootenay Lake from the Kokanee Range of the Selkirk Mountains. It has a rectilinear drainage pattern with a 12-kilometre long, single main stem channel that is confined in a narrow, steep-sided valley. Mount Grohman at 2296m and Mount Cornfield at 2347m are two the highest points in the watershed while Kootenay Lake at 530 meters is the lowest point. Two third-order tributaries (7.4 and 7.2 km^2) enter the main stem channel from the west side of the watershed and dozens of first to second order snow avalanche/debris flow tributaries occur along both sides of the main stem channel. Mean annual precipitation ranges from 800 at lower elevations up to 2200 mm annually along upper elevation slopes.

Most of Duhamel Creek is underlain by coarsely crystalline granodioritic rocks of the Nelson Batholith. The linear nature of Duhamel Creek suggests that bedrock structures such as faults are controlling drainage patterns. Surficial geology includes veneers of sandy, blocky colluvium along the upper and mid-elevation steep valley side slopes, blankets and veneers of sandy to silty (locally clay) slightly compact till on the mid and lower elevation side-slopes, and remnant sandy glaciofluvial (kame) terraces along the lower valley slopes in the lower half of the watershed.

Reach Descriptions

Duhamel Creek comprises six morphologically distinct reaches (Figure 2). These reaches, which display different channel gradients, confinement and morphology differ from reaches defined in an earlier watershed assessment (Deverney, 1999). Reach 6, the uppermost reach is characterized by a broad, low gradient, U-shaped valley that contains the Six-Mile Lakes and beaver dam controlled wetlands. Reach 5 is a relatively steep gradient, confined, semi-alluvial segment with many snow avalanche/debris flow tributaries that supply large angular colluvium and woody debris to the main stem channel. Many of these cones/fans constrict the valley bottom of Duhamel Creek creating low gradient areas on the upstream sides and steep cascade channel segments along the cone deposit and for a distance downstream. Reach 4 is a steep, bedrock confined reach that contains large angular colluvial blocks and bedrock. Reach 3 is similar to Reach 5 in that it has multiple debris/avalanche cones impinging on the valley bottom creating lower gradient areas upstream and steeper gradient cascade segments downstream. In this reach low gradient wetland areas are present on the upstream side of the colluvial cones (Figure 3).

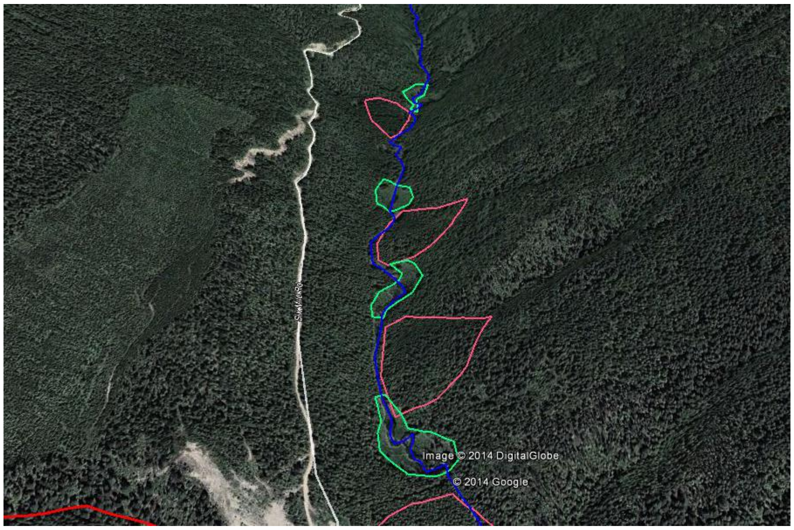


Figure 3. Google Earth image looking upstream at Reach 3 of Duhamel Creek showing wetland segments (green) above colluvial cones (pink)

An example of the influence of the colluvial cones along the profile of Duhamel Creek is evident in Figure 4. The break between Reach 2 and Reach 3 corresponds to the upstream location of the large debris flow fan of Tributary 1 (Figure 2). The steep gradient of Reach 2 is controlled by the slope of the outer edge of the debris flow fan. From this reach break down to the fan of Duhamel Creek (Reach 1) a large amount of the bedload sediment is derived from debris flows/floods from Tributary 1.

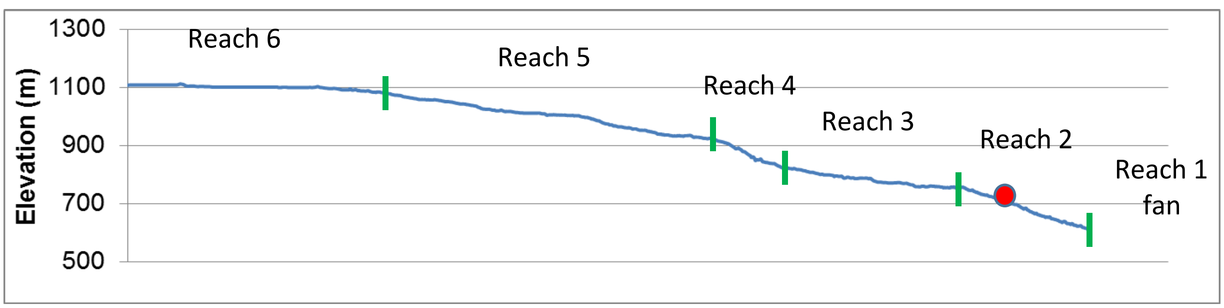
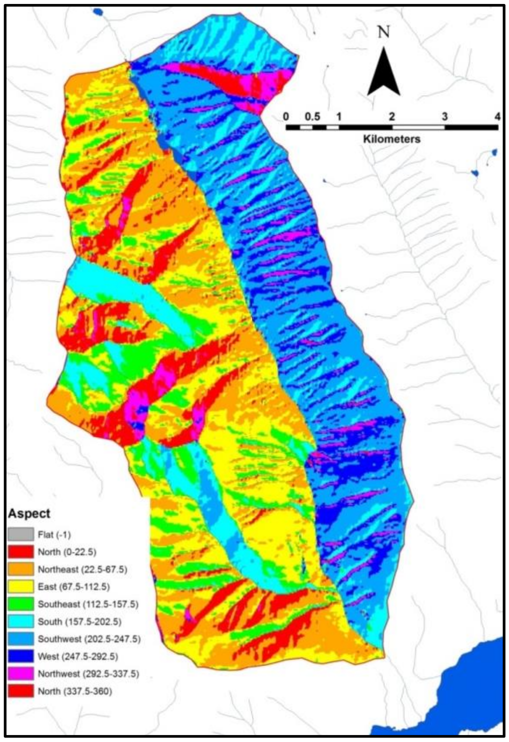


Figure 4. Channel profile with reach breaks (green). Red dot identifies intake of 6-mile water users which is the upper-most POD in Duhamel Creek.

Aspect Distribution

A GIS analysis of the watershed indicates that slope aspect is generally east-west. The two major slope aspects are east-northeast (37.5%) and south-southwest-west (40.2%). North aspect slopes represent 9.2% of the total area, southeast aspect represent 9% of the total area while northwest represents 4 % respectively (Figure 5).



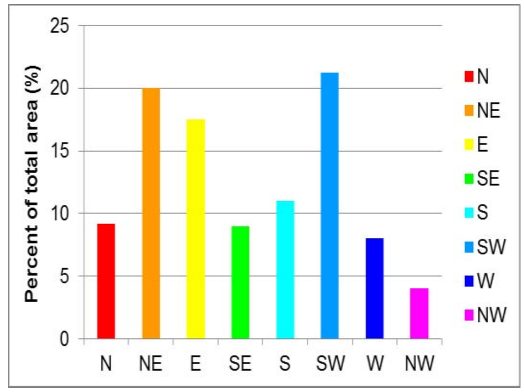


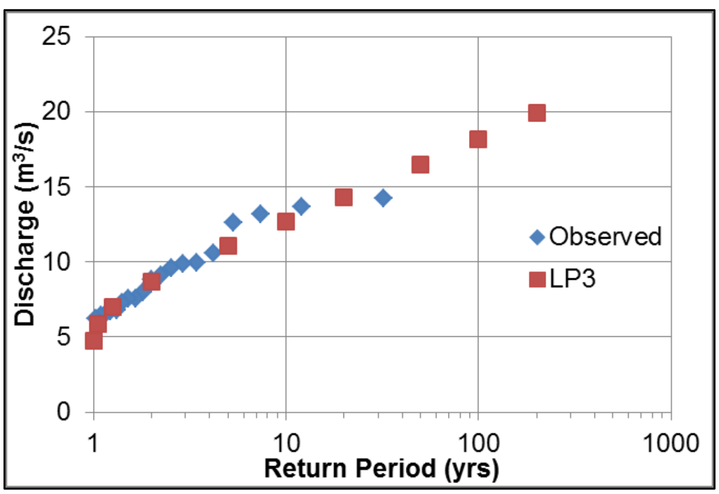
Figure 5. Aspect distribution of Duhamel Creek. Steep gradient east-west aspect slopes result in shading of either side during the spring snowmelt period during portions of the day. (See Figure 6)

Figure 6. June 1st 8:00am east side in shade, 5:30pm west side in shade

The steep slope gradients combined with the East-West aspect distribution in Duhamel Creek results in shading of portions of the watershed through the day during the majority of the snow melt period. A google earth image showing sunlight distribution for May 1st (start of spring freshet) indicates that up until 9:00 am west aspect slopes on the east side of the watershed are in shade and by 4:30pm east aspect slopes on the west side are in shade. By June 1st there is approximately 1 hour of additional sunlight on both aspects (Figure 6). The shading in Duhamel Creek results in roughly 40% less direct solar energy available to melt snow during the spring freshet period compared to a lower gradient watershed such as Selous Creek.

Flood frequency analysis

A flood frequency analysis using the 19 year record of peak flows in Duhamel Creek (Env. Canada station 08NJ026 downloaded July 2014 from http://wateroffice.ec.gc.ca/) yields the cumulative frequency distribution curve shown in Figure 7. The annual maximum daily flood in 2012, which recorded an average daily discharge of 14.2 m^3/s, is the largest flood on record for the 19 year period of gauging. A flood frequency analysis using a Log Pearson III frequency distribution suggests that a 1:200 year flood event (minimum event for design works) is likely to reach 20 m^3/s (Figure 7). A discussion on the possible impacts of climate change on the Duhamel Creek flood frequency analysis and the implications for forest development is presented in Appendix 3.



Rank	Year	Dischar	Exc Pro	Rtn Pd
1	2012	14.2	3.125	32
2	1997	13.7	8.333	12
3	2006	13.2	13.54	7.38
4	1999	12.6	18.75	5.33
5	2013	10.6	23.96	4.17
6	2011	9.93	29.17	3.43
7	2007	9.9	34.38	2.91
8	2002	9.57	39.58	2.53
9	2008	9.1	44.79	2.23
10	2009	8.83	50	2
11	1998	7.95	55.21	1.81
12	2003	7.56	60.42	1.66
13	2003	7.56	65.63	1.52
14	1995	7.29	70.83	1.41
15	2010	6.76	76.04	1.32
16	2004	6.68	81.25	1.23
17	2005	6.55	86.46	1.16
18	2000	6.4	91.67	1.09
19	2001	6.22	96.88	1.03

Figure 7. Flood frequency curve. Table on right is ranked historical frequency distribution. 2012 flood was largest flood on record with an estimated return period of greater than 1:30 yrs.

Causes of flooding

An investigation of the processes triggering large floods in Duhamel Creek such as those that occurred in 1997 and 2012 indicates that rapid snowmelt driven solely by warm sunny weather

(2012) and snowmelt driven by heavy spring rain-on-snow are capable of causing large flood events (Figure 8).

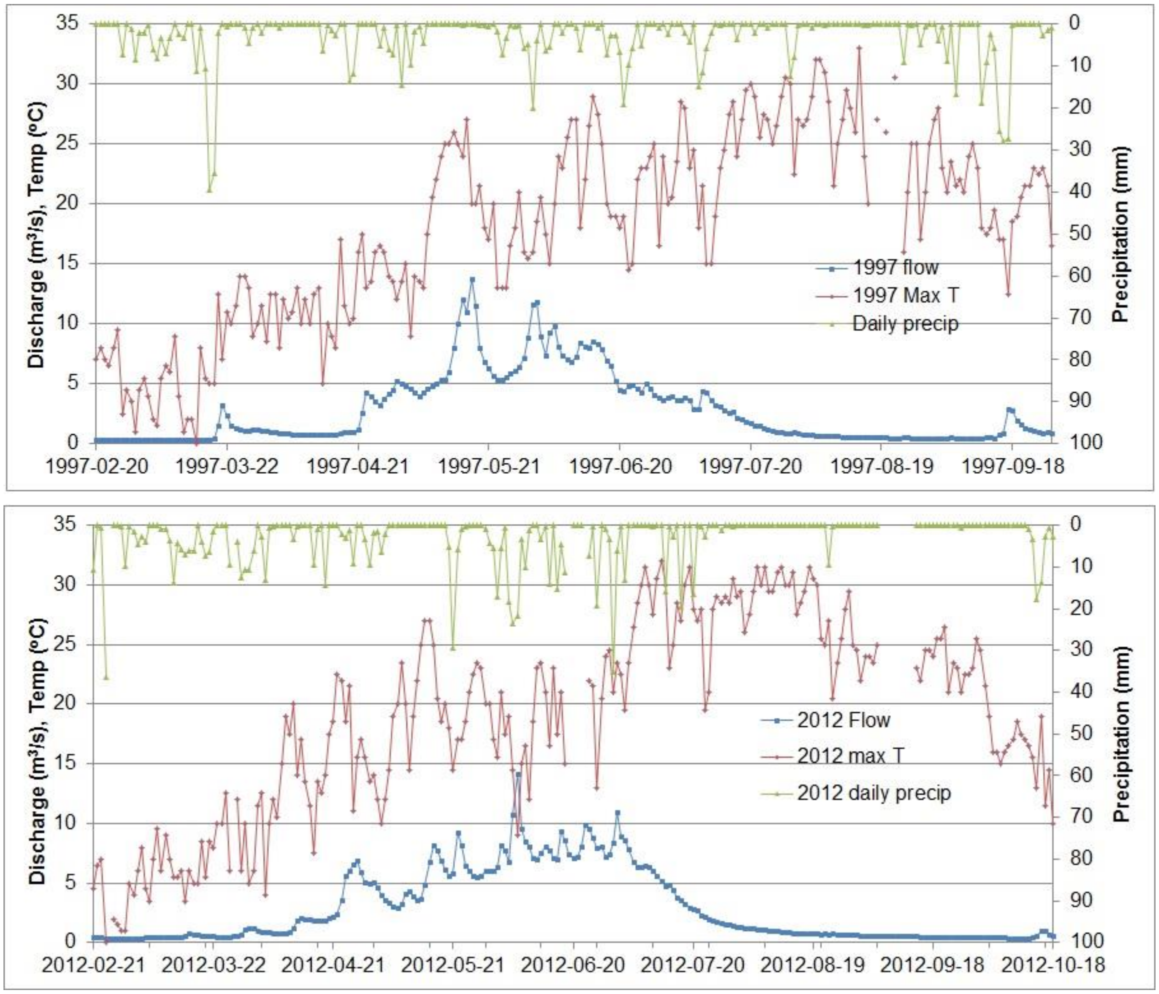


Figure 8. Relationships between temperature, precipitation and discharge in Duhamel Creek reveals that the 1997 flood (top) was due entirely to warm temperatures while the 2012 flood (bottom) was associated with a rain-on-snow event.

4. Observations

The channel of Duhamel Creek was field surveyed in October 2013 and August 2014. The survey recorded channel geometry data, information on sediment transfer processes, the size and composition of mobile bed load, observations of riparian function and channel disturbance/flood history. Survey information was collected along the length of Duhamel Creek from Six-Mile Lakes to the fan and along the middle and lower reaches of Tributary 1 (Figure 9, red dots). Due to poor access Reach 4 was not surveyed in the field.

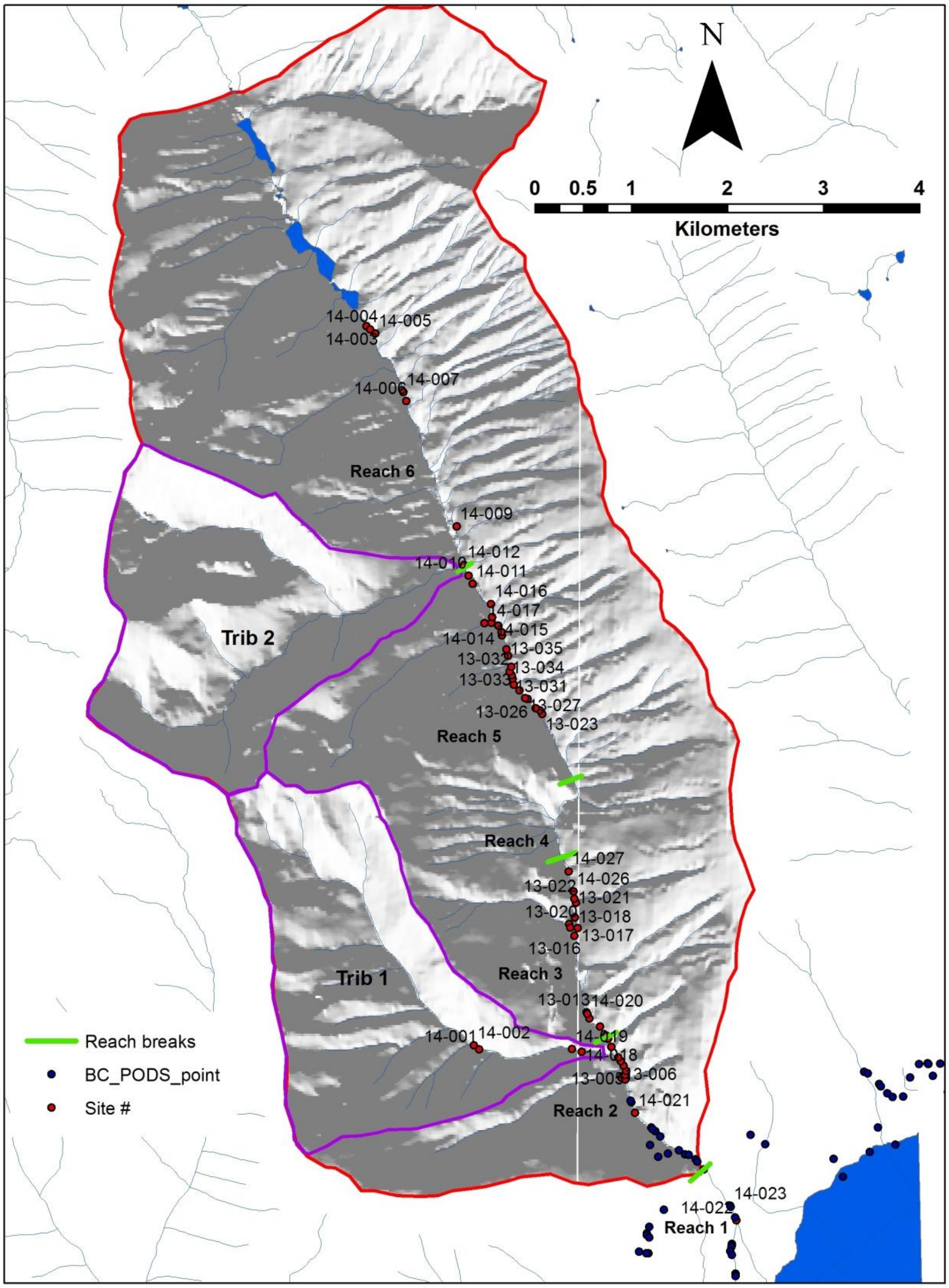


Figure 9. Watershed map showing field survey locations from 2013 (13-#)and 2014 (14-#) field sites, Reach breaks and POD's.

Reach 6 – Headwater (Six-Mile) lakes

Photo 1. Duhamel wetlands in Reach 6

The wide U-shaped valley of Duhamel Creek above approximately 1000 meters elevation contains lakes and beaver dammed wetlands. Colluvial cones of avalanche/debris flow channels impinge into the valley bottom creating confined channel segments interspersed with lakes and wetland areas. The valley gradient ranges from less than 1 percent at lakes and wetlands to 4 percent in confined channel segments between colluvial cones. Mobile bed material is mostly comprised of gravel (<2cm) and sand material but locally increases to small cobbles (12cm) through the steeper (4%), confined channel reaches. Larger angular cobble and boulder material is covered in a thick layer of moss indicating it has not moved or moved very little in the past decade or more.

Photo 2. Confined channel segment of Reach 6. Mobile bedload is primarily gravel and sand. Larger angular colluvium in channel is mossy and appears immobile.

Sediment enters this reach primarily from steep first order tributaries which transport substantial volumes of gravel and finer material annually from headwaters down to the valley bottom. Larger colluvium and woody debris is transported to the Duhamel channel less frequently through debris flow/snow avalanche processes. Once this coarse textured material reaches the Duhamel Creek channel it is limited in mobility by the low valley gradients. Sediment coarser than about 5 cm that entered Duhamel Creek during the 1997 road-related debris flow from Tributary 2 has moved a total of 200 meters in the past 17 years. Most of this deposit is now vegetated with willows and alder but the channel is still aggraded with cobbles and finer sediment.

Disturbance from early 1900's logging is still evident along confined channel segments. There is very little functioning woody debris in the channel through Reach 6. Mature coniferous stems are lacking from much of the riparian area. Riparian vegetation includes willows, dogwood, sedges and herbaceous plants along lakes and wetland areas. In confined reaches channel banks are vegetated with grasses, herbaceous plants and deciduous shrubs. Mixed age hemlock and cedar occur along upper banks – some is starting to fall across channel. There is still some very old, rotten and broken woody debris along margins of channel from early 1900's logging. Recent accumulations of small woody debris along the channel suggest a large (overbank) flood event occurred in the past few years. A much larger (channel forming) flood event that broke up large woody debris accumulations, deposited lateral cobble/gravel bars and locally eroded banks in this reach appears to have occurred roughly 20 years ago or more.

Reach 5 – Upper semi-alluvial reach

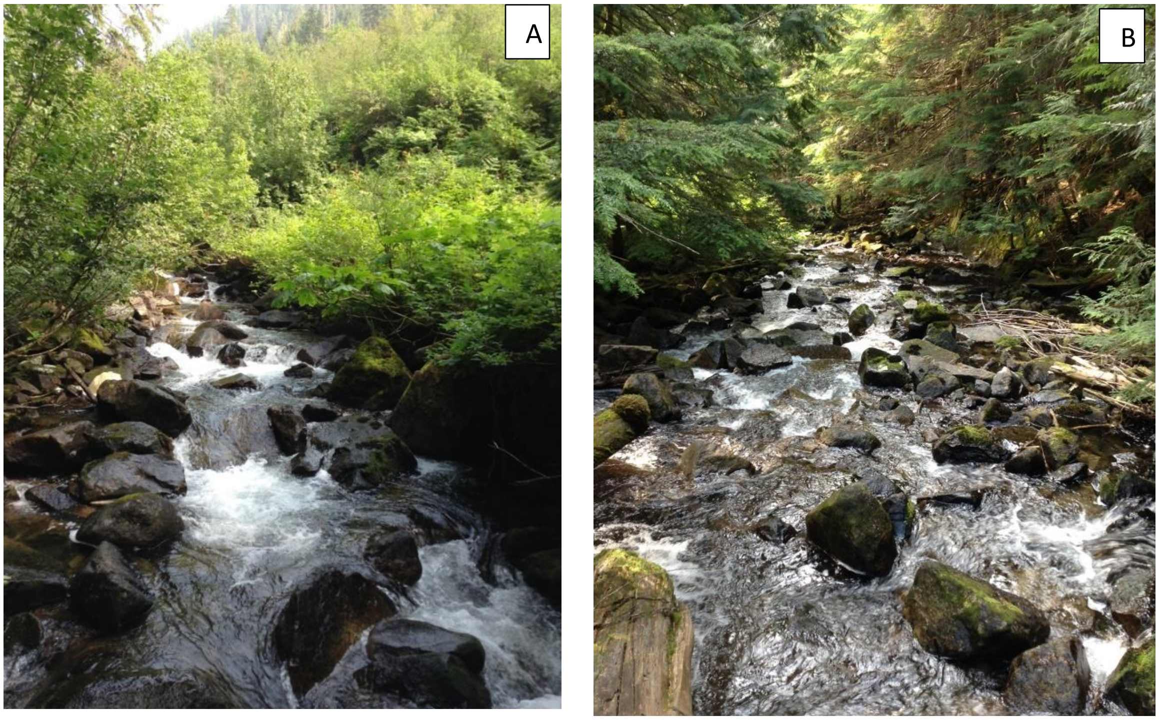


Photo 3. Duhamel Creek looking upstream (A) and downstream (B) in vicinity of survey site 14-14.

Reach 5 of Duhamel Creek has a boulder cascade to step pool morphology. Cascade reaches are due to angular colluvial boulders from avalanche cones. Channel gradient ranges from 14 percent in steeper sections to 3 percent in lower gradient sections upstream from avalanche cones. Bed material up to 23 cm is mobile annually through steeper reaches and up to approximately 15 cm through the lower gradient segments. Large angular colluvium in the channel is moss covered and appears immobile. Channel bed is bimodal in appearance with sand and gravel surrounding large colluvial boulders.

Banks are vegetated and mossy. Riparian vegetation consists of mostly willow and dogwood along channel banks with mixed age cedar and hemlock on upper banks to 60 cm (DBH).

Sediment, mostly small cobble and finer, enters the channel through steep 1st order tributaries on either side of the valley. Two road drainage-caused debris slides have entered Reach 5 of Duhamel Creek in the last several years. The majority of sediment from these debris slides is deposited along the channel margins but the channel of Duhamel Creek is locally aggraded for approximately 50 meters downstream from the 2011 debris slide which deposited a few hundred cubic meters of sediment on the valley flat.

Photo 4. Tributary at Station 14-13 with small cobble and finer bedload is typical of natural sources of sediment to Duhamel annually.

Much of the woody debris in this reach is very old and cut-ends suggest that it entered the channel during old logging activities. Old LWD debris is partially functioning in jams to retain bed sediment but most is broken and oriented parallel to channel margins.

Photo 5. Woody debris jam comprised of old woody debris, some have cut ends. Survey Site 14-16.

Recent (2 to 3 yr) flood event has mobilized small woody debris but large woody debris jam at site 14-16 appears to be at least 3 decades old indicating a flood capable of moving this material has not occurred for some time.

Reach 4 – Bedrock confined reach

A steep-sided bedrock canyon extends for approximately 1 kilometer upstream from survey site 13-22. This channel reach was not surveyed due to steep terrain which limits access to this reach. Channel gradient averages approximately 10 percent and the channel is confined on both sides by bedrock cliffs.

Reach 3 Alluvial reach

Below the bedrock canyon the channel of Duhamel Creek is mostly alluvial so that the channel geometry and bed characteristics are more directly controlled by the contemporary flood regime. Channel morphology ranges from cobble-boulder cascade adjacent to colluvial cones to step-pool morphology in transition areas to low gradient wetlands above the cones. Bed material up to approximately 20 cm is mobile annually.

Photo 6. Sites 13-019 (below) and 13-021 (above) display the transition from wetland to step-pool morphology above colluvial cone confined valley bottom. Bedload consists of a very large volume of sand and gravel stored in these low gradient channel segments.

The lower channel gradient segments through Reach 3 contain a large volume of sand and gravel sized bedload that has been transported from upstream reaches. Large volumes of fine sediment are stored in the low gradient wetland sections. Sediment is also entering this section of Duhamel Creek from steep first order tributaries on either side of the valley.

Channel width ranges from 8 to 10 meters and banks are generally overhanging to slightly entrenched (<1m) and are mossy and vegetated with a mixed stand of cedar and hemlock to roughly 50 cm (DBH). In wetland segments banks are overhanging and vegetated with deciduous shrubs including willow and red ozier dogwood.

Although there is some recently recruited wood from the riparian area suspended above the channel most of the woody debris in this section of the channel is very old. In addition much of the old woody debris displays cut-ends indicating it entered the channel in association with old logging activities. Several very large old woody debris jams occur through this reach that retain large volumes of sand and gravel bedload. The jam that occurs at survey site 13-016 is estimated to retain up to 100 m^3 of sand and gravel. This jam spans a substantial portion of the valley bottom and causes the stream to branch into multiple channels over the valley flat. Much of the old woody debris in this jam has cut ends.

Reach 2 Debris flood reach

Reach 2 has a boulder cascade to step pool morphology. Channel gradient ranges from 6 to 12 percent. Channel banks are generally mossy and vegetated but scoured in places due to recent large flood event. The channel is entrenched 1 meter or more into the valley flat and locally confined by bedrock and boulder levees. Most of the sediment in the channel is bright and appears mobile including large boulders up to approximately 80cm in diameter.

Photo 7. Looking upstream at 13-001.

Woody debris is starting to enter the channel from the adjacent riparian stand but most of this recently recruited wood is still suspended above the channel. Woody debris currently in the channel is mostly old and many pieces are cut. There are a number of woody debris jams comprised of old, cut and broken LWD in Reach 2. A large (mega-jam) is present at Survey Site 13-009. This jam is estimated to be storing approximately 100 to 200 m^3 of fine sand and gravel. A partial break of this jam released roughly 90 m^3 of fine grained material likely during the 2012 flood event.

Disturbance indicators in the riparian area and the age of riparian vegetation indicate that the last channel forming flood event occurred roughly 20 to 30 years ago. This event pushed woody debris out of the channel and deposited it parallel to banks, eroded banks and deposited lateral cobble/boulder bars that now are vegetated with mosses, grasses, shrubs and sapling hemlock. The last very large flood that caused extensive disturbance to the riparian area and deposited a boulder levee that is upwards of 1 meter or more higher than the bankfull channel appears to have occurred roughly 50 years ago. This deposit has a mixed stand of birch, hemlock and cedar established on it that are roughly 20 cm (DBH). The largest woody debris jams in this reach of Duhamel Creek appear to have been in place since this last major flood event.

Photo 8. (A) Old LWD jam at Survey site 13-009. light coloured bed is fine sand and gravel stored upstream of the dam. Below: (B) looking downstream towards jam. Jam is roughly 3 meters high on the downstream side.

The coarse textured morphology and relatively steep gradient of Reach 2 (compared to Reach 3) is due to the presence of a large debris flow fan that has built up at the bottom of Tributary 1 over the past 10,000 years since deglaciation. Multiple boulder levees over the surface of this fan and a bright, mobile channel bed attest to its frequent activity (Photo 9). The large volume of coarse textured bedload in Duhamel Creek below the confluence with Tributary 1 has entered the stream through debris flows/floods from this steep active tributary.

A visual comparison of the Duhamel Creek channel at a survey site immediately up stream of Tributary 1 confluence suggests that there has been no substantial change in channel morphology in this location over the past 10 years (Photo 9).

Photo 9. Photo taken at the same location on Duhamel Creek in 2003 and 2014 provides evidence that there has been no large channel forming flood in Duhamel Creek in the past 10 years.

Reach 1 Alluvial fan

The alluvial fan of Duhamel Creek above Highway 3a has a gradient of 6% and is constructed of cobbles and boulders. Boulders to approximately 35 cm diameter are moving annually in this lowest reach of Duhamel Creek. Channel banks are mossy and vegetated with shrubs but are vertical to laid-back as a result of a 40 to 50 year old flood. Locally the channel banks show some recent erosion and scour.

Near the apex of the fan (Site 14-23) disturbance indicators including an abandoned channel indicate that the very large flood that occurred roughly 40 to 50 years ago caused the channel of Duhamel Creek to shift laterally and deposited a cobble/boulder levee along the eastern bank that is approximately 1.3 to 1.5 meters higher than the existing bank full elevation.

Log crib walls, which appear to have been built immediately after the large flood along the channel margins, are back-filled with the cobble/boulder material in an effort to contain Duhamel Creek in two channels during flood flows. The majority of logs in these crib walls are now rotten and beginning to collapse (Photo 10). Additional cobble/boulder material has been placed on top of the log crib walls in the recent past (2 years) to provide additional containment to the channel.

Photo 10. Looking downstream at 40 to 50 year old log crib wall along eastern bank that was built to contain Duhamel Creek during flood events. Additional material has been added to the top of this crib wall in the past few years.

Photo 11. Looking upstream near apex of Duhamel fan at old channel of Duhamel Creek that was abandoned during the last large flood (1983?)

Tributary 1

Tributary 1 has a steep (>25%) bedrock to boulder cascade morphology in the middle and upper sections (Site 14-001) and a forced step-pool to boulder cascade morphology (14-16%) at lower elevations in the vicinity of the Six-Mile Road. At the lower elevations above the Six Mile Road, the channel is confined on a 10 to 15 meter wide valley flat by steep valley sides. Woody debris jams are present in the channel and are causing the channel to shift laterally over the valley flat. Channel banks are vertical to overhanging and vegetated with a mixed age stand of cedar and hemlock. Recent scour of channel banks and adjacent forest floor indicates that this tributary carried an overbank flood in the last couple of years.

Multiple boulder levees on the fan of Tributary 1 of various ages indicate that the channel of Tributary 1 carries debris floods/flows with an apparent frequency of about 1:20 to 1:50 years. The last debris flood event that mobilized boulder-sized sediment and woody debris appears to have occurred roughly 20 to 30 years ago. Boulder levees from this last debris flood are moss covered and have 3 meter high hemlock saplings established on them (Photo 12). Archived hydrometric data for Duhamel Creek and nearby Five-Mile Creek, together with climate data for Nelson (NelsonNE climate station), show that large flood events occurred in 1983 and 1997 and that these floods were due to rapid snowmelt following several consecutive days of exceptionally warm spring weather.

Photo 12. Looking downstream at vegetated boulder deposit from last large debris flood. Age is estimated at between 20 and 30 years on the basis of vegetation.

Photo 13. Looking downstream (left) and upstream (right) on Tributary 1 at the mid elevations. Survey site is located just at the bottom end of a large recent (2012) snow avalanche deposit of broken LWD.

The channel of Tributary 1 is fully confined in a steep bedrock gully in the middle and upper portions. Steep, north facing headwater tributaries appear to carry frequent snow avalanches. A large accumulation of woody debris at site 14-001 is present on the 2009 Google Earth image. A field investigation of this deposit indicates that it is, for the most part, suspended above the active channel and is not restricting the flow. Downstream from this site the channel appears to be 'cleaned out'. Riparian vegetation is limited to sapling conifers, willow, alder and herbaceous plants. Boulders to 25 cm are recently deposited on the top of lateral cobble/boulder deposits.

There are multiple abandoned channels on the fan of Tributary 1. The active channel has a woody debris step pool to boulder cascade morphology. The bedload, including the larger boulders appears bright and mobile indicating the discharges in this tributary are capable of mobilizing large boulders and debris on an annual basis.

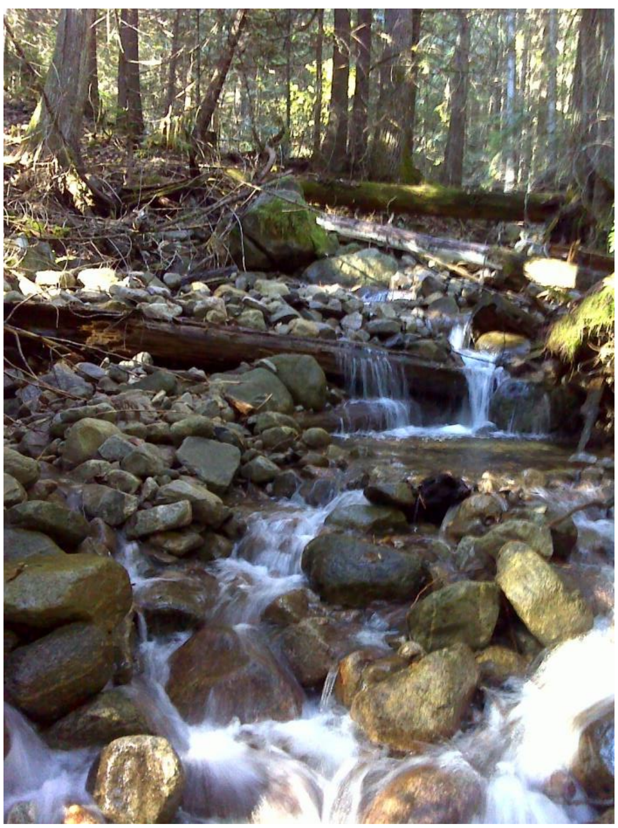


Photo 14. Looking up at active debris flood channel of Tributary 1 at confluence with Duhamel Creek.

5. Hydraulic geometry and grain size analysis

The channel of Duhamel Creek displays well defined downstream hydraulic geometry relations between channel width and watershed area (R^2 = 0.98). The relation between bankfull depth and watershed area is somewhat weaker (R^2 = 0.64) but typical for coarse textured mountain streams.

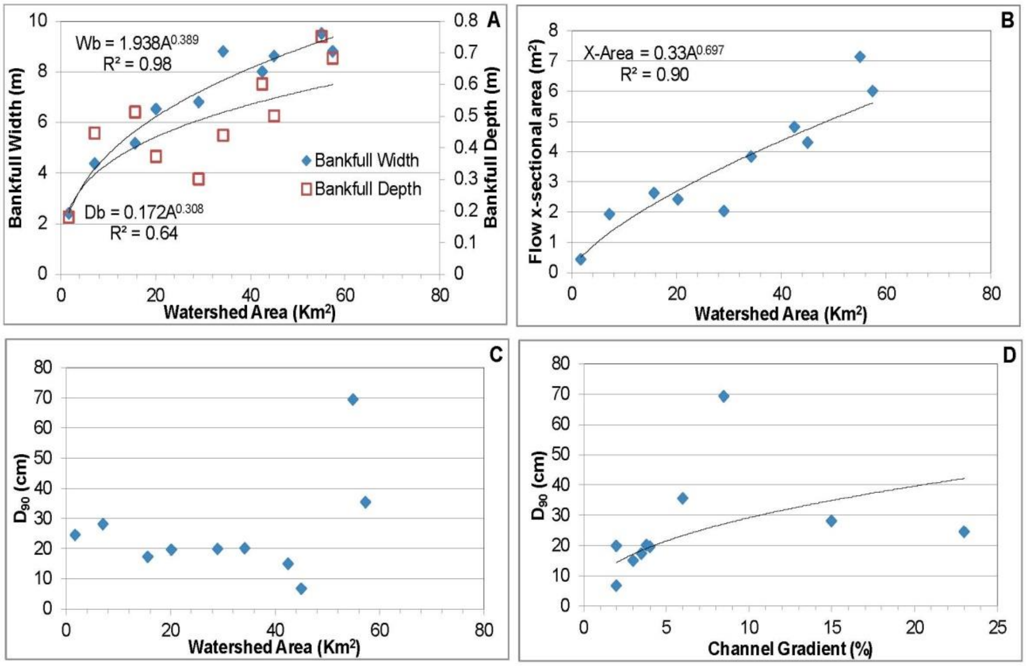


Figure 10. Hydraulic geometry of Duhamel Creek (A,B) defines a robust power law relation between channel width and watershed area. The higher degree of variability between bankfull depth and watershed area is typical of coarse textured mountain streams. The graphical representation of maximum mobile grain size and watershed area highlight the effect of dozens of colluvial cones (1) on the sediment supply along the length of Duhamel Creek and (2) channel gradient. The large jump in mobile grain size at 55 Km^2 corresponds to the confluence of Tributary 1. The poor relation between channel gradient and maximum mobile grain size also relates to the effect of the colluvial inputs.

The relationship between the maximum mobile grain size and watershed area (Figure 10C) reveals the influence of dozens of colluvial cones that impinge on the channel of Duhamel Creek. In a typical mountain stream the maximum mobile grain size increases in the downstream direction as watershed area increases and by association, the total discharge (or stream power), increases. In Figure 10C there appear to be steps in the relation between maximum mobile grain size and watershed area. There is an obvious decrease in maximum mobile grain size between the tributary channels (up to 7km^2) compared to the main stem channel (16 Km^2 to 45 Km^2). Along the main stem channel there is a downward step in mobile grain size between 42 and 45Km^2. This decrease corresponds to the decrease in channel gradient upstream from Tributary 1. The sharp increase in mobile grain size above 50 Km^2 corresponds to the influx of coarse bed material directly below the confluence of Tributary 1. Figure 10D further highlights the variability in maximum mobile grain size in Duhamel Creek related to the influence of the colluvial cones. In general, coarse textured mountain streams subject to fluvial processes (as opposed to colluvial processes such as debris flows) display a decrease in maximum mobile grain size with increasing channel gradient in response to increased turbulence and decreased flow velocity. However, in Duhamel Creek Figure 10D reveals no clear trend of grain size with channel gradient.

Despite the lack of a trend between maximum mobile grain size and watershed metrics there is a general coarsening of the channel bed in the downstream direction (Figure 11). Grain size distributions for 7 sites determined using the method of Wolman pebble counts are ordered from the upstream-most site (14-03) to the most downstream site (14-21). This figure shows that sites 14-19 and 14-21 (with curves furthest to the right) have the coarsest channel beds. It is interesting to note that site 14-12, which is downstream from sites 14-03 and 14-07 has the finest textured bed of all the sites. The fine textured bed at 14-12 reflects the fact that this site is situated immediately below the beaver-dammed wetland reach directly upstream from the confluence of Tributary 2. Sites 14-03 and 14-07 are located upstream from the wetlands and, for this reason, have less fine grained material in their bedload.

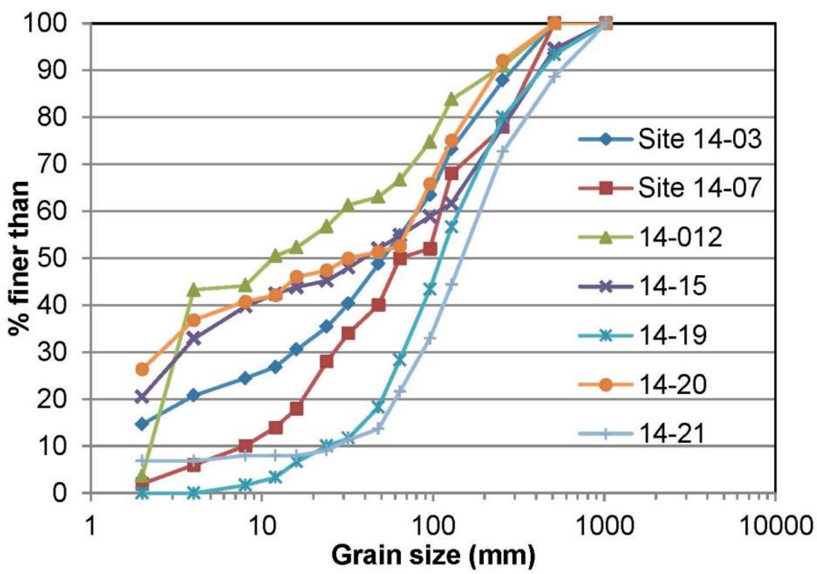


Figure 11. Channel bed grain size distribution along Duhamel Creek. Sites are in order from upstream (14-03) to downstream (14-21). Graph shows that the channel bed is generally becoming coarser.

6. Risk Analysis

Risk is assessed as the product of the probability of a hazardous event and the consequence of the hazardous event on the element at risk. The likelihood of a hazardous event occurring is assigned a quantitative probability or qualitative likelihood according to the following criteria (Table 2).

Table 2. Quantitative and qualitative frequency definitions for a hazard adapted from LMH 61.

Quantitative frequency (annual probability)	Qualitative likelihood	Description
≥ 0.19 (1:5.26 yrs)	Very high	An event will occur frequently within a human lifespan
0.05, <0.19 (1:5.26 to 1:20)	High	An event will occur several times within a human lifespan
0.02, <0.05 (1:20 to 1:50)	Moderate	An event is possible within a human life span
0.005, <0.02 (1:50 to 1:200)	Low	There is a small likelihood of an event occurring within a human lifespan
≤0.005 (1:200 yrs)	Very Low	There is a very remote likelihood of an event occurring within a human lifespan

Consequence is assessed qualitatively as the extent of impact to the element at risk. Given quantitative information about the vulnerability of the water intake to sedimentation or infrastructure damage it would be possible to assign a consequence rating such as shown in the example in Table 3.

Table 3. Example consequence assignment.

Consequence	Water Quality
High	On-going deleterious impacts to water quality causing water to be non-potable for several weeks or more annually.
Moderate	Short term impacts to water quality requiring temporary measures (less than several weeks) to improve potability
Low	No substantial change in management protocols for maintaining water quality

The risk is determined using a qualitative risk analysis matrix such as the one shown below in Table 4.

Table 4. A qualitative risk matrix adapted from Wise et al., 2004.

	Consequence		
Hazard	**High**	**Moderate**	**Low**
Very high	Very high	Very high	High
High	Very high	High	Moderate
Moderate	High	Moderate	Low
Low	Moderate	Low	Very low
Very low	Low	Very low	Very low

Definition of Element at Risk

The Duhamel Creek risk assessment considers that (1) water quality at the intake and (2) channel stability at the intake are elements at risk. Private land below the intake and Highway 3A on the fan are not considered elements at risk in this study as an assessment of risk to these elements is beyond the terms of reference of this assessment.

Definition of Hazardous events in Duhamel Creek

The Duhamel Creek risk analysis considers two hazardous events; (1) a debris flood in Reach 2 of Duhamel Creek and (2) a flood capable of substantially increasing sedimentation at the intake (i.e. above the normal range of variability). The analysis of the effects of forest harvesting on these two hazardous events is based on published scientific studies and professional knowledge of forest harvesting effects on the flood regime (i.e. flood frequency and magnitude) in snowmelt environments.

Processes of Debris floods in Tributary 1 and Reach 2

Field observations indicate that Tributary 1 and Reach 2 of Duhamel Creek are subject to debris floods. Debris floods are hyperconcentrated flows that form a transition between purely water floods and debris flows. Debris floods can contain approximately 20% sediment by volume and can be triggered by a variety of processes including landslides and debris flows in steep headwater reaches or evolve from purely flood flows through entrainment of debris.

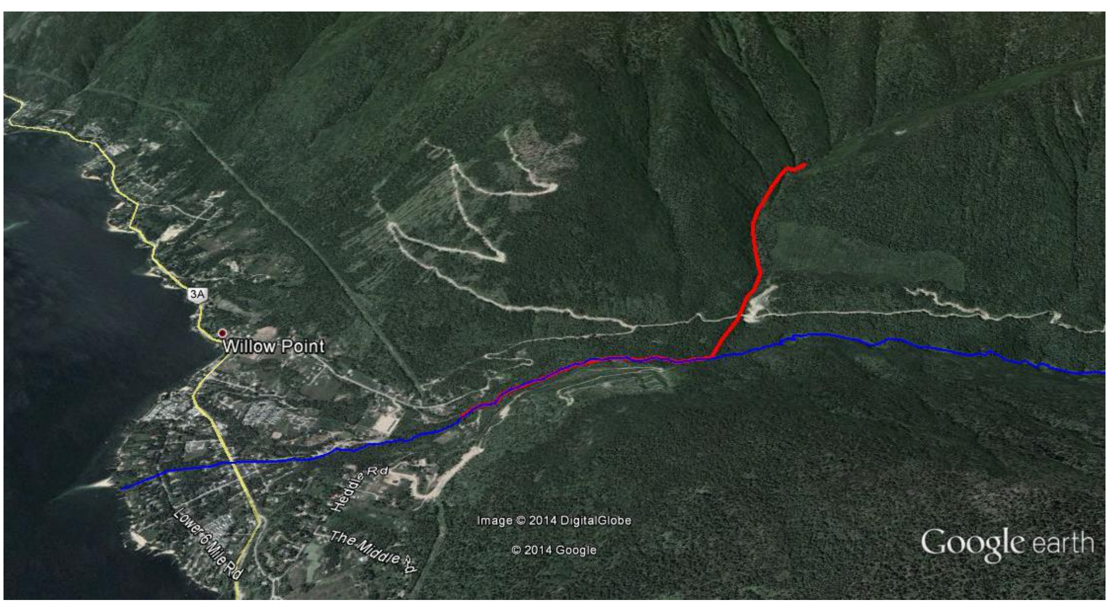


Figure 12. Google Earth image of Tributary 1 with approximate location of channel subject to debris floods shown in red.

The moderate gradient (7-12%) and coarse textured bed of Duhanmel Creek below the confluence of Tributary 1 suggests that debris floods that initiate in Tributary 1 (probably initiating as debris flows or slush avalanches) continue for at least some distance downstream once they enter Duhamel Creek. The red-highlighted channel in Figure 12 is an estimation of the portion of Duhamel Creek impacted by debris floods originating in Tributary 1. The portion of the Duhamel channel highlighted in red corresponds to Reach 2 and is confined on one or both sides by boulder levee's from past debris flood events.

A preliminary investigation of the hydroclimate conditions that trigger debris floods in Tributary 1 suggests that flood magnitude as well as flood duration are important factors. Hydrometric data from Environment Canada for Five-Mile Creek indicate that the 1983 and 2012 floods were similar magnitude however they differed substantially in flood duration. The 1983 flood, which likely triggered the last debris flood in Tributary 1 recorded 7 consecutive days of discharge with flood magnitude exceeding a 1:20 year flood while the 2012 flood was similarly elevated for only 1 day. Consequently in Tributary 1 the 2012 flood only resulted in overbank flooding and localized scour of the channel banks and forest floor.

Floods capable of substantially increasing sedimentation at the intake

Dozens of snow avalanche/debris flow tributaries along the length of Duhamel Creek convey sediment from steep headwater reaches to the main stem of Duhamel Creek on an annual basis. Above Reach 2 much of this sediment (coarser than about 2mm) is deposited and stored in low gradient wetland 'settling ponds' located along Duhamel Creek. Cumulatively, these wetland segments store many thousands or possibly 100's of thousands of cubic meters of fine grained sediment.

Photo 15. Typical wetland segment with sand, gravel and small cobble bed.

Because of the occurrence of numerous wetland segments along the length of Duhamel Creek, only exceptional flood events such as the 2012 event (estimated as a 1:32 year flood in Duhamel Creek) are capable of substantially increasing the rate of transport of the fine grained sediment. Floods of this magnitude are also capable of breaking apart woody debris jams that are currently storing large volumes of fine textured sediment along the length of Duhamel Creek.

Assessment of Consequence

Due to a limited knowledge of the vulnerability of the community waterworks to sedimentation and channel instability the assessment undertaken here assumes that the consequence of a hazardous event (debris flood and sediment-mobilizing flood) is 'high' – that is, that the occurrence of these hazardous events will always cause damage to private land and waterworks structure or cause long term impacts to water quality at the intakes.

Risk Assessment

The influence of forest harvesting on frequency of debris floods in Tributary 1.

Current Conditions

The naturally occurring hazard of a debris flood in Tributary 1 is assessed as 'moderate' according to Table 2. Floods with a sufficient magnitude and duration to initiate a debris flood have a likelihood of occurrence of between 1:20 and 1:50. Combined with the high consequence of debris floods on the waterworks, the natural risk (without forest development) to the waterworks from debris floods in Duhamel Creek is 'high'.

Only a small area accounting for roughly 4 hectares of logging has occurred in Tributary 1 (Figure 2). The single cut block which was logged in the 1970's or early 1980's is partially regenerated with an average stand height of 15 meters and a 40% crown closure. This existing block represents an ECA of about 0.3% of the watershed area of Tributary 1. The existing level of harvest represents no change in the existing hazard of a debris flood in Tributary 1. Consequently there is no change in the existing 'high' risk to the waterworks from the current level of forest harvesting in Duhamel Creek.

Proposed Harvesting (CP – 53)

CP 53 does not affect Tributary 1 and therefore represents no change in the existing hazard of debris floods in Tributary 1 or risk of debris floods on the waterworks in Duhamel Creek.

The influence of forest harvesting on the frequency of sediment mobilizing floods

Current Conditions

Forest harvesting in snowmelt regions causes increases in snow accumulation and increases in snowmelt rates relative to the forested condition (Buttle et al., 2005; Winkler et al., 2005; Ellis et al., 2010)). Changes in snow accumulation and melt at the stand level can result in changes in the flood regime at the watershed scale. Recent studies have shown that the influence of forest harvesting on processes of snow accumulation and melt vary considerably with elevation and aspect (Winkler et al., 2005; Jost et al., 2007; Ellis et al., 2010). These stand level studies reveal that changes in hydrology at the stand level are linked directly to changes in net radiation at the snowpack following harvesting. The greatest changes in net radiation following harvesting occur on south and southwest aspect slopes and flat areas and are the result of large increases in direct shortwave (solar) radiation (Ellis et al., 2010). The smallest increases in net radiation following logging occur on north aspect slopes which are naturally shaded from the sun. West aspect slopes appear to respond similarly to south aspect slopes in terms of changes in net radiation following harvesting (Jost et al., 2007) however there are no studies to indicate how east-aspect slopes respond to harvesting.

Interpreting the outcomes of stand level studies in terms of the potential watershed-scale response is challenging. The results of stand level studies suggest that logging, when concentrated on north aspect slopes is likely to have a smaller influence on changes in the magnitude and frequency of floods than when concentrated on south aspect slopes. However, this outcome likely applies only to floods stemming from solar-radiation driven snowmelt that occur early in the freshet period. Applying these stand level study outcomes to Duhamel Creek is further complicated by the fact that slope aspects are primarily east - west rather than north - south.

The current equivalent clear-cut area in Duhamel Creek is estimated at just over 9%. The majority of this harvesting is situated below 1600 meters on slopes with east and northeast aspects. Given the limited state of knowledge with respect to the potential for changes in the frequency of large floods in steep east-west aspect watersheds a conservative assessment of hazard is warranted. The outcomes of a hydrological modeling study undertaken in near-by Redfish Creek for the 'Current' harvesting scenario (ECA = 9%) provides some indication of the potential for changes in the flood regime in Duhamel Creek associated with the current conditions. It is important to note that these two watersheds differ in that Redfish Creek has relatively equal amounts of east, west and south aspect slopes and the harvesting scenarios comprise openings that are distributed evenly around the basin (Schnorbus and Alila, 2004). The results of the Redfish study shows that the current (9%) level of harvest results in no substantial change in the frequency of large flood events. This study also shows that when harvesting is evenly distributed across aspects in the lower one-third of the watershed, harvest levels less than roughly 20% have no substantial influence on the flood regime. Similar results were established in an earlier modeling exercise (Whitaker et al., 2001). This preliminary study also found that cutblocks located in the lower 20% of the watershed had no obvious effects on flood peaks. These modeling outcomes agree with an empirical study of the snowline retreat in Redfish Creek which determined that snow has mostly melted from slopes in the lower third of the watershed when peak flows occur in Redfish Creek (Gluns, 2001). Based on these studies the current level of harvest in Duhamel Creek, the majority of which is situated on slopes mostly below 1350 meters (corresponding to the lower 34% of the watershed area, Figure 13), is unlikely to change the existing frequency of large flood events (i.e. 1:20 year or greater) or the existing risk of sedimentation events at the intake.

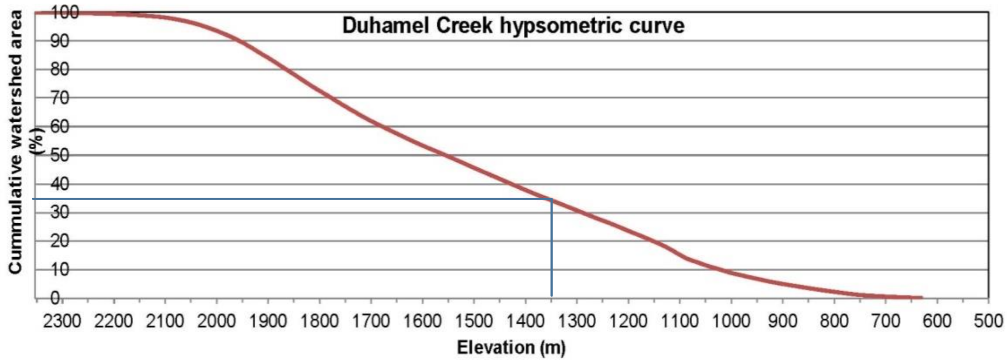


Figure 13. Duhamel hypsometric curve. 1350m elevation corresponds to the lower 1/3 (33%) of the watershed.

Proposed Harvesting (CP-53)

Three additional blocks are proposed as part of CP 53. These blocks, which have a cumulative area of slightly less than 45 hectares, will bring the total ECA up to 579 hectares or 10.4% of the watershed area above the uppermost intake. All three of the proposed blocks are situated in the lower third of the watershed below 1350 meters. The results of the Redfish Creek studies mentioned above (Whitaker et al., 2002, Schnorbus and Alila, 2004) suggests that the proposed harvesting will have no detectable influence on the frequency distribution of floods and therefore no change in risk of sedimentation events at the intake.

7. Summary and Recommendations for Forest Management

Summary

Sediment Delivery

Duhamel Creek is a very active fluvial system situated in steep V-shaped valley that receives sediment and debris from a multitude of steep snow avalanche/debris flow tributaries located along its length. The colluvial cones at the base of these avalanche gullies constrict the valley bottom of Duhamel Creek forming low gradient wetland reaches upstream and steeper cascade segments in the constricted segments. The low gradient wetlands trap and store many thousands of cubic meters of sediment larger than about sand size in all but the largest flood events.

Three road-related landslides have entered Duhamel Creek over the last 17 years. In all cases the slides were caused by concentration and diversion of surface and subsurface runoff along roads and trails. Sediment from the 1997 debris flow is still evident in Duhamel Creek for approximately 200 meters downstream from the tributary confluence. Vegetation established on the slide deposits has stopped surface erosion from contributing fine sediment to the channel.

Peak flows and channel forming floods

Duhamel Creek displays a well-developed downstream hydraulic geometry indicating its morphology is a function of the contemporary flow regime. In most years peak flows in Duhamel Creek are driven by snowmelt from upper elevation slopes. Exceptional floods can occur following several days of very warm weather (i.e., temperatures of 25°C in Nelson) and/or large rainfall on snowmelt events. The last channel forming flood event appears to have occurred roughly 30 years ago (likely 1983). During this prolonged runoff event, which was triggered by several consecutive days of warm spring temperatures, a debris flood initiated in Tributary 1 that traveled for a considerable distance down Duhamel Creek.

The current level of forest harvesting (9.6%) is assessed as having a low likelihood of increasing the frequency of debris floods that could pose a risk to the integrity of water intakes or increasing the frequency of flood events that create a risk of sedimentation at the intakes. Likewise, proposed harvesting of CP 53 which brings the ECA to 10.4% is also assessed as having a low likelihood of increasing the frequency of these hazardous events and therefore will not increase the risk of these hazardous events on the intake.

Riparian function

Large woody debris recruited from the adjacent riparian stand plays an important role in Duhamel Creek with respect to channel bed structure and aquatic habitat. Riparian function along the entire length of Duhamel Creek from Six-Mile Lakes to the fan has experienced extensive disturbance from early 1900's logging activities. Although the majority of Duhamel Creek currently displays stable, vegetated channel banks the majority of the woody debris in the stream channel is very old, rotten and broken and has cut ends indicating it was deposited in the channels during the early logging activities. Much of this old LWD is distributed along the channel in very large woody debris jams that are partially functioning to retain fine textured sediment or as accumulations of broken woody debris pieces along the upper channel banks. Over the next few decades it is likely that greater volumes of fine sediment will be release from behind these decomposing jams as they continue to break apart during flood event. The existing riparian stand, which comprises mature cedar and hemlock stands with basal diameters exceeding 50 cm, is just starting to contribute woody debris to the stream channel.

Recommendations

Level of Harvest and harvest distribution

Hydrological modeling undertaken in Redfish Creek suggests that harvest levels below approximately 20% when situated across aspects in the lower third of the watershed will not result in detectable changes in the frequency distribution of floods (i.e. have a low likelihood for increasing the existing frequency of the hazardous event). Currently the majority of blocks in Duhamel Creek are situated on a single aspect (E - NE). Concentrating harvesting on a single aspect is more likely to increase synchronization of runoff from a watershed compared to distributing blocks across aspects. A recent study by Green and Alila, 2012 found that the effects of harvesting on the flood regime are increased where harvesting functions to increase the synchronization of runoff from slopes. To maintain a low likelihood of altering the frequency of larger floods it is recommended that harvest levels in Duhamel Creek be limited to less than 20% and any future blocks should be planned so as to balance the cut across aspects on slopes below 1350m elevation.

If future harvesting is concentrated on western slopes over a broader elevation range rather than distributed across aspects below 1350m changes in the frequency of flooding may occur at lower levels of harvesting. Although there are currently no studies that can be used to establish definitively the potential hydrological impacts of concentrating harvesting on a single (east) aspect slope the outcomes of modeling studies in Redfish Creek suggest that harvesting of roughly 20% of the watershed with 13% situated in central 2/3 elevations between the H60 and H40 (Schnorbus and Alila, 2004) has the potential to increase the magnitude of floods by approximately 4% over a range of return periods. As with Green and Alila (2012) this study determined that increases in runoff synchronization between various elevation bands largely drive the magnitude of change in peak flows. If future harvesting in Duhamel were to be concentrated on a single aspect and include slopes between 1350 meters and 1700 meters rather than a distributed across aspects it is likely that the increases in peak flows could be substantially larger than those reported in the modeling studies because of the greater increase in runoff synchronization. The effect of an increase of just 8% in peak flow magnitude (i.e. double the increase reported for a distributed cut) has the effect of increasing the frequency of the hazardous event (20 year return period flood) by over 2 times (20 year to about 7.5 year RI) (see black arrow in Figure 13). This increases the probability of a damaging flood from moderate to high (Table 2).

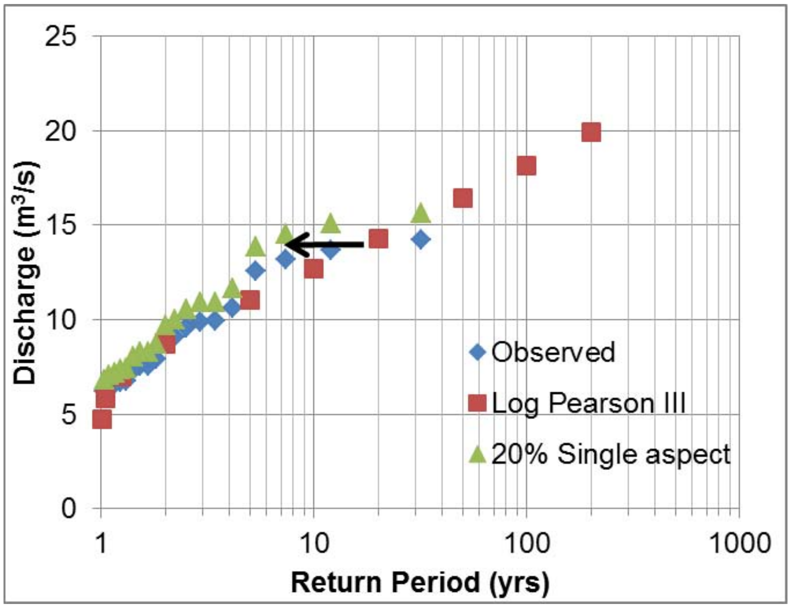


Figure 14. Hypothetical change in frequency if harvesting of 20% of the watershed area is concentrated on a single aspect slope. The blue diamonds show the ranked distribution of floods from the actual 19 years of flow data from Duhamel Creek. The red squares show the estimated flood frequency distribution using the Log Pearson III function which is calculated using the 19 years of gauging in Duhamel Creek. The green triangles show the estimated ranked distribution of floods given an 8% increase in flood magnitude across the full range of return periods.

Harvesting on active debris flow and snow avalanche fans/cones

Harvesting on the fans and cones of active debris flow/debris flood tributaries (such as Tributary 1) should be undertaken with exceptional care as harvesting in these areas can increase channel instability (See BC FLNRO, LMH 56). Clear-cut harvesting on debris flow and fluvial fans reduces the natural erosion protection afforded by the root networks of coniferous trees. Proposed harvesting in the vicinity of fans should include an assessment by a qualified professional to delineate the potential extent of the fan/cone landform, an assessment of the frequency of debris flood events, and prescriptions to maintain a sufficient density of mature coniferous stems to maintain forest floor integrity over the period of the regenerating stand.

To limit the potential for increasing the frequency of debris floods harvesting in Tributary 1 should be limited to less than 5% of the watershed area of Tributary 1 and should be limited to south aspect slopes or low elevation slopes (below 1100m). Similar limitations are also recommended for the debris flow tributary directly south of Tributary 1 which shares the same fan and appears to carry debris flows with a similar frequency.

Road construction and deactivation

Several slides have occurred in Duhamel Creek as a result of concentrated and diverted runoff along roads and trails. Roads and trails on or above unstable or potentially unstable slopes must be designed and deactivated by a Qualified Registered Professional experienced in terrain stability mapping and assessment and resource road design (QRP) to avoid concentrating and diverting surface and subsurface runoff. Drainage structures are to be sized to accommodate increased surface flows following harvesting. Projected climate change scenarios for the West Kootenay region suggests that fall, winter and spring rain-on-snow events could become more frequent (Appendix 3). Roads and trails on low elevation slopes, especially those situated in or below cutblocks could experience a higher frequency of high intensity runoff events in future decades compared to the recent past.

Riparian Management to maintain ecosystem function

Riparian vegetation plays an important role in Duhamel Creek with respect to channel stability and protection to the channel bank and adjacent floodplain during overbank floods. In addition riparian vegetation along reaches 3 to 6 provides valuable terrestrial and aquatic habitat for beaver, ungulates, raptors, waterfowl and many wetland species. Riparian management strategies to maintain channel and riparian ecosystem integrity along the main stem (S2) channel in Duhamel Creek are provided in draft form in Volume 2 of the Integrated Riparian Assessment document *Detailed Riparian Management Strategies* (Apex, 2013, Draft document). Additional riparian management strategies to maintain physical ecosystem function along S3 to S6 streams in Duhamel Creek are also contained in the draft *Detailed Riparian Management Strategies* document.

8. Closure and Limitations

The information in this hydrological assessment report is for the sole use of Kalensikoff Lumber Company Ltd of Thrums, BC and is intended to provide guidance for forest management in Duhamel Creek. The recommendations in this report are based on field observation of active hydrologic and geomorphologic processes in the watershed and on historical data collected from various sources. In addition, assessment of hazard presented in this report considers the results of numerous recent studies from BC and North America that identify the effects of harvesting on hydrologic response of interior snowmelt dominated mountainous watersheds. The hazard assessment and recommendations provided here are precautionary in nature due to the limited availability of hydrological studies relevant to Duhamel Creek. A more accurate assessment of the hydrological effects of logging in Duhamel Creek would be achieved by undertaking a modeling exercise to better quantify the effects of canopy removal in a watershed with steep east – west aspect slopes.

Fluvial geomorphology data collected during this assessment quantify the existing channel conditions. This data can be used to compare against channel condition during future channel assessments to determine if there have been changes.

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Apex Geoscience Consultants Ltd.
Nelson, B.C.

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Appendix 1 Water License information

Downloaded from http://a100.gov.bc.ca/pub/wtrwhse/water_licences.input (September 2014)

Licence No	WR Map/	Purpose	Quantity	Units	Licensee	Priority Date	Issue Date
C028761	5230C HH (PD27725)	Domestic	1.514	MD	WORKING PROJECTS INC 724 2ND STREET NELSON BC V1L2L9	18990619	
"	"	Irrigation	12951.54	MY	WORKING PROJECTS INC 724 2ND STREET NELSON BC V1L2L9	18990619	
C028762	5230B X (PD27704)	Domestic	2.273	MD	KOHOUT JERRY GEORGE & CAROLYN ROSE KELLY 2728 HWY 3A NELSON BC V1L6L6	18990619	
"	"	Irrigation	419.383	MY	KOHOUT JERRY GEORGE & CAROLYN ROSE KELLY 2728 HWY 3A NELSON BC V1L6L6	18990619	
"	5230B Z4 (PD27714)	Domestic	2.273	MD	KOHOUT JERRY GEORGE & CAROLYN ROSE KELLY 2728 HWY 3A NELSON BC V1L6L6	18990619	
"	"	Irrigation	419.383	MY	KOHOUT JERRY GEORGE & CAROLYN ROSE KELLY 2728 HWY 3A NELSON BC V1L6L6	18990619	
C029513	5230B A5 (PD27709)	Domestic	2.273	MD	HOWARD ALLAN C & DOREEN A 2813 HWY 3A NELSON BC V1L6M1	18990619	
"	5230B X3 (PD27705)	Domestic	2.273	MD	HOWARD ALLAN C & DOREEN A 2813 HWY 3A NELSON BC V1L6M1	18990619	
C031153	5230C Z (PD27728)	Domestic	1.818	MD	WHITEHEAD WATERWORKS DISTRICT BOX 845 NELSON BC V1L6A5	19030512	
"	"	Irrigation Local Auth	5920.704	MY	WHITEHEAD WATERWORKS DISTRICT BOX 845 NELSON BC V1L6A5	19030512	
C031341	5230C AA (PD27733)	Domestic	1.137	MD	HARRISON DOUGLAS W & TETZ BRENDA L 3129 HEDDLE ROAD NELSON BC V1L6M2	18990619	
"	"	Irrigation	3873.127	MY	HARRISON DOUGLAS W & TETZ BRENDA L 3129 HEDDLE ROAD NELSON BC V1L6M2	18990619	
C032639	5230B L5 (PD27717)	Domestic	2.273	MD	KELLY CAROLYN R 2737 LOWER SIX MILE ROAD NELSON BC V1L6L5	19631009	
C041300	5230B R5 (PD27716)	Irrigation	937.445	MY	PRIVE MADELEINE 2727 LOWER SIX MILE RD NELSON BC V1L6L5	18990619	
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C045010	5230C Z (PD27728)	Domestic	2.273	MD	WHITEHEAD WATERWORKS DISTRICT BOX 845 NELSON BC V1L6A5	19730518	

Licence No	WR Map/	Purpose	Quantity	Units	Licensee	Priority Date	Issue Date
C046225	5230C AA (PD27733)	Irrigation	5402.642	MY	HEDDLE MARILYN H 108 2828 YEW ST VANCOUVER BC V6K4W5	19030331	
C046438	5230C AA (PD27733)	Domestic	2.273	MD	MCGRATH DAVID C & VICKY M C/O WILLIAM MCGRATH 5815 PARKVIEW DR VERMILION AB T9X1V9	19050530	
C052965	5230C CC (PD27729)	Irrigation Local Auth	1110.132	MY	WHITEHEAD WATERWORKS DISTRICT BOX 845 NELSON BC V1L6A5	19260929	
C052966	5230C CC (PD27729)	Irrigation Local Auth	407.048	MY	WHITEHEAD WATERWORKS DISTRICT BOX 845 NELSON BC V1L6A5	19260929	
C052968	5230C CC (PD27729)	Domestic	2.273	MD	WHITEHEAD WATERWORKS DISTRICT BOX 845 NELSON BC V1L6A5	19341102	
C052969	5230C CC (PD27729)	Domestic	2.273	MD	WHITEHEAD WATERWORKS DISTRICT BOX 845 NELSON BC V1L6A5	19341102	
C052971	5230C CC (PD27729)	Irrigation Local Auth	12088.1	MY	WHITEHEAD WATERWORKS DISTRICT BOX 845 NELSON BC V1L6A5	18990619	
C052972	5230C CC (PD27729)	Irrigation Local Auth	616.74	MY	WHITEHEAD WATERWORKS DISTRICT BOX 845 NELSON BC V1L6A5	19260929	
C052973	5230C CC (PD27729)	Irrigation Local Auth	2343.612	MY	WHITEHEAD WATERWORKS DISTRICT BOX 845 NELSON BC V1L6A5	19380510	
C052974	5230C CC (PD27729)	Irrigation Local Auth	530.396	MY	WHITEHEAD WATERWORKS DISTRICT BOX 845 NELSON BC V1L6A5	19260929	
C053147	5230C CC (PD27729)	Irrigation Local Auth	1554.185	MY	WHITEHEAD WATERWORKS DISTRICT BOX 845 NELSON BC V1L6A5	18990619	
C053148	5230C CC (PD27729)	Irrigation Local Auth	1578.854	MY	WHITEHEAD WATERWORKS DISTRICT BOX 845 NELSON BC V1L6A5	18990619	
C053149	5230C CC (PD27729)	Irrigation Local Auth	1233.48	MY	WHITEHEAD WATERWORKS DISTRICT BOX 845 NELSON BC V1L6A5	18990619	
C053150	5230C CC (PD27729)	Irrigation Local Auth	1788.546	MY	WHITEHEAD WATERWORKS DISTRICT BOX 845 NELSON BC V1L6A5	18990619	
C053151	5230C CC (PD27729)	Irrigation Local Auth	1591.189	MY	WHITEHEAD WATERWORKS DISTRICT BOX 845 NELSON BC V1L6A5	18990619	
C053488	5230C R4 (PD27732)	Domestic	2.273	MD	JONES GLEN V & MARIAN 2899 DUHAMEL ROAD NELSON BC V1L6L9	18990619	
"	"	Irrigation	42555.06	MY	JONES GLEN V & MARIAN 2899 DUHAMEL ROAD NELSON BC V1L6L9	18990619	
C053524	5230C W (PD27726)	Irrigation Local Auth	3293.392	MY	WHITEHEAD WATERWORKS DISTRICT	19090222	

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					BOX 845 NELSON BC V1L6A5		
C053525	5230C T4 (PD62414)	Irrigation Local Auth	1467.841	MY	WHITEHEAD WATERWORKS DISTRICT BOX 845 NELSON BC V1L6A5	19090222	
C053526	5230C T4 (PD62414)	Irrigation Local Auth	1332.158	MY	WHITEHEAD WATERWORKS DISTRICT BOX 845 NELSON BC V1L6A5	19090222	
C054698	5230C AA (PD27733)	Domestic	2.273	MD	BOYER DWAIN & SHEILA 3196 HEDDLE RD NELSON BC V1L6M2	19790418	
C054699	5230C AA (PD27733)	Domestic	2.273	MD	BROCK RAY L 3185 HEDDLE RD NELSON BC V1L6M2	19790621	
C054700	5230C AA (PD27733)	Domestic	2.273	MD	DREHER BRADLEY RICHARD 3195 HEDDLE ROAD NELSON BC V1L6M2	19790621	
C055296	5230C CC (PD27729)	Irrigation Local Auth	12334.8	MY	WHITEHEAD WATERWORKS DISTRICT BOX 845 NELSON BC V1L6A5	19770804	
C055661	5230C CC (PD27729)	Waterworks Local Auth	33186.46	MY	WHITEHEAD WATERWORKS DISTRICT BOX 845 NELSON BC V1L6A5	19800121	
C055662	5230C T4 (PD62414)	Domestic	2.273	MD	WHITEHEAD WATERWORKS DISTRICT BOX 845 NELSON BC V1L6A5	19790801	
C056180	5230C T4 (PD62414)	Domestic	2.273	MD	WHITEHEAD WATERWORKS DISTRICT BOX 845 NELSON BC V1L6A5	19790801	
C056568	5230C AA (PD27733)	Domestic	2.273	MD	WOOLLS GARY N 518 SILICA ST NELSON BC V1L4M9	19800611	
C056954	5230C AA (PD27733)	Domestic	2.273	MD	INGRAHAM DAVID BRUCE 3170 HEDDLE ROAD NELSON BC V1L6M2	19030331	
C057553	5230C AA (PD27733)	Domestic	2.273	MD	NESBITT MICHAEL C & MARY L 3149 HEDDLE RD NELSON BC V1L6M2	19810205	
C057557	5230C AA (PD27733)	Domestic	2.273	MD	FLEET RICHARD & LANDRY STEPHANIE 2988 HEDDLE RD NELSON BC V1L6Z8	19810710	
C057558	5230C AA (PD27733)	Domestic	2.273	MD	PHILLIPS LORI K & KEITH D 2994 HEDDLE RD NELSON BC V1L6Z8	19810710	
C057559	5230C AA (PD27733)	Domestic	2.273	MD	MISAN DALE S & LORRI L 3018 HEDDLE RD NELSON BC V1L6Z8	19810710	
C057560	5230C AA (PD27733)	Domestic	2.273	MD	BACHYNSKI ROBERT S & SHANNON L 6212 SILVER RIDGE DR NW CALGARY AB T3B3S7	19810710	
C057807	5230C HH (PD27725)	Domestic	2.273	MD	ZAITSOFF ARNOLD G	18990619	

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					2821 GREENWOOD ROAD NELSON BC V1L6L3		
C058284	5230C AA (PD27733)	Domestic	2.273	MD	COBURN NEIL & ALISON K	19810202	
					3186 HEDDLE RD NELSON BC V1L6M2		
C059980	5230C HH (PD27725)	Domestic	2.273	MD	NICHOLAS LINCOLN T & VALDA M	19820531	
					2747 GREENWOOD RD NELSON BC V1L6L2		
C062535	5230C CC (PD27729)	Domestic	2.273	MD	STEIN JUERGEN	19810914	
					2961 SIX MILE LAKES ROAD NELSON BC V1L6W3		
C062547	5230C CC (PD27729)	Domestic	2.273	MD	GIBSON VALERIE J	19840507	
					2919 SIX MILE LAKES ROAD NELSON BC V1L6W3		
C072691	5230C CC (PD27729)	Domestic	2.273	MD	GRAYCHICK SCOTT P	19860612	
					504 ANDERSON ST NELSON BC V1L3Y4		
C100405	5230C AA (PD27733)	Domestic	2.273	MD	MCGRATH DAVID C & VICKY M	19871029	19941114
					C/O WILLIAM MCGRATH 5815 PARKVIEW DR VERMILION AB T9X1V9		
C100426	5230C AA (PD27733)	Domestic	2.273	MD	WILKINSON TANDI L	19890905	19940704
					3210 HEDDLE RD NELSON BC V1L6M2		
C102516	5230C CC (PD27729)	Domestic	2.273	MD	HARLOW L DANIEL & DEIDRE I	19910711	19941114
					2951 SIX MILE LAKES RD NELSON BC V1L6W3		
C104353	5230C AA (PD27733)	Domestic	1.137	MD	WHITE ERIC R & BOWERS VIVIEN E	18990619	19920529
					3093 HEDDLE RD NELSON BC V1L6M2		
"	"	Irrigation	2911.013	MY	WHITE ERIC R & BOWERS VIVIEN E	18990619	19920529
					3093 HEDDLE RD NELSON BC V1L6M2		
C104354	5230C AA (PD27733)	Irrigation	912.775	MY	UPPER CRAIG M	18990619	19920529
					3111 HEDDLE RD NELSON BC V1L6M2		
C104355	5230C AA (PD27733)	Irrigation	1184.141	MY	WOOLLS GARY N	18990619	19920529
					518 SILICA ST NELSON BC V1L4M9		
C104359	5230C AA (PD27733)	Domestic	2.273	MD	NEWELL THOMAS H	19030331	19920529
					3224 HEDDLE RD NELSON BC V1L6M2		
"	"	Res. Lawn/Garden	925.11	MY	NEWELL THOMAS H	19030331	19920529
					3224 HEDDLE RD NELSON BC V1L6M2		
C104800	5230C HH (PD27725)	Domestic	2.273	MD	JOHNSON DANIEL L & SHERYL K	19920527	19950728
					2852 HARLOW RD NELSON BC V1L6L3		
C106051	5230C CC (PD27729)	Res. Lawn/Garde	1233.48	MY	SUGGITT HOLLY KATHLEEN	19051116	19930726

Licence No	WR Map/	Purpose	Quantity	Units	Licensee	Priority Date	Issue Date
		n					
					6102 WINDSOR STREET VANCOUVER BC V5W3J3		
C106755	5230B C6 (PD67902)	Domestic	2.273	MD	OLSSON CARL H & NIKKI L	19930621	19951027
					2805 HWY 3A NELSON BC V1L6M1		
C107644	5230C AA (PD27733)	Domestic	2.273	MD	ROBINSON DAVID S	19050530	19940803
					3063 MILLER RD NELSON BC V1L6Z6		
C107646	5230C AA (PD27733)	Res. Lawn/Garden	1233.48	MY	ENGSTAD PHILIP C & CAROLLE D	19050530	19940803
					3140 KENIRIS RD NELSON BC V1L6Z8		
C107647	5230C AA (PD27733)	Res. Lawn/Garden	1233.48	MY	MOONEY KIMBERLY E	19050530	19940803
					3150 KENIRIS RD NELSON BC V1L6Z8		
C107649	5230C AA (PD27733)	Res. Lawn/Garden	1233.48	MY	KRISTENSEN HANS ELMEGAARD & MURPHY COLLE	19050530	19940803
					JOHANNES VERHULSTSTRAAT 1 1071NC AMSTERDAM NETHERLANDS		
C109542	5230C HH (PD27725)	Domestic	2.273	MD	VILLALUZ CATHERINE J & SCHELLENBERG PAUL	19831115	19950728
					31741 TOWNSHIPLINE RD ABBOTSFORD BC V4X1W4		
C111034	5230C HH (PD27725)	Domestic	2.273	MD	FISCHER CATHERINE A	19960515	20040315
					2755 GREENWOOD RD NELSON BC V1L6L2		
C111044	5230C T4 (PD62414)	Processing	4.546	MD	RENNIE JOHN ET AL	19090222	19960823
					PO BOX 3155 STN MAIN CASTLEGAR BC V1N3H5		
C111645	5230C AA (PD27733)	Domestic	2.273	MD	SUTHERLAND HUNT ADAMS & TYRRELL MARGERY	19601124	19980908
					3114 HEDDLE ROAD NELSON BC V1L6M2		
C111749	5230C AA (PD27733)	Domestic	2.273	MD	LEONG ROSE M	19050530	19961127
					3134 HEDDLE RD NELSON BC V1L6M2		
"	"	Irrigation	11101.32	MY	LEONG ROSE M	19050530	19961127
					3134 HEDDLE RD NELSON BC V1L6M2		
C111750	5230C AA (PD27733)	Res. Lawn/Garden	1850.22	MY	SUTHERLAND HUNT ADAMS & TYRRELL MARGERY	19050530	19961127
					3114 HEDDLE ROAD NELSON BC V1L6M2		
C111752	5230C AA (PD27733)	Res. Lawn/Garden	11829.07	MY	STRATA CORPORATION NES190	19941213	19961127
					STRATA CORP NES 190 3180 THE MIDDLE RD NELSON, BC V1L6M3		
"	"	Waterworks (Other)	27.277	MD	STRATA CORPORATION NES190	19941213	19961127
					STRATA CORP NES 190 3180 THE MIDDLE RD NELSON, BC V1L6M3		

Licence No	WR Map/	Purpose	Quantity	Units	Licensee	Priority Date	Issue Date
C111831	5230C F5 (PD73375)	Domestic	2.273	MD	WATT GORDON A & YVONNE 2910 SIX MILE ROAD NELSON BC V1L6W3	19051116	19971210
"	"	Irrigation	10262.55	MY	WATT GORDON A & YVONNE 2910 SIX MILE ROAD NELSON BC V1L6W3	19051116	19971210
C111832	5230C C5 (PD73372)	Domestic	2.273	MD	COLBECK JOHN D & SCHUTTER SNOWFLOWER 2990 SIX MILE LAKES RD NELSON BC V1L6W3	19051116	19971210
C111834	5230C E5 (PD73374)	Domestic	2.273	MD	JACOBSON HELGA & HYDE NAIDA D 2873 DUHAMEL ROAD NELSON BC V1L6L9	19051116	19971210
C111950	5230C AA (PD27733)	Domestic	2.273	MD	FLETT STEPHEN J & JANICE 3087 HEDDLE RD NELSON BC V1L6M2	18990619	19970201
"	"	Irrigation	1480.176	MY	FLETT STEPHEN J & JANICE 3087 HEDDLE RD NELSON BC V1L6M2	18990619	19970201
C112068	5230C AA (PD27733)	Domestic	2.273	MD	WALL EDWIN P & SWENSON JULIE K 3048 HEDDLE RD NELSON BC V1L6Z8	19050530	19970312
C112243	5230C HH (PD27725)	Domestic	2.273	MD	MELATINI JOSEPH C BOX 877 NELSON BC V1L6A5	19721201	19970526
C112969	5230C AA (PD27733)	Res. Lawn/Garden	1233.48	MY	GIBBON JOHN A 3120 KENIRIS RD NELSON BC V1L6Z8	19980209	19981005
C113063	5230C T4 (PD62414)	Domestic	2.273	MD	FLETTE MARK L & COLLEEN A C/O 10618 81 AVE GRANDE PRAIRIE AB T8W2H2	19980309	20040304
C113714	5230C AA (PD27733)	Domestic	2.273	MD	TURNER IRIS A 829 NELSON AVENUE NELSON BC V1L2N8	19050530	19990202
"	"	Irrigation	34081.05	MY	TURNER IRIS A 829 NELSON AVENUE NELSON BC V1L2N8	19050530	19990202
C113971	5230C AA (PD27733)	Domestic	4.546	MD	TIMMERMANS LAURIE A 3067 MILLER RD NELSON BC V1L5P4	19050530	19991122
"	"	Irrigation	1899.559	MY	TIMMERMANS LAURIE A 3067 MILLER RD NELSON BC V1L5P4	19050530	19991122
C113972	5230C AA (PD27733)	Domestic	2.273	MD	GRANT RICHARD A & GAY H 3065 MILLER RD NELSON BC V1L6Z8	19050530	19991122
"	"	Res. Lawn/Garden	567.401	MY	GRANT RICHARD A & GAY H 3065 MILLER RD NELSON BC	19050530	19991122

Licence No	WR Map/	Purpose	Quantity	Units	Licensee	Priority Date	Issue Date
					V1L6Z8		
C114053	5230C AA (PD27733)	Domestic	2.273	MD	SAUTER ULRICH 3075 HEDDLE RD NELSON BC V1L6M2	18990619	19990831
"	"	Irrigation	2725.991	MY	SAUTER ULRICH 3075 HEDDLE RD NELSON BC V1L6M2	18990619	19990831
C114054	5230C AA (PD27733)	Res. Lawn/Garden	740.088	MY	YAKIMOV MARGARET 3071 HEDDLE ROAD NELSON BC V1L6M2	18990619	19990831
C114055	5230C AA (PD27733)	Res. Lawn/Garden	838.766	MY	VAN NEST KLEIN ALISON J 3067 HEDDLE RD NELSON BC V1L6M2	18990619	19990831
C114899	5230C AA (PD27733)	Irrigation	4317.18	MY	UPPER CRAIG M 3111 HEDDLE RD NELSON BC V1L6M2	18990619	20000412
C114950	5230C AA (PD27733)	Res. Lawn/Garden	1270.484	MY	MANSON VICTOR N & KATHLEEN N 3065 HEDDLE RD NELSON BC V1L6M2	18990619	20000928
C114951	5230C AA (PD27733)	Res. Lawn/Garden	1433.304	MY	PISANO ANTONIO & BERGMAN JODI M 3021 HEDDLE ROAD NELSON BC V1L6Z8	18990619	20000928
C114982	5230C AA (PD27733)	Domestic	2.273	MD	HANLEY WILLIAM DAVID & FOSTER PATRICIA A 3181 HEDDLE ROAD NELSON BC V1L6M3	18990619	20010118
C114983	5230C AA (PD27733)	Domestic	2.273	MD	FURROW EDWARD THOMAS & SETTER SANDRA JAN 3179 HEDDLE ROAD NELSON BC V1L6M2	18990619	20010118
C114984	5230C AA (PD27733)	Domestic	2.273	MD	FARAGUNA ALLAN M & MELISSA A 3169 HEDDLE ROAD NELSON BC V1L6M2	18990619	20010118
C115039	5230C AA (PD27733)	Domestic	2.273	MD	MANSON VICTOR N & KATHLEEN N 3065 HEDDLE RD NELSON BC V1L6M2	19781220	20000929
C115040	5230C AA (PD27733)	Domestic	2.273	MD	PISANO ANTONIO & BERGMAN JODI M 3021 HEDDLE ROAD NELSON BC V1L6Z8	19781220	20000928
C115757	5230C AA (PD27733)	Domestic	2.273	MD	UPPER CRAIG M 3111 HEDDLE RD NELSON BC V1L6M2	19800611	20010327
C118015	5230C R4 (PD27732)	Domestic	2.273	MD	JONES MICHAEL L & BERNICE M 2905 DUHAMEL RD NELSON BC V1L6L5	20030210	20040308
C119652	5230C AA (PD27733)	Domestic	2.273	MD	DOWDEN CHERYL L 3053 KENIRIS RD NELSON BC	19050530	20041101

Licence No	WR Map/	Purpose	Quantity	Units	Licensee	Priority Date	Issue Date
					V1L6Z8		
"	"	Irrigation	869.603	MY	DOWDEN CHERYL L 3053 KENIRIS RD NELSON BC V1L6Z8	19050530	20041101
C119653	5230C AA (PD27733)	Domestic	2.273	MD	WEILAND GORDON & DEBORA 3051 KENIRIS RD NELSON BC V1L6Z8	19050530	20041101
"	"	Irrigation	869.603	MY	WEILAND GORDON & DEBORA 3051 KENIRIS RD NELSON BC V1L6Z8	19050530	20041101
C119832	5230C HH (PD27725)	Domestic	1.514	MD	RINGROSE JOSEPH HENRY & KAREN JOYCE 2731 GREENWOOD ROAD NELSON BC V1L6L2	18990619	20050309
C119880	5230C D5 (PD73373)	Domestic	2.273	MD	SHEWFELT LEONARD J & YVONNE R 2916 SIX MILE LAKES RD NELSON BC V1L6W3	19051116	20050314
C120320	5230C CC (PD27729)	Irrigation Local Auth	3700.44	MY	WHITEHEAD WATERWORKS DISTRICT BOX 845 NELSON BC V1L6A5	19030512	20060605
C120807	5230C AA (PD27733)	Domestic	2.273	MD	JENSEN RANDA LUCILLE 3060 HEDDLE ROAD NELSON BC V1L6M2	19050530	20060314
"	"	Res. Lawn/Garden	1023.788	MY	JENSEN RANDA LUCILLE 3060 HEDDLE ROAD NELSON BC V1L6M2	19050530	20060314
C120955	5230C T4 (PD62414)	Domestic	2.273	MD	WICKENS JOHN R & ROBERTA E 2846 SIX MILE LAKES RD NELSON BC V1L6W3	19090222	20060608
C121011	5230C AA (PD27733)	Domestic	2.273	MD	MATHIESON CAMERON W 3061 KENIRIS ROAD NELSON BC V1L6Z8	19050530	20060612
C121012	5230C AA (PD27733)	Domestic	2.273	MD	PODMOROFF NADINE 3059 KENIRIS ROAD NELSON BC V1L6Z8	19050530	20060612
C121057	5230C AA (PD27733)	Domestic	2.273	MD	MOGENTALE ILARIO F 2925 TEES RD NELSON BC V1L6M1	18990619	20060612
"	"	Irrigation	4132.158	MY	MOGENTALE ILARIO F 2925 TEES RD NELSON BC V1L6M1	18990619	20060612
C121280	5230C HH (PD27725)	Domestic	2.273	MD	SHAH SHANNON L 2664 HIGHWAY 3A NELSON BC V1L6L1	20051021	20060315
C123389	5230C HH (PD27725)	Domestic	2.273	MD	VAN DONSELAAR RAPH V 2873 DUHAMEL RD NELSON BC V1L6L9	19790607	20080103
"	"	Irrigation	2257.268	MY	VAN DONSELAAR RAPH V 2873 DUHAMEL RD NELSON BC V1L6L9	19790607	20080103

Licence No	WR Map/	Purpose	Quantity	Units	Licensee	Priority Date	Issue Date
C123390	5230C HH (PD27725)	Domestic	2.273	MD	KIRBY MICHAEL RICHARD & NADINE EILEEN 2869 DUHAMEL ROAD NELSON BC V1L6L9	19790607	20080103
C124478	5230C AA (PD27733)	Domestic	2.273	MD	LAFLEUR WALTER & SCHLEUSS CAROLA 3164 HEDDLE ROAD NELSON BC V1L6M2	19030331	20090316
C125532	5230C AA (PD27733)	Domestic	2.273	MD	GREEN PATRICK GEORGE 3166 HEDDLE ROAD NELSON BC V1L6M2	19030331	20130606
"	"	Irrigation	2466.96	MY	GREEN PATRICK GEORGE 3166 HEDDLE ROAD NELSON BC V1L6M2	19030331	20130606
C127332	5230C AA (PD27733)	Res. Lawn/Garden	1233.48	MY	FARAGHER ELDON THOMAS 3141 KENIRIS RD NELSON BC V1L6Z8	19050530	20120201
C130199	PD185627 - 5230C	Waterworks (Other)	56.31	MD	0911214 B.C. LTD. 615 SILICA STREET NELSON BC V1L4N2	20130215	20130425
C130259	5230C HH (PD27725)	Domestic	2.273	MD	LATHAM DAVID B 2930 COLORADO AVE D20 SANTA MONICA CA 90404 USA	20100210	20130503
C130260	5230C AA (PD27733)	Domestic	4.546	MD	ABRAHAM MARIANNE G 3178 HEDDLE ROAD NELSON BC V1L6M2	19030331	20130501
"	"	Irrigation	2047.58	MY	ABRAHAM MARIANNE G 3178 HEDDLE ROAD NELSON BC V1L6M2	19030331	20130501
F017965	5230B H4 (PD27712)	Domestic	2.273	MD	HOWE SUSAN MAY 1 2727 LOWER SIX MILE ROA NELSON BC V1L6L5	19580909	
F017981	5230B H4 (PD27712)	Domestic	4.546	MD	RINGROSE JOSEPH HENRY & KAREN JOYCE 2731 GREENWOOD ROAD NELSON BC V1L6L2	18990619	
"	5230B X3 (PD27705)	Domestic	4.546	MD	RINGROSE JOSEPH HENRY & KAREN JOYCE 2731 GREENWOOD ROAD NELSON BC V1L6L2	18990619	
F017982	5230B H4 (PD27712)	Domestic	6.819	MD	MCGUIRE DANIEL JAMES 25-3397 HASTINGS STREET PORT COQUITLAM BC V3B4M8	18990619	
"	5230B X3 (PD27705)	Domestic	6.819	MD	MCGUIRE DANIEL JAMES 25-3397 HASTINGS STREET PORT COQUITLAM BC V3B4M8	18990619	
F017983	5230B U4 (PD27711)	Domestic	2.273	MD	WEST KATHERINE W 2785 HWY 3A NELSON BC V1L6L6	18990619	
"	5230B X3 (PD27705)	Domestic	2.273	MD	WEST KATHERINE W 2785 HWY 3A NELSON BC V1L6L6	18990619	

Licence No	WR Map/	Purpose	Quantity	Units	Licensee	Priority Date	Issue Date
F017984	5230B T4 (PD27710)	Domestic	2.273	MD	LEHNERT CHRISTOPHER CALE & BLASCHEK JULI 2795 3A HIGHWAY NELSON BC V1L6L6	1899061 9	
"	5230B X3 (PD27705)	Domestic	2.273	MD	LEHNERT CHRISTOPHER CALE & BLASCHEK JULI 2795 3A HIGHWAY NELSON BC V1L6L6	1899061 9	
F018229	5230C HH (PD27725)	Domestic	22.73	MD	WORKING PROJECTS INC 724 2ND STREET NELSON BC V1L2L9	1960052 7	
F018372	5230C HH (PD27725)	Domestic	2.273	MD	BRIONNE THIERRY D 2790 WAITE RD NELSON BC V1L6K9	1899061 9	
"	"	Irrigation	629.075	MY	BRIONNE THIERRY D 2790 WAITE RD NELSON BC V1L6K9	1899061 9	
F018373	5230C HH (PD27725)	Domestic	2.273	MD	WHITEHEAD WATERWORKS DISTRICT BOX 845 NELSON BC V1L6A5	1899061 9	
"	"	Irrigation Local Auth	740.088	MY	WHITEHEAD WATERWORKS DISTRICT BOX 845 NELSON BC V1L6A5	1899061 9	
F020664	5230B B5 (PD27713)	Domestic	2.273	MD	ROBINSON PETER 2746 HWY 3A NELSON BC V1L6L6	1965052 7	
"	"	Irrigation	1356.828	MY	ROBINSON PETER 2746 HWY 3A NELSON BC V1L6L6	1965052 7	
"	5230B X (PD27704)	Domestic	2.273	MD	ROBINSON PETER 2746 HWY 3A NELSON BC V1L6L6	1965052 7	
"	"	Irrigation	1356.828	MY	ROBINSON PETER 2746 HWY 3A NELSON BC V1L6L6	1965052 7	
F059193	5230C HH (PD27725)	Domestic	2.273	MD	SKELSTAD HOLDINGS LTD INC 558846 2723 GREENWOOD RD NELSON BC V1L6L1	1899061 9	

Total number of Licences and/or Applications found is 121

Appendix 2. Background literature for new hydrological recovery curve

All studies are from snowmelt dominated regions.

Winkler et al. 2005 (3 year study at two sites)

Site 1

Mayson Lake – 4 sites at 1250m elevation all within 1km.

- Mature Forest – 23 m 100 yr, multi-layer spruce, subalpine fir, pine, 54% crown closure and 4400 stems/ha
- Juvenile stand – 15 year, pine (spruce, fir) average height of 4.5m 28% cc and 2600 st/ha.
- Juvenile thinned – 15 yr, pine, avg height 6.4m, 21% cc and 1000 st/ha
- Clearcut – pine less than 1m

Accumulation

Study determined that clearcuts accumulated between 37 to 75% more snow than the forest stand and 11 to 40% more snow than the juvenile stands. The juvenile stands accumulated on average 27% more snow than the forest stand (measured during the peak accumulation around April 1st of each year). Results indicate that process of snow accumulation are beginning to recover in the 4.5 to 6.4 m juvenile stands.

Melt rate

Study determined that melt rate varies considerably from year to year (this is probably because melt rate is directly dependent on amount of solar radiation (temperatures) which vary from year to year). On average melt rate in the clearcut is 2.4 times that of the mature forest. The ratios of juvenile stand to clearcut melt rates were 0.8 to 0.9. In the juvenile stands, melt rates were reduced by less than 0.1 cm day^{-1} in the juvenile-thinned stand and by 0.17 cm day^{-1} in the juvenile unthinned stand (10% and 17% respectively), relative to the clearcuts. Winkler et al., (2005) conclude that "These results indicate that juvenile stands, such as those included in this investigation, have a small effect on snowmelt rates."

Additional information from snowmelt lysimeters in the clearcut and juvenile stands indicated that melt rate early in the snowmelt period was actually higher in the juvenile thinned stand than in the clearcut. On average for the 3 years snowmelt ‘recovery’ is estimated as 13% and 23% in the juvenile-thinned and juvenile pine stands respectively.

Site 2

Upper Penticton Creek – 5 sites at 1600 to 1700 m

- Mature Pine approx 18m stand with 40% cc and 4000 st/ha
- Mature mixed spruce, subalpine fir, pine, approx 19m stand with 44% cc and 3800 st/ha.
- 2 -clear cut stands adjacent to these mature stands
- 4 meter juvenile stand mixed spruce, fir, pine with 3400 st/ha and 0%cc

Snow Accumulation

At Upper Penticton Creek, April 1st SWE in both mature stands was significantly different from that in adjacent clearcuts in all years. Differences in April 1st SWE varied from 27 to 35% higher in the clearcut than in the mature spruce-fir stand (Figure 4.2). but only 6 to 19% relative to the mature pine stand. SWE in the juvenile stand at Upper Penticton Creek was also significantly larger (26 to 42%) than that in the spruce-fir stand, but not larger than that in the clearcut. Since April 1st SWE in the juvenile stand was equal to or slightly greater than in the clearcut, depending on the year, these data suggested that there has been no reduction in peak snow accumulation as a result of forest regrowth in this juvenile stand.

Melt rate

At Upper Penticton Creek, the average snowmelt rate in the clearcut was 38% higher than in the pine stand and 62% higher than in the spruce-fir stand . Melt rates in the juvenile spruce-fir stand at Upper Penticton Creek were greater than those in the mature spruce-fir stand in all years, by 0.26 cm d^{-1} on average, but were not different from those measured in the clearcut, except in 1996 when they were 0.06 cm d^{-1} higher.

Buttle et al. 2005.

NE Ontario ten sites within 22 km on flat terrain. Snowmelt dominated (no rain) 1yr study

- Mature black spruce approx 7m with 73% cc and 5400 st/ha (s8)
- Mature balsam fir, black & white spruce 16m with 80% cc and 1529 st/ha (s9)

- Mature balsam fir and white spruce, 16.4 m with 82% cc and 1000 st/ha (s10)
- 2 clearcuts (sites 1 and 2)
- 1.7m white spruce juvenile stand, 9%cc and 1947 st/ha (site 3)
- 1.8m black spruce juvenile stand, 0%cc and 6421 s/ha (site 4)
- 2.4m black spruce (minor balsam) juvenile stand 3%cc and 1552 st/ha (site 5)
- 3.2m juvenile stand black/white spruce, balsam fir, 22% cc and 12400 st/ha (s6)
- 3.3m juvenile stand black/white spruce, balsam fir, 36% cc and 7316 st/ha (s7)

Snow Accumulation

Generally 20 to 40% less snow in the mature forest than in the clearcut sites at peak SWE, however, in the 15 yr, 3.2 meter juvenile stand with over 12000 stems/hectare (Site 6), peak SWE is approaching 80% that of the mature stand (only 20% greater accumulation than the mature stand). Note: It is probably important to consider that snow accumulation may evolve differently through the winter months in NE Ontario as compared to intermontane BC. This is possibly due to larger variability in mid-winter air temperatures (associated with mild gulf coast weather systems)

Melt Rate

Highest melt rate was observed at site 3 , a 14yr old 1.7m white sp with 1947 stems per hectare and lowest melt rate was observed at site 10 (Mature, 16.4 m average balsam fir/spruce stand). The relationship between mean melt rate (*MMR)* and canopy height and density showed an increase in *MMR* with initial regeneration, followed by a decrease in *MMR* to values equal to or less than those measured in the clearcut sites. Buttle et al., 2005 state: “Conversely, MMR values suggest that snowmelt rates may actually increase above melt rates in recent clearcuts during the initial stages of stand regeneration, and do not drop significantly below those observed for Site 3 (harvested in 1990) until at least 14 years after harvesting.”

Hardy, Hansen-Bristow, 1990. Southwest Montana 2085m

<u>Lick Creek – 4 sites with similar aspect, elevation and slope characteristics – 1yr study</u>

- Mature Douglas fir 18 – 26m, 85% crown closure
- Juvenile pine stand (35yr) 10 to 14m, 56% cc.
- Clearcut (10-15yr - young pine stand) 0.5 to 4m, 6% cc
- Meadow

Snow Accumulation

Of the four sites the meadow accumulated the most snow and the mature forest accumulated the least. There is no significant difference in snow accumulation between the meadow and the young pine (clearcut) stand. The juvenile stand had roughly 12% less SWE at max SWE than the meadow and the mature stand accumulated roughly 26% less SWE than the meadow. They suggest that there is very little change in peak SWE relative to the meadow in stands with canopy closure between 0 and 55%.

Melt Rate

Melt rate was highest in the meadow early in the melt season. The young and juvenile stands prolonged the melt but the average melt rate in the young (clearcut) was not significantly different than the meadow. The avg. melt rate in the juvenile stand was roughly 38% faster than the forest. They suggest that there is a gradual change in melt rate until the canopy density reaches 70 to 75% of the mature stand.

Bewley et al., 2010 - plots on level ground at 990 and 1220 m

<u>Baker Creek west of Quesnel</u>

All plots on level ground (avg 3^{o} gradient) at either 990 or 1220 m Baker Creek west of Quesnel

- 2 Juvenile pine stands (25-50yr), 10-15m, 1700 – 2900 st/ha (green/red attack)
- 1 Juvenile pine (10-25yr), 1-5m, 2000 st/ha.
- 2 Clearcuts

Snow Accumulation

No significant difference in total SWE accumulation between sites at 990m elevation. Sites at 1220 meters showed some differences with the clearcut accumulating more SWE (175mm) than the forest (~157mm) or approximately 12% more SWE.

Melt Rate

The avg melt rate in the clearcut was significantly higher than the melt rate in the forest at 990 metres but not significantly higher than the melt rate in the (1-5m) regen stand at 990m. The average melt rate in the clearcut is higher than that of the forest at 1220 meters but the difference is not as great as at the lower elevations.

Ellis et al., 2010 – Plots on north versus south aspect in Marmot Creek Alberta

This study did not include an investigation of recovery in juvenile stands but does highlight the differences in snow accumulation and melt dynamics between north-aspect, south-aspect and flat ground clearcut/forest pairs. This investigation found that slope aspect plays a key role in determining differences in accumulation and melt dynamics. It follows that recovery of snow accumulation and melt processes will vary considerably depending on the slope aspect/gradient.

Summary of Snow Accumulation and Melt data from snowmelt dominated regions

Much more research is needed to fully understand the combined effects of watershed physiography and stand composition on the recovery of snow accumulation and melt in the Kootenay region. Most of the studies summarized above suggest that maximum snow accumulation begins to decrease in the young blocks (~15 yrs) relative to the clearcut but that there is no significant decrease in the rate of melt in these young stands relative to the clearcuts. Most studies found that more snow accumulates in the young regenerating stands relative to the forest and the melt rate varies from slightly slower to slightly faster than the clearcut. In terms of 'hydrological recovery' these young stands (that ranged in height from 1 to 6.4m depending on the study) are not showing significant recovery relative to the unharvested stands. An exception to this was observed by Buttle et al. (2005) that documented a much lower melt rate in the 3.3 meter regen stand that had a stem density of over 12000 st/ha.

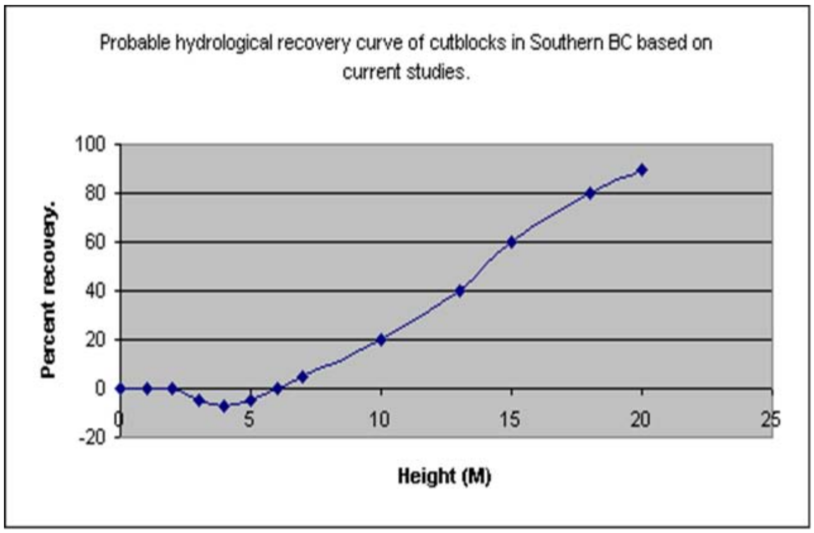
Most studies agree that recovery of melt rate is dependent on an increase in crown closure (crown density). Hardy and Hansen-Bristow report recovery of melt rate relative to the forest of roughly 40% in a 35yr 10-14m (12m avg) juvenile stand. Canopy density of this juvenile stand had recovered to approximately 65% of the unharvested forest.

Conclusions interpreted from these studies:

Up to approximately 6 meters and less than 30% crown closure hydrological recovery is essentially 0%. Beyond 7 meters hydrological recovery increases gradually and depends on stem density. Once stand height exceeds roughly 12 meters and crown closure exceeds roughly 60% of the unharvested forest the stand is somewhere around 40% recovered. The rate of recovery likely increases slightly beyond this point as crown closure increases in the maturing stand. Once crown closure reaches roughly 75 to 80% or more of the unharvested stand hydrological recovery begins to approach 100%. Hardy and Hansen-Bristow suggest that complete hydrological recovery does not occur in the mixed species stands of southwestern Montana until upwards of 80 years. Regenerating stands of between 10 and 20 years old in central BC and northern Ontario show very minimal to no recovery, which is consistent with the Montana findings.

A conservative hydrological recovery curve for flat ground blocks based on the summarized studies and adapted for southeastern BC might take the form of the following curve:

Height m	% recov.
0	0
1	0
2	0
3	-5
4	-7
5	-5
6	0
7	5
10	20
13	40
15	60
18	80
20	90



Additional Notes:

- While this graph shows hydrological recovery by height in meters - it is probably more accurate to represent height as a percentage of the height of the unharvested stand rather than an absolute value.
- Crown closure (or canopy density) is an important factor in hydrological recovery. Studies suggest that crown closure must reach upwards of 30% (absolute) or 50% of the unharvested stand before recovery of melt rate begins. Regenerating stand with low basal area relative to the forest will take longer to recover. Stands with higher basal area will probably recover faster.
- This curve is likely to be substantially different for blocks with north, south, east and west aspects. Much more research is necessary to understand the effect of slope aspect on recovery

This conservative hypothetical curve dips into the negative recovery in the earliest stage of stand regeneration due to the increase in longwave radiation emitted to the snowpack associated with exposed stems of the new trees. The curve as drawn is predicated on the recovery of canopy density as well as crown height. Lower canopy density (relative to the forest) will shift the curve to the right (slower recovery) and substantially higher canopy density (at least 2 times) may shift the curve to the left.

Literature cited:

Bewley, D., Alila, Y and A. Varhola, 2010. Variability of snow water equivalent and snow energetics across a large catchment subject to Mountain Pine Beetle infestation and rapid salvage logging. Journal of Hydrology, 388: 464-479.

Buttle, J.M., C.J. Oswald, and D.T. Woods. 2005. Hydrologic recovery of snow accumulation and melt following harvesting in northeastern Ontario. In Proceedings of the 62nd Annual Eastern Snow Conference, June 7–10, 2005, Waterloo, Ont., pp. 83–91.

Ellis, C.R., Pomeroy, J.W., Essery, R.L.H., and Link, T.E., 2010. Effects of needle-leaf forest cover on radiation and snowmelt dynamics in the Canadian Rocky Mountains, Canadian Journal of Forest Research, 41, 608–620, doi:10.1139/X10-227.

Hardy, J.P. and K.J. Hansen-Bristow, 1990. Temporal accumulation and ablation patterns in forests representing various stages of growth. In: Proceedings of the 58th Annual Western Snow Conference, April 1990, Sacramento, California.

Winkler RD, Spittlehouse DL, and DL, Golding, 2005. Measured differences in snow accumulation and melt among clearcut, juvenile, and mature forests in southern British Columbia. Hydrological Processes 19: 51–62.

Appendix 3 - Climate Change, Flood Frequency in Duhamel Creek and implications for Forest Harvesting.

A statistical test for a trend over time in the Duhamel peak flow time series showed that for the 20 years of gauging there are no significant trends with time. An analysis of three near-by long-term hydrometric stations (Kaslo River, Five-Mile Creek and Anderson Creek) was undertaken to determine if there were any consistent trends in the regional historical hydrometric data that can be used to determine possible future changes to the frequency of flood events in Duhamel Creek. The analysis determined that the historical discharge data for the three near-by streams display no consistent trends over time or changes in the mean or variability of annual peak discharge over the period of gauging (31 years to 56 years).

Recent publications by the Pacific Climate Impacts Consortium at the University of Victoria report the results of projected changes in a number of hydroclimate variables within the southern BC Columbia Basin based on the application of the Variable Infiltration Capacity Model. (Hamlet et al., 2012). The PCIC study found that;

> "Of all the metrics evaluated, hydrologic extremes, and particularly high flow extremes, showed the greatest inconsistencies between modeling approaches. Substantial differences were also found in the percent changes in cool and warm-season streamflow, and changes in the timing of peak flows..."

The PCIC modeling study projects that by 2050 in the Southern Kootenay region, summer months will experience higher temperatures on average while winter months will experience increased precipitation on average. The PCIC group suggests that for alpine-dominated watershed such as Duhamel Creek increased precipitation could result in increased winter snow packs, while increased spring and summer temperatures could result in a shift to earlier peak flows. However, it is not clear how these changes will affect the magnitude or frequency of larger-than-average (i.e. extreme) flood events. It is possible that there will be an increase in the number of rain-on-snow peak events compared to solar radiation driven peaks particularly during the fall, late winter and early spring months.

The historical hydrometric data analysis from the Kalso River, which, like Duhamel is primarily high elevation alpine-dominated, determined that both the mean and variability of the annual maximum peak flows have decreased in the last 25 years compared to the first 25 years of gauging. In the Kalso River the decrease in the mean and variability of the annual maximum flood time series over the last 50 years means that peak flows overall have decreased and the cumulative frequency curve has become flatter. This observed change in the frequency distribution of floods runs somewhat contrary to those based on projections of the climate models which suggest that peak flow variability should increase (the frequency curve should get steeper) with increasing spring temperatures and increasing winter precipitation (Pike et al., 2010).

The following excerpt is from APEGBC document *Professional Practice Guidelines – Legislated Flood Assessments in a Changing Climate in BC* (APEGBC, 2012).

> “Projections of future climate or runoff are best assessed in terms of the mean and range of outputs from an ensemble of model runs. Such results must be obtained from climatologists who specialize in model analysis, from the sources listed in section 3.6.2 or from specialized consultants. In the absence of applicable hydroclimate model results, magnitude-frequency analyses based on recent experience (approximately 30 years) may remain valid for short-term (<30 years) projections, provided no trend is evident in the historical sequence of flood flows.”

The following excerpt is from the Columbia Basin Trust website (Water and Climate Change in the Canadian Columbia Basin, CBT website publication download October 2014)

“…cold winter temperatures will protect mountain snowpack from warming and capture water from wetter winters. Some high-elevation areas may even see increasing snowpack due to cold winter temperatures and increasing precipitation. “

For the purpose of the Duhamel Creek Hydrogeomorphic Risk analysis the projected change in climate is deemed unlikely to have a substantial influence on the existing flood frequency curve for Duhamel Creek and therefore will not influence the outcomes of the risk analysis. However, the projected increase in frequency of rain-on-snow events during fall, winter and early spring months could result in increased hillslope runoff on the lower elevation slopes of Duhamel Creek.

Some selected literature concerning climate change projections in the Columbia Basin:

Hamlet, A., M. Schnorbus, A. Werner, M. Stumbaugh, and I. Tohver. (2012). A Climate Change Scenario Intercomparison Study for the Canadian Columbia River Basin. Prepared for the Columbia Basin Trust

Murdock, T.Q. and A.T. Werner, 2011: Canadian Columbia Basin Climate Trends and Projections: 2007- 2010 Update. Pacific Climate Impacts Consortium, University of Victoria, Victoria, BC, 43 pp.

Murdock, T.Q., S.R. Sobie, 2013: Climate Extremes in the Canadian Columbia Basin: A Preliminary Assessment. Pacific Climate Impacts Consortium, University of Victoria, Victoria, BC, 52 pp.

Pike, R. G., K. E. R. Bennett, T.E., A. T. S. Werner, D.L., R. D. M. Moore, T.Q., J. S. Beckers, B.D.,, K. D. F. Bladon, V.N., and D. A. T. Campbell, P.J., 2010: Climate Change Effects on Watershed Processes in British Columbia, Chapter 19. Compendium of forest hydrology and geomorphology in British Columbia, R. G. Pike, T. E. Redding, R. D. Moore, R. D. Winkler, and K. D. Bladon, Eds., BC Ministry of Forests and Range with FORREX Forum for Research and Extension in Natural Resources, 699-747.

Appendix 4. Field form data from 2013 and 2014 surveys

Survey Site	Site ID	Time	Wb(m)	Dbf(m)	D90(cm) 1	D90(cm) 2	D90(cm) 3	D90(cm) 4	D90(cm) 5	Avg	S%	Morphology	Description	Lwd Function	Lwd (#/10m)	Riparian
1	Site#01	Aug 6, 2014, 9:57 AM	6.1	0.39	32	22	27	25	25	26	27	Ca(b)	Confined boulder bedrock cascade. Bottom edge of woody debris deposit from snow avalanches. Most recent woody deposit is several years old but also there is wood from old deposits. Width and depth here is appx avg flood. D90s from 3/4 yr old flood/ slush avalanche.	// Margins	10	Cleared by avalanches to about 3 m. Above is maple and sapling hemlock
2	Site#02	Aug 6, 2014, 10:28 AM	0	0	0	0	0	0	0		0	Brk	Top of wood deposit	-None Selected-	0	N/A
3	Site#03	Aug 6, 2014, 12:24 PM	4.6	0.34	4.5	4.5	4	4.2	5	4.4	2.5	Plane Bed	Angular cv from valley side. Material in bed >48mm is mossy and angular. No function lwd here. Banks are veg with willow and grasses and moss. Wolman done here.	-None Selected-	0	Mixed age hemlock to 40 cm
4	Site#04	N/A	0	0	12	13	14	16	13	14	2	Plane Bed	Deposit of SWD along channel margins from 5yr flood deposit appx	-None Selected-	0	N/A
5	Site#05	Aug 6, 2014, 1:05 PM	0	0	2.1	2.3	1.2	2	1.5	1.8	0.5	FRp	Pools above old broken beaver dam	-None Selected-	0	N/A
6	Site#06	Aug 6, 2014, 1:36 PM	5.2	0.55	9	16	14	12	13	13	4	FSp	Channel confined both sides. Cv from deposits both sides is in channel mossy and angular. Forming stepped morph.	Partly	0.5	Mixed age hemlock and cedar. Some starting to go down across channel. Still list if v old wd from logging along margins.
7	Site#07	Aug 6, 2014, 1:48 PM	5.1	0.47	19	20	27	24	19	22	3	Sp	Confined as at last Stn. Lots of mossy cv in channel. Some steps forming. V old lwd along margins here from 20+ yr flood. Also branches from more e Recent 2 to 5 yr flood. Wolman done here	// Margins	1	As at last
			5.15	0.51						17	3.5					
9	Site#09	Aug 6, 2014, 2:38 PM	0	0	0	0	0	0	0		0	-None Selected-	Beaver pond	-None Selected-	0	N/A
10	Site#10	Aug 6, 2014, 3:02 PM	6.8	0.3	19	22	17	19	22	20	2	FRp	Below bridge cobble load. Channel is unconfined over 30 m wide floodplain. Cobbles from debris flow channel. Recent flood deposit branches.	-None Selected-	0	Willow
11	Site#11	Aug 6, 2014, 3:16	0	0	6	5	7	7	10	7	0	Rp	Unconfined channel near toe of old debris flow deposit .	-None Selected-	0	N/A

		PM														
12	Site#12	Aug 6, 2014, 3:29 PM	6.5	0.37	20	19	22	20	17	20	4	Mixed	Above debris flow trib. Below beaver dams. Wolman done. Channel is colluvial angular boulders with sand gravel matrix. Dark mossy cv.	-None Selected-	0	Willow
13	Site#13	Aug 7, 2014, 9:36 AM	2.4	0.18		23	21	28	26	25	23	Cv	Debris flow trib. Some recent flood activity within past 10 yrs. bed material is boulders to 25 cm. broken wd in channel under recent deposit. Boulder levees on fan are pre this stand so 100 to 200 yrs. cedar to 80 cm on levees.	Partly	0	N/A
14	Site#14	Aug 7, 2014, 10:07 AM	12.7	0.8	19	23	24	25	23	23	14	Ca(b)	Cv boulder cascade. Confined both banks by cv deposits and some brk. Sand gravel matrix to bed. Cv blocks mossy and immobile.	// Margins	1	Mixed age cd hem to 60cm. V old broken wd // to banks. Some smaller wd starting to enter from riparian. Lots of broken wood along channel.
15	Site#15	Aug 7, 2014, 10:28 AM	6.1	0.76	17	19	20	21	19	19	5	Mixed	Cv cascade to sp. starting to see steps forming with small boulders. Channel confined both sides. Sand gravel matrix. Cv boulders to 1 m. Wolman done here.	// Margins	1	Avalanche cone on r bank. Mixed cd hm to 60 cm on left.
16	Site#16	Aug 7, 2014, 10:59 AM	9.3	0.54	5	4	5	7	8	5.8	11	Ca(b)	Cv boulder cascade with sand gravel matrix. Confined both sides by cv deposits. Cv boulders mossy. Branches against wd jam from recent flood 2/3 years. Lwd jam here is 2 to 4 decades old.	Partly	1	Mixed cedar hem to 1 m. Some across channel. V old broken lwd // to banks.
17	Site#17	Aug 7, 2014, 11:24 AM	0	0	0	0	0	0	0		45	Cv	Last large flood about 40+_ 20 years. But not debris flow.	Partly	0	Mixed cedar hemlock
18	Site#18	Aug 7, 2014, 11:59 AM	4.1	0.44	26	27	25	22	27	25	14	Ca(b)	Last flood 2 yrs ago. Scoured forest floor and sand to cobble material deposited overbank. Last debris flow about 20 years ago now has sapling hemlock to 3 m height on levee. Also boulder deposits from 10 to 20 years with moss and hebaceous. Banks are scoured to eroded from recent flood.	Partly	1	Mixed cedar hem to 50 cm. some wood suspended across channel recently 40 yrs.
19	Site#19	Aug 7, 2014, 12:14 PM	4.6	0.45	31	30	30	32	31	31	16	Ca(b)	Boulder cascade.	// Margins	0.5	N/A
			4.35	0.445						28	15					

20	Site#20	Aug 7, 2014, 1:12 PM	0	0	0	0	0	0	0		0	Sp	Wolman done here	-None Selected-	0	N/A
21	Site#21	Aug 7, 2014, 2:22 PM	9.8	0.64	52	50	60	60	52	55	6	Sp	Boulder step pool to cascade. Confined on l by bedrock. Entrenched on r by old levee by 1 m.	Partly	0.5	Cedar hemlock to 40 cm. banks are vertical and veg with moss. Recently scoured. Banks are boulder deposits. Cedar to 30 cm growing in deposits.
22	Site#22	Aug 7, 2014, 3:26 PM	8.8	0.68	38	39	30	36	34	35	6	Sp	Boulder step. Banks are boulder deposits vegetated with willow. Channel entrenched 1 to 2'meters.	-None Selected-	0	N/A
23	Site#23	N/A	0	0	0	0	0	0	0		0	Sp	Same as last	-None Selected-	0	N/A
marked as 021	Site#26	N/A	0	0	0	0	0	0	0		0	Sp	Upstream in cobble boulder step. Boulders are sub angular and dark. Sand in matrix of channel	-None Selected-	0	N/A
marked as 022	Site#27	N/A	0	0	0	0	0	0	0		0	-None Selected-	Cv slope on east side supplying angular cobbles and boulders to channel	-None Selected-	0	N/A

October 17, 2013 survey data

Survey site	Time	Wb(m)	Dbf(m)	D90(cm) 1	D90(cm) 2	D90(cm) 3	D90(cm) 4	D90(cm) 5	Average	S%	Morphology	Description	Lwd Function	Lwd Density (#/10m)	Riparian
001	N/A	0.00	0	0	0	0	0	0		0	-None Selected-	N/A	-None Selected-	0	N/A
002	N/A	9.00	0.75	60	65	58	75	85	69	11	Sp	Boulder step pool to cascade. Banks overhanging and veg with cedar hem. Evidence of recent overbank flood. Sand deposits downstream from large step boulders.	-None Selected-	0	N/A
003	N/A	0.00	0	0	0	0	0	0		8	Sp	As at site 2	-None Selected-	0	N/A
004	N/A	0.00	0	0	0	0	0	0		0	-None Selected-	Pictures up and down stream	-None Selected-	0	N/A
005	N/A	9.50	0.9	0	0	0	0	0		7	Sp	Old flood deposit along margin appx 10 years. Broken lwd. Bed load moved appx 20 m downstream.	-None Selected-	0	N/A

006	N/A	0.00	0	0	0	0	0	0		0	Ca(b)	Bank slough and avulsion of channel. Trib enters from west here. Boulder step to cascade morph.	-None Select ed-	0	N/A
007	N/A	10.00	0.6	65	70	75	60	80	70	8	Ca(b)	Above debris flow trib. Channel is still bimodal with sand but much less cobbles. Now bed has mossy boulders. Picture taken looking upstream from high bank. Upstream from 07. Pic of empty lwd jam due to lack of cobbles.	-None Select ed-	0	N/A
Average		9.50	0.75						69	8.50					
008	N/A	8.80	0.8	70	0	0	0	0		6	Sp	Mossy boulder step pool to cascade. Stone lines very mossy. Bank scour less apparent but still present.	-None Select ed-	0	N/A
009	N/A	0.00	0	0	0	0	0	0		0	-None Select ed-	Old very large LWD jam. Possibly old bridge site.	-None Select ed-	0	N/A
010	N/A	0.00	0	0	0	0	0	0.4		4	-None Select ed-	20 m long sand wedge above old LWD jam. Cobbles are mossy but gravel to 2 cm is bright. Appx. Recent erosion to 50 cm of lateral deposit of sand and organic.	-None Select ed-	0	N/A
011	N/A	0.00	0	0	0	0	0	8		1	Rp	Broken beaver dam at outlet of wetland.	-None Select ed-	0	N/A
012	N/A	0.00	0	7	5	6	7	8	6.6	0	Rp	Upper end of wetland. Beaver dams recently broken .. Maybe 2 yrs ago. Channel bed has lots of moss.	-None Select ed-	0	N/A
013	Oct 17, 2013, 2:01 PM	8.60	0.5	5	0	0	0	0		2	Plane Bed	Banks veg with mixed age cedar hemlock. Vertical and mossy. No obvious scour here.	-None Select ed-	0	N/A
014	N/A	0.00	0	0	0	0	0	0		20	Cv	Fan of debris flow trib. Over 100 m in length	-None Select ed-	0	N/A
015	N/A	7.50	0.6	0.5	0	0	0	0		6	Sp	Looking downstream at old LWD jam and upstream at step pool channel with stonelines of angular boulders. Channel is entrenched/confined by bedrock and fan on west. Channel has sand matrix around cv boulders.	-None Select ed-	0	N/A
016	N/A	0.00	0	0	0	0	0	0		0	Sp	Old debris jam. Channel has avulsed and has multi thread morphology over 40 m wide valley flat. Bed contains quite a lot of angular cobbles as well as subrounded mossy cobbles and boulders. Sand accumulated behind part func lwd.	Partly	0	N/A

017		N/A	0.00	0	0	0	0	0	0	0	Rp	Upstream from 16. Pics up and down. Up is cobble riffle channel	-None Selected-	0	N/A
018		N/A	10.10	0.6	10	0	0	0	0	0.5	Rp	Meandering riffle pool with sand and gravel unconfined over appx. 50 m flat. Banks veg with willows and grass.	-None Selected-	0	N/A
019		N/A	0.00	0	0	0	0	0	10	2	Rp	Still riffle pool with sand and gravel. Elevated sand bar picture. Grasses and shrubs established suggest it is from 10 yr appx flood. Banks vertical and mossy.	-None Selected-	0	N/A
020		N/A	8.00	0	0	0	0	0	20	4	Rp	Lwd jam in riffle pool multi branch reach. With cobble sand wedge upstream.	-None Selected-	0	N/A
021			8.00	0.6					15	3					
022															

18-Oct-13

Survey site	Site ID	Time	Wb(m)	Dbf(m)	D90(cm) 1	D90(cm) 2	D90(cm) 3	D90(cm) 4	D90(cm) 5	S%	Morphology	Description	Lwd Function	Lwd Density (#/10m)	Riparian
023	Site#25	N/A	0	0	0	0	0	0	5	0.5	Rp	Low gradient sand wetland. Channel is mostly gravel and sand. Evidence of large flood appx 2 yrs is seen as scour along banks. Otherwise banks are overhanging with willows and grasses. Bedrock on both sides of wetland.	-None Selected-	0	N/A
024	Suthld 42	N/A	8.2	0.5	15	0	0	0	0	3	Sp	Top of wetland reach into bedrock confined step pool with large cv. Sand and cobble bars along margins are recent appx 2 yrs.	-None Selected-	0	N/A
025	Suthld 42	N/A	0	0	0	0	0	0	0	0	Rp	Above sp reach. Gradient drops due to v old wd pile 50 yrs or more. Channel now meandering rp with mossy bed. Picture of recent avalanche wood in channel.	-None Selected-	0	N/A
026	Suthld 42	N/A	0	0	0	0	0	0	0	0	Rp	Channel becomes multi branched over 50 m wide flat due to old wd piles. Pictures taken in panorama.	-None Selected-	0	N/A
027	Suthld 42	N/A	0	0	0	0	0	0	0	0	-None Selected-	Old slide appx 20 to 30 yrs. woody debris and culvert from slide appx 10 to 20 m downstream also cobble boulder bar deposit.	-None Selected-	0	N/A

028	Suthld 42	N/A	8.4	0.4	25	0	0	0	0	5	Ca(b)	Lots of mossy cv creating cascade channel with sand matrix. This stn is appx 40 m downstream from recent avalanch path appx 20 yrs. cv cone of avalanche with lots of blocky cv. This is source of cv in channel... Long term process.	-None Select ed-	0	N/A
			8.3	0.45	20					4					
029	Suthld 42	N/A	0	0	0	0	0	0	10	4	Ca(b)	Just downstram from recent avalanche path. Lwd jam with 12 m long sand and gravel wedge. Lots of mossy cv in channel.	-None Select ed-	0	N/A
030	Suthld 42	N/A	9.4	0.3	0	0	0	0	15	2	Rp	Just below 2012 slide	-None Select ed-	0	N/A
031	Suthld 42	N/A	0	0	0	0	0	0	0	0	-None Select ed-	2012 slide site	-None Select ed-	0	N/A
032	Suthld 42	N/A	0	0	0	0	0	0	0	0	-None Select ed-	Apex of slide deposit	-None Select ed-	0	N/A
033	Suthld 42	N/A	9.1	0.45	20	0	0	0	0.15	4	Ca(b)	Channel directly above slide. Channel has abundant mossy angular boulders. Banks veg with red ozier dogwood.	-None Select ed-	0	N/A
034	Suthld 42	N/A	9.4	0.4	20	0	0	0	0	3	Ca(b)	Cascade with cv boulders up to 1 m. Mossy and dark.	-None Select ed-	0	N/A
035	Suthld 42	N/A	0	0	0	0	0	0	0	0	-None Select ed-	Recent scour along west bank.	-None Select ed-	0	N/A
036	Suthld 42	N/A	0	0	0	0	0	0	0	0	-None Select ed-	Very large old avalanche deopsit with lots of cv woody debris and sand.	-None Select ed-	0	N/A
037	Suthld 42	N/A	0	0	0	0	0	0	0	12	Ca(b)	Looking upstream at cv cascade reach just below avalanche track.	-None Select ed-	0	N/A
			8.775	0.4375	20					3.75					