2006 Hydrologic Assessment for Selected Sub-basins in the Horsefly River Watershed

View of the Prairie Creek sub-basin from the 100 Road – October 28, 2006

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1.0 INTRODUCTION

This hydrological assessment report addresses selected sub-basins in the Horsefly River watershed and was requested by Tolko Industries Ltd (Tolko), Cariboo Woodlands. The report will address the following:

Background Information Review, including the 1997 IWAP, the 2002 IWAP and information provided by Department of Fisheries and Oceans (DFO).

Forest Health and Hydrology, including affects of the mountain pine beetle on snow accumulation and snowmelt as well as potential increased peak flows.

GIS Analysis, including current equivalent clear-cut area (ECA), stands species distribution and 20 year ECA recovery.

Surface Erosion, field based assessment of roads and drainage structures.

Channel Conditions, field based assessment of stream channels in selected sub-basins.

Stream Crossing Capacity, field measurements and predicted flow volumes to determine appropriate sizing of structures.

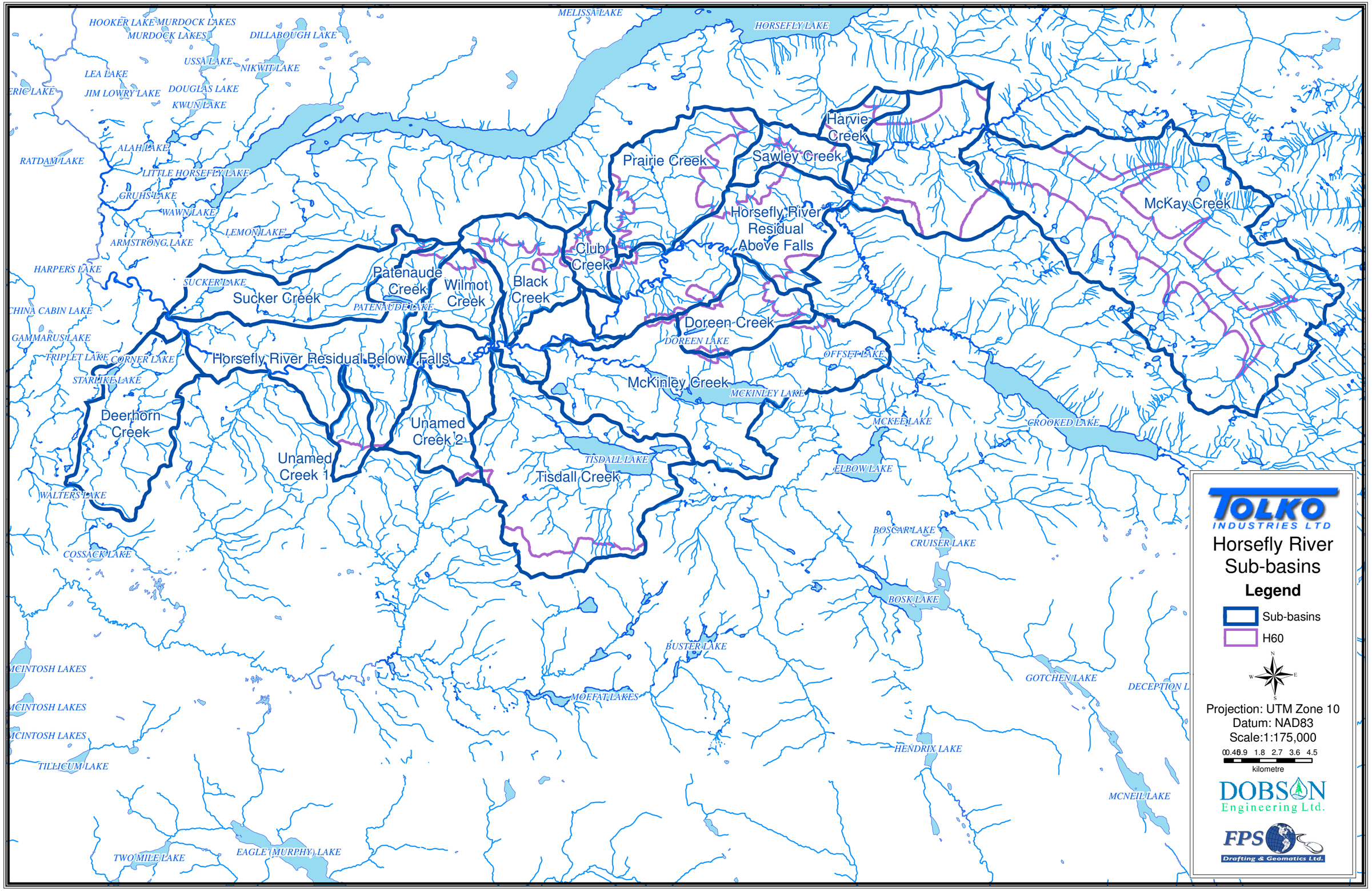
Hydrologic Risk and Recommended Harvest Levels, based on GIS analysis, field data and current research on the effects of timber harvest, mountain pine beetle and potential increased peak flows.

2.0 WATERSHED CHARACTERISTICS

The Horsefly River watershed is located southeast of Williams Lake and covers approximately 286,000 ha. Elevations in the watershed range from 800 m near the town of Horsefly to over 2,500 m in the upper MacKay watershed. The Horsefly River drains into Quesnel Lake, which in turn drains through the Quesnel River to the Fraser River (refer to Figure 1).

The watershed is important for Sockeye, Coho and Chinook salmon as well as Rainbow Trout and Kokanee, which are part of the Quesnel Lake sports fishery. Forest Licensees operating in the watershed include; Tolko Industries Ltd., Ainsworth Lumber Co. Ltd., West Fraser Mills Ltd., Weldwood of Canada Ltd., Lignum Ltd. and the BC Timber Sales.

Both the mountain pine beetle and the spruce bark beetle are present in the watershed. At the current rate of infestation in the British Columbia interior, the pine beetle has the potential to affect all mature pine stands in the watershed. The amount of mature spruce affected by the spruce bark beetle is not known. Tree mortality results in loss of canopy, which affects snow accumulation and peak flows similar to clear cut harvesting. This is discussed in more detail in Section 2.3. Tolko is targeting beetle affected stands in their current forest development plans to salvage timber affected by the beetle.



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The portions of the watershed assessed in this report cover approximately 68,245 ha, and include the Black Creek, Horsefly River Above the Falls and MacKay River sub-basins. Several other sub-basins within these areas were identified through consultation with Tolko staff and DFO staff (refer to Figure 1). The expanded list of sub-basins is:

- Black Creek
- Club Creek
- Prairie Creek
- Sawley Creek
- Harvie Creek
- MacKay River
- Un-named Creek 1
- Horsefly River above the Falls Residual Area
- Sucker Creek
- Patenaude Creek
- Wilmot Creek
- Doreen Creek
- McKinley Creek
- Tisdall Creek
- Un-named Creek 2
- Deerhorn Creek
- Horsefly River below the falls Residual Area

3.0 BACKGROUND INFORMATION

3.1 Fisheries Summary

The watershed provides important habitat for Pacific salmon species as well as other game and non-game fish. Information provided by Don Lawrence from the Department of Fisheries and Oceans (DFO) indicates that the Horsefly River main stem between the point of interest (POI) at Sucker Creek and the waterfalls is important salmon habitat. The channels upstream from the falls also provide important habitat for resident fish populations. The highest value salmon spawning reaches are between the mouth of Sucker Creek and Deerhorn Creek and between the waterfalls and the mouth of Tisdall Creek. In addition, McKinley Creek from McKinley Lake to the mouth and Black Creek downstream from the 100 Road are also high quality salmon spawning areas.

DFO also indicated that increased stream temperatures are reducing fish survival and that protecting riparian vegetation in tributary streams is very important, especially with the loss of riparian vegetation over much of the lower river due to activities on private lands. Late summer snowmelt from the high elevations provides a cooling effect that helps reduce the extreme summer water temperatures. The north facing slopes downstream from McKinley Creek are important as runoff from these areas may also have a cooling effect on summer water temperatures in the lower Horsefly River. The main stem of Black Creek has experienced significant disturbance from placer mining approximately 2km upstream from the mouth. DFO staff would like to see further channel recovery before any additional stress is put on the system from future logging.

The 1997 and 2002 IWAP reports were reviewed as part of this report and a section highlighting recent research regarding forest development, forest health and forest hydrology is also included.

3.2 1997 IWAP Summary

In 1996, Dobson Engineering Ltd. completed an IWAP for the Horsefly River watershed. In 1997, Inland Timber Management Ltd. re-calculated the ECA's and IWAP hazard indices and updated the report with this information.

The 1997 IWAP Conclusions were:

- There is a low potential peak flow hazard in all of the sub-basins.
- Moderate potential surface erosion hazards exist for the watershed, and in the MacKay River and Horsefly River above the Falls sub-basins. Surface erosion concerns result from the density of stream crossings and the length of road located within 100 m of streams. All other sub-basins in the watershed have low potential surface erosion hazard ratings. Overall road density was considered to be of low concern for suspended sediment problems in the sub-basins inventoried.
- There was a low riparian hazard rating in the watershed and all sub-basins, but Molybdenite Creek and the McKinley Creek above Bosk Lake had moderate riparian hazards ratings.
- The landslide hazard ratings in the Horsefly River above the Falls and the McKusky Creek sub-basins were high. There was a moderate landslide hazard rating in the McKinley Creek above Bosk Lake and MacKay River sub-basins. The remaining sub-basins had a low potential landslide hazard rating. It should be noted that some of the features noted as landslides in the 1997 IWAP are sections of eroding stream bank along the mainstem channels in glacio-fluvial gravels.
- Overall, 1997 IWAP results indicate minimal past forest development related concerns in the Horsefly River watershed above the confluence with the Little Horsefly River.
- The MacKay River is stable bedrock and boulder controlled channel.
- Landslides have occurred in Pegasus Creek as a result of forest development on unstable terrain. Coarse sediment and debris was deposited in the channel causing increased bank erosion and avulsions on the alluvial fan. No direct impact on the MacKay River was observed.
- Based on observed landslides and the geomorphology of the sub-basin, potentially unstable kame terrace deposits may exist along the middle and lower slopes of the main valley, and on middle slopes in each tributary valley.
- Considerable semi-permanent road deactivation has been completed in the MacKay River sub-basin. Tension cracks were, however, observed on deactivated roads in Pegasus Creek.
- Several failures have occurred on the lower mainstem of the MacKay River, one of which was related to the MacKay Mainline built above the break in slope.
- The proposed level of forest development (1.4%) is low, however, proposed road construction on lower valley slopes is a concern for sedimentation in the MacKay River.

The 1997 IWAP Recommendations were:

- Complete a total development plan for the Horsefly River watershed above the Little Horsefly River to assist in managing forest development for a low peak flow hazard rating

as defined in the IWAP. The objective would be to minimize the risk of peak flow increases and subsequent bank erosion and channel widening.

- Maintain a 5.0 m no-machine buffer (along all S4, S5 and S6 stream channels), and protect all immature and non-merchantable species in the riparian management zones to maintain channel bank stability and stream shading.
- Deactivate roads that are no longer required (as determined by an access management strategy) to standards appropriate to the terrain sensitivity.
- Upgrade drainage on active roads including increasing cross-drain frequencies on long uninterrupted ditch lines and constructing sumps in ditch lines at all stream crossings.
- Implement sediment control measures to control erosion during road construction.
- Use temporary structures such as sumps, silt fences, waterbars, cross-ditches, etc., to contain sediment.
- Install sediment control structures such as sumps, geotextile filter fences, etc., in ditch lines (and especially in ditch lines proximal to streams) during the period of road construction and early use.
- Consider operational shutdown guidelines for road construction during wet weather.
- Complete overview terrain mapping for portions of the Horsefly River watershed above the confluence of Black Creek. Use the terrain maps to assist in forest development plans for roads and cut blocks.
- A riparian zone rehabilitation program should be considered for private land along the lower 20 km of Moffat Creek, and the Horsefly River between Black Creek and the Little Horsefly River. The following steps should be considered:
- Develop and implement a riparian zone awareness program for private landowners.
- Establish riparian reserve zones along the channel according to the *Riparian Management Area Guidebook.*
- Fence the reserve zones to control livestock access.
- Plant native shrubs and trees in the riparian reserve zone.
- Stabilize disturbed channel reaches using bioengineering techniques.
- Complete a road assessment in Pegasus Creek to determine deactivation requirements to restore natural hillslope drainage.
- Complete a road assessment on the lower MacKay Mainline to determine if adequate drainage structures are in place to maintain the natural hillslope drainage.

3.3 2002 IWAP Summary

In 2002 P. Beaudry and Associates Ltd. completed an IWAP update and prepared the report *Interior Watershed Assessment Update for Eight Watersheds Tributary to the Horsefly River* for the following drainages: Moffat Creek, Woodjam Creek, McKinley Creek, McKinley above Bosk, McKuskey Creek MacKay River, Horsefly River above MacKay, and Horsefly River above the Falls.

Of the eight drainages assessed, only the MacKay and Horsefly above the Falls were assessed in this 2006 report. The 2006 report also assessed several drainages in the Black Creek sub-basin that were not assessed in the 2002 report.

The 2002 report includes details on the Stream Crossing Quality Index (SCQI) and Water Quality Concern Ratings (WQCR). These were calculated using procedures developed by P. Beaudry and

Associates Ltd. that rated road related sediment sources and it's potential affect on water quality. Additional information was included on the hydrology of the area. The 2002 report indicated various unit area discharges for the following Water Survey of Canada hydrometric stations in the watershed:

- MacKay River – 08KH022 (0.134 $m^3/s/km^2$)
- Moffat at the Mouth – 08KH019 (0.028 $m^3/s/km^2$)
- McKinley Creek - 08KH020 (0.044 $m^3/s/km^2$)
- Horsefly River above McKinley – 08KH010 (0.096 $m^3/s/km^2$).

The 2002 IWAP Conclusions were:

MacKay River

- The watershed was reported to have a very low peak flow index, a low riparian hazard index and a very low sediment source (landslide) hazard in the upper watershed.
- The lower watershed however has a very high sediment hazard due to several old large landslides that are directly connected to streams (Pegasus Creek).
- Overall, the road related sediment hazard is rated high for the watershed, but moderate for the upper watershed only.
- There is a low hazard rating for accelerated mass wasting due to limited forestry activities on slopes greater than 60%. However, there are several forest development related landslides in Pegasus Creek in the lower watershed.

Horsefly Above the Falls

- The watershed has a low peak flow hazard, and this remains low with proposed development from 2002 - 2007.
- The peak flow hazard is Very High in Club Creek and High in Doreen Creek. Channel conditions in Club Creek were not visible during the overview flight, however there was no indication of channel instability in Doreen Creek.
- Overall the riparian hazard is moderate due to harvest along several tributary streams. The riparian area along the Horsefly Mainstem is intact and functional, but in both Doreen and Club Creeks, the riparian hazard is very high based on past riparian harvesting. The field review identified extensive re-vegetated conditions in the previously harvested riparian areas and indicated that although the areas are not fully functional, they are well on the way towards being fully recovered.
- The overall sediment source hazard/landslide hazard is moderate, however it is very low in both Club and Doreen Creeks.
- The road related sediment source inventory resulted in a high surface erosion hazard. Due to access constraints, Club and Doreen Creeks were not assessed separately.
- There is a low hazard rating for accelerated mass wasting from logging steep slopes in the Horsefly above the Falls basin. This rating is very low for both Club Creek and Doreen Creek.

The 2002 IWAP Recommendations were:

MacKay River

- Review the status of the moderate and high WQCR stream crossings identified.

- Continue restoration and stabilization on the logging related landslides that are contributing sediment to the stream network.
- Defer forest development in Hawkley, Cayuse and Pegasus Creeks until unstable channel conditions recover.
- Implement more effective erosion control structures at all stream crossings and develop erosion and sediment control plans.

Horsefly Above the Falls

- Implement an erosion control and monitoring plan, and improve erosion control at small stream crossings.
- Conduct site specific slope stability assessments prior to logging steep slopes in the upper watershed.

3.4 Forest Cover, Forest Health, ECA and Hydrological Effects

Tree species, age/size, stem density and canopy closure all affect how a forested stand can intercept snow and affect peak flow response. Healthy mature spruce and fir stands can be more effective at intercepting snow than pine stands. Snow survey research has shown that clear-cut harvesting in mature mixed spruce stands can result in up to 32% more snow water equivalent (SWE) than in adjacent forested mixed spruce stands. Clearcut harvesting in mature pine stands can result in up to a 22% increase in SWE. In addition to changes in SWE, clearcut areas typically melt up to two weeks earlier than adjacent forested areas. Clear-cut effects diminish as the forest regenerates and as trees grow, canopy closure increases. For every 10% increase in canopy closure there is approximately a 6% reduction in SWE.[1] This is typically referred to as hydrological recovery, which increases with increasing tree height (refer to Table 1).

Table 1 – Equivalent Clearcut Area (ECA) and Hydrological Recovery

Tree Height Category (m)	ECA (%)	Hydrological Recovery (%)
0 – 3	100	0
3 – 5	75	25
5 – 7	50	50
7 – 9	25	75
9 – 12	10	90
>12	0	100

The removal of pine stands has less affect on peak flow increases than would the removal of mixed spruce stands. Because deciduous stands have less effective canopy closure, they intercept less snow than pine stands. The removal of deciduous leading stands will have the least effect on peak flows. Forest disturbance in the snow accumulation zone has the most dramatic affect on the timing and magnitude of peak flows in snowmelt dominated watersheds.

Ministry of Forests and Range research at Upper Penticton Creek suggests that ECA's over 20% can change the magnitude of the annual peak flow event. The increase depends on the area harvested and the return period of the peak flow event, but with 100% ECA, the maximum peak flow increase is 47% for the 50-year return period event.[2] Table 2 shows the effects of increased harvest in the snow sensitive zone on peak flows.

[1] Streamline Watershed Management Bulletin, Vol. 9/No. 1 Fall 2005, pp. 1-5
[2] Extension Note 67, Schnorbus et al, Ministry of Forests, Forest Sciences Program, 2004

Table 2 – Changes in Peak Flows with Increased Forest Harvesting (Adapted from MoFR Extension Note 67)

% Area Harvested	Peak Flow Event Return Periods		
	2 Year Return Period % Increased Flow	*10 Year Return Period % Increased Flow*	*50 Year Return Period % Increased Flow*
0	0	0	0
10	0	2	5
20	<1	4	10
30	1	7	15
40	4	10	19
50	7	15	23
100	36	40	47

Based on the results from Penticton Creek as reported in Extension Note 67, peak stream flows can be increased by a maximum of 47% with 100% tree removal. Summer evapotranspiration (ET) from forested sites exceeds ET in clear-cut sites by up to 30%. This can result in a 30% to 87% increase in summer stream flows, depending on precipitation[3].

The results of this research from Upper Penticton Creek are not necessarily transferable to all interior watersheds with snowmelt dominated peak flows, but they are useful for guidance in watersheds with similar attributes.

Hydrometric data from the Water Survey of Canada is available for the Horsefly River above McKinley Creek (WSC 8KH010) from 1956 to 2006. Analysis of this data (using maximum daily discharge) indicates on average, the annual peak flow is 111 m^3/s, which equates to approximately a 2-year return period (refer to Appendix A – Hydrometric Data). The 10-year return period flow is approximately 145 m^3/s and the 50-year return period is approximately 190 m^3/s. Integrating this data with the data in Table 2 provides an estimate of the increased peak flows with increased ECA in the Horsefly River watershed (refer to Table 3).

Table 3 – Horsefly River above McKinley Creek Potential Changes in Peak Flows with Increased Forest Harvesting

% Area Harvested	Peak Flow Event Return Periods		
	2 Year Return Period Flow (m^3/s)	*10 Year Return Period Flow (m^3/s)*	*50 Year Return Period Flow (m^3/s)*
0	110	145	190
10	110	148	200
20	110+	151	209
30	111	155	219
40	114	160	226
50	118	167	234
100	150	203	279

The data in Table 3 outlines the potential increased peak flows resulting from increased ECA's. The predicted increases are based on removal of forested stands that are primarily lodgepole pine. Many of the stands in the lower Horsefly River watershed are mixed pine and deciduous, so

[3] Snow, road, soil moisture and harvest distribution effects on streamflow at Upper Penticton Creek, BC Ministry of Forests and Range, (www.for.gov.bc.ca/rsi/research/Penticton/index.htm)

the effects of increased ECA's in the lower watershed will likely have a lesser effect on the increased peak flows (refer to Appendix B – GIS Data).

Loss of forest cover due to beetle infestation is occurring in the Horsefly River Watershed, but there is limited data available regarding the effect on runoff from the loss of canopy in dead pine stands[4]. It has been documented that some snow interception still occurs in dead stands, therefore the accumulation of snow on the ground will be greater in a dead pine stand than under a live pine stand, but less than for a clear-cut. It is also important to consider under story vegetation/secondary structure in pine stands, as the secondary structure can contribute to hydrological recovery.

There are a number of research projects in progress that are focused on this issue by researchers from the Ministry of Forests and Range in Kamloops, Williams Lake and Prince George, various consultants and the Faculty of Forestry at UBC[5]. Preliminary research results for stands in the northern interior indicate that the potential ECA for dead pine stands in that area may be in the 50% range of those for a clear-cut. The adjustment factor is intended to represent the "average" stand; the actual value will depend upon the species composition and the secondary structure. In addition, the snow melt rates with the standing dead stems will still be greater than for a live stand but likely less than for a clear-cut.

Until final results from these research projects are available, the application of a 50% adjustment factor for the ECAs from live stands to dead stands is estimated for the Horsefly River Watershed.

Watersheds with a snowmelt dominated hydrograph are most sensitive to forest disturbance in the snow sensitive zone. The snow sensitive zone is watershed specific and is defined as the snowmelt area in the watershed that is responsible for the spring peak flow.

The annual peak flows in the Horsefly River are generated from snowmelt in the upper elevations. Forest harvesting in the snow sensitive zone can have the greatest affect on increased peak flow events. The snow sensitive zone is typically accepted as the upper 60% of the watersheds area, or the area above the H60 for a given watershed (H_{60} – the elevation that separates the upper 60% of the watershed area from the lower 40%). For this assessment, the H_{60} for the Horsefly River above the Falls (1460 m) has been applied to all study basins, rather than using the H_{60} for each individual basin.

Recent work completed in the BC southern interior has investigated the H_{60} concept and the snowmelt zone/elevations that contribute to the annual peak flow event. Ministry of Forests research in the West Arm Demonstration Forest east of Nelson BC has confirmed the H_{60} concept using aerial estimates of the extent of snow cover and the timing of the peak flow event[6]. Dobson Engineering Ltd. conducted similar studies in the Okanagan for Riverside Forest Products Ltd.[7] The elevation of the snow line is determined before and during the annual peak flow event

[4] *Review and Synthesis of Potential Hydrologic Impacts of Mountain Pine Beetle and Related Harvesting Activities in British Columbia*, J.F. Hélie; D.L. Peters; K.R. Tattrie; J.J. Gibson, Mountain Pine Beetle Initiative Working Paper 2005–23, Canadian Forestry Service, 2005; *Determining the impact of MPB-killed forest and elevated harvesting on snow accumulation and the projected impacts on melt and peak flow.* BC Ministry of Forests, S. Boon, UNBC, FIA-FSP Report #M065006; *Snow Surveys in Supply Block F Prince George, January to April 2006,* P. Beaudry, P. Beaudry and Associates Ltd. CANFOR report, 2006.

[5] Projects include work by: R. Winkler, MoFR, Kamloops (research projects include Upper Penticton Creek and Mayson Lake); P. Teti, MoFR, Williams Lake (research projects in various pine stands in the Cariboo),

[6] Ministry of Forests Research Program, Watershed Assessment in the Southern Interior of British Columbia: Workshop Proceedings, Working Paper 57, pp. 68-80

[7] Dobson Engineering Ltd., 2002, *Synthesis of the 1999 to 2001 Snow Course and Snowline Results For the Chase Creek Watershed.*

and the areas at and above this line are considered the snow sensitive zone (with consideration given to lag times from snowmelt to channel response). Typically in the Okanagan, the annual peak flows were generated from snowmelt above the H40.

This demonstrates variability in the snow sensitive zone in two different watersheds, and that the H_{60} concept is not universal throughout the interior of the province.

Although the H_{40} delineates the snow sensitive zone in some Okanagan watersheds, snow cover was 150-200 meters higher along south/southwest facing slopes vs north facing slopes, and shaded gulley areas remained snow covered even after higher elevation plateaus had completely melted. Although it is difficult to quantify the combined effects of all the above on peak flows, the distribution of the forest harvest (including areas affected by wildfire and natural disturbance) has a great affect on snowmelt and peak flow response. When available, watershed specific information provides a more accurate estimate of the 'snow sensitive' zone.

In 1997, DEL conducted an overview flight of the Horsefly River watershed as part of a watershed assessment. This flight was on June 1, 1997, which was the same day as the 1997 peak flow event (recorded by WSC at Station #08KH010 Horsefly River above McKinley Creek). Additional information is provided in Appendix A – Hydrometric Data

Slopes below approximately 1,500 m were snow free on this date, which suggests the peak flow in 1997, was generated by the snowmelt in areas around this elevation. Although this is only one year, anecdotal information from Ministry of Forests and Tolko Staff suggests the annual peak flow event is generated from snowmelt in the upper watershed, above the 1400-1500 m elevation. For this report, the H_{60} for the watershed above the falls (1,460 m) was used and elevations above this are considered the snow sensitive zone. This information is one tool used as a guideline for forest development thresholds and individual basin characteristics are also considered when harvest thresholds are suggested.

Equivalent clearcut area (ECA) is a useful tool for rating hydrological risk. ECA thresholds for individual watersheds/sub-basins should be considered using a basin specific approach, that takes all other basin and drainage features into account. Although peak flows can typically increase once ECA values exceed 20%, many channels have experienced higher naturally occurring ECA's from past forest disturbance (pests, disease and wildfires) and have adjusted to the flow regimes that follow these events. ECA threshold values do not have a universal effect on watershed peak flows. Upland lakes, topography, aspect, vegetative cover, soil types and level of disturbance all affect the timing and magnitude of run off related stream flow responses.

4.0 METHODOLOGY

This report involves both office and field components. The office components include a review of past watershed reports, a review of current information regarding ECA and hydrological recovery and the potential effects of the mountain pine beetle and spruce bark beetle. GIS exercises include sub-basin delineation, equivalent clearcut area (ECA) calculations and 20-year hydrological recovery predictions (refer to Appendix B). All GIS calculations are based on information provided by Tolko Industries Ltd. and tree regeneration/growth is estimated using VDYP modelling. The ECA calculations also include areas cleared for agriculture. Stand species distribution is also investigated to better understand the hydrological function of various stand types by calculating the dominant or leading tree species in each sub-basin. The traditional IWAP indices/report card calculations are not included in this report.

The field components include sediment production and delivery assessments, stream channel condition assessments and a review of major stream crossing structures and flow capacities. Unit

discharge areas that were derived in the 2002 IWAP are used when estimating the discharges and flow capacities of various structures (refer to Appendix C).

This report assesses many of the smaller sub-basins within the residual areas of the Horsefly River Watershed, and the point of interest for this report is the Horsefly River at the confluence with Sucker Creek. Proposed forest development was reviewed with Tolko staff, and where necessary, sub-basins were delineated in areas with significant proposed development to better determine the thresholds for future road construction and forest harvesting in those areas (refer to Appendix D – Watershed Maps). This assessment uses GIS generated ECA's and field conditions to assign a maximum harvest level for each sub-basin. The 20-year hydrological recovery projections accounts only for regeneration of existing forest cover and does not include proposed development (refer to Appendix B).

This report focuses on the tributary streams and major sub-basins in the Horsefly River watershed. The Horsefly River main stem was not specifically assessed; as previous reports indicate no significant channel changes have occurred over the last several decades.

5.0 ASSUMPTIONS

This report is based on the following assumptions:

Peak flows are generated from snowmelt in the snow sensitive zone. The snow sensitive zone in this watershed is the area above 1,460 m. The study basins are separated into two areas, the upper Horsefly (sub-basins with significant areas in the snow sensitive zone) and the lower Horsefly (sub-basins with little area in the snow sensitive zone). Forest development in the upper watershed has the greatest potential to increase peak flows, whereas development in the lower watershed is not likely to affect peak flows.

ECA is based on tree height category and the results of the GIS tree height analysis (using VDYP and Site Index) are considered accurate. The ECA calculations include areas affected by wildfire and cleared areas on private land.

Peak flow hazards are a function of ECA. ECA's from 0%-30% are considered a low peak flow hazard, 31%-45% a moderate and greater than 45% a high peak flow hazard. The peak flow hazards for the upper watershed basins were determined by using both the ECA above the snowline (1,460 m) and the ECA for the entire sub-basin. Because that portion of a sub-basin below the snow sensitive zone does not significantly contribute to the peak flow, the ECA for the entire sub-basin was used. The peak flow hazards and hydrologic risks for the lower watershed sub-basins are presented as guidelines.

When assigning hydrologic risk ratings, peak flow hazards from sub-basins that are directly connected to the high value salmon spawning reaches have a "high consequence". These reaches are; Horsefly River between Sucker and Deerhorn Creeks, Horsefly River between the falls and Black Creek, Black Creek below the 100 Road and McKinley Creek below McKinley Lake. Because late season snowmelt from the MacKay River cools water temperatures in the lower Horsefly River and aids salmonid survival, this sub-basin is also given a high consequence rating. The consequences of peak flow hazards to other reaches of the Horsefly River are considered moderate.

Most, if not all of the mature pine is going to die from the current mountain pine beetle infestation, and all stands with pine leading >40% are considered pine dominated and are treated the same for harvest scenarios and ECA analyses.

Un-logged dead pine stands have a 50% residual hydrological function. For example, a 100 ha dead pine stand only has an ECA of 50 ha.

The spruce bark beetle has not reached epidemic levels and mature spruce stands are considered viable and healthy.

Maximum suggested harvest levels are based on channel conditions, the ECA/peak flow hazard categories and connectivity with the Horsefly River reaches indicated above.

The forest development/management targets for each sub-basin should not exceed a moderate hydrologic risk rating.

Due to the complexity of numerous harvest scenarios, this report only considers one scenario using the current ECA (December 2006) combined with mortality of all the mature pine. Forest managers must investigate other scenarios using a sub-basin specific approach that considers hydrologic recovery and the timing of future harvest.

The effects of new road construction on peak flow timing and magnitude are considered negligible, as long as road construction includes frequent cross drains and does not divert natural drainage patterns.

Surface erosion problems exist only when there is visible erosion and it is directly connected to the stream network.

Overall channel conditions are based on assessment results from discrete field inspection locations. Sites not visited in the field were typically in sub-basins with very low levels of development and poor access, and unless air photos or previous reports have identified them as problematic, they are considered stable.

Major stream crossing structures were assessed in the field to determine flow capacities. Unit area discharge data provided in the 2002 IWAP was used to predict peak flows from the watershed areas upstream from the drainage structures. The required crossing capacity is based on the 100-year flow event, and this capacity was estimated using three times the estimated mean annual peak flow capacity.

6.0 2006 ASSESSMENT RESULTS

The summary information is contained in Table 4 below and the sections following the table provides additional details. The GIS data is in Appendix B, Appendix C contains the stream crossing capacity information, Appendix D contains the watershed maps and Appendix E contains the photographs.

Table 4 – 2006 Field Conditions

Sub-basin	Gross Area (ha) and ECA (%)		Area Above 1,460 m (ha) and ECA(%)		Road Sediment Sites (Y/N)	Channel Instability (Y/N)	Drainage Structure Capacity Problems (Y/N)
Upper Horsefly							
Black Creek	2,184	26.1%	805	39.9%	N	Y (recovery)	N
Club Creek	865	37.1%	390	19.6%	N	Y (recovery)	N
Prairie Creek	3,757	29.5%	1,016	40.7%	Y (recovery)	N	N
Sawley Creek	1,171	25.3%	718	29.9%	N	N	N
Harvie Creek	774	25.4%	291	7.7%	Y	N	N
MacKay River	14,348	10.4%	10,724	2.7%	N	Y (recovery)	N
Un-named 1	696	10.0%	244	26.0%	N	N	N
Residual Above Falls	9,825	28.5%	1,750	29.4%	Y	Y (recovery)	Y
Lower Horsefly							
Sucker Creek	3,098	18.2%	45	46.7%	N	N	N
Patenaude Creek	1,007	6.1%	102	4.9%	N	N	N
Wilmot Creek	1,272	4.6%	125	0%	N	N	Y
Doreen Creek	1,920	21.4%	391	19.5%	N	N	N
McKinley Creek	7,667	15.0%	148	14.5%	N	N	N
Tisdall Creek	7,178	26.0%	745	39.6%	N	N	N
Un-named 2	1,596	12.5%	42	0%	N	N	N
Deerhorn Creek	3,678	22.2%	0	0%	N	N	N
Residual below Falls	7,209	19.0%	13	0%	Y	N	Y
Watershed	68,245	19.6%	17,548	13.2%	Y	Y (recovery)	Y

A field review was conducted from October 28, 2006 through October 31, 2006. Snow was encountered at high elevations during the assessment and in some cases snow-cover impaired field observations.

Black Creek

Peak Flow - Black Creek area is 2,184 ha, has been 32% harvested and the current ECA (26.1%) is expected to recover to 11.3% by 2026. Approximately 74% of the mature forest in this sub basin is non-pine leading.

Roads - Access was limited in this sub-basin. The 100 Road likely contributes fine sediment to the channel during rain and snowmelt events, but there was no evidence of excessive erosion at this site.

Channels - The stream channel is recovering from past disturbance, but remains disturbed, with elevated bedload and loss of riparian vegetation near the mouth with the Horsefly River.

Club Creek (refer to Photos 1-2)

Peak Flow - Club Creek is 865 ha, and has been 84% logged or burned. Portions of the forest were burned in 1961, and much of the past logging occurred in 1966-1970. Due to recovery since the disturbance, the current ECA is 37.1% and is expected to be 16.4% in 2026 without

additional forest development. Approximately 92% of the mature forest is non-pine leading, therefore loss of canopy from the pine beetle is not considered significant in this sub basin.

Roads - The roads in this area were generally coarse surfaced and well drained with no evidence of significant running surface erosion. The ditches along the 100 Road are connected to Club Creek at the crossing, however sediment production and delivery are considered low to moderate.

Channels - Club Creek near the 100 Road has ~3% gradient, a cobble and gravel bed (moss was seen on larger cobbles) and is slightly to moderately aggraded however sidebars are re-vegetated. Evidence of past scour along the banks was identified. The riparian vegetation is mostly deciduous, and no functioning LWD was noted within the channel. Channel conditions indicate this creek is recovering from past disturbance.

Prairie Creek (refer to Photos 3-6)
Peak Flow - Prairie Creek is 3,757 ha and has been 77% harvested or burned. The current ECA is 29.5% and is expected to recover to 17.3% by 2026. Approximately 85% of the mature forest is non-pine leading, which suggests minimal risk to this watershed from the pine beetle infestation.

Regenerating stands on the lower slopes are dense pine stands with some spruce (9m and greater tree heights, and approximately 700-900 stems per hectare). The new forest growth in previously burned areas 1.5 km up the 6500 Road was pine dominated (>70% by visual estimate, and >9 m high). In the pine dominated regen, approximately 10% of the stems are at the red attack stage from the pine beetle. Pine beetle success in immature stands is not well understood, however, information provided by Tolko indicates that although some stands are dying off, the spread of the red attack has not increased in the last several years. It has been suggested that the immature regen may not provide adequate habitat for all life stages of the mountain pine beetle.

Roads - The roads were in good condition with no significant running surface erosion. A small ephemeral stream/eroded tributary channel runs parallel to the 6500 Road near the junction with the 100 Road. Past erosion along the lower 400 m of the 6500 Road was extensive, however the sediment delivery to Prairie Creek was low. The majority of the sediment at this site has washed away and only coarse material remains. This stream was likely a floodwater channel that formed following the 1961 wildfire. The drainage passes through a 1000 mm culvert on the 6500 road, however the channel bed downstream from the culvert is vegetated with 3-5 meter tall deciduous trees (refer to Map2 – Assessment Site #1). Most of the culverts along the upper 6500 Road were 12" and may have to be upgraded to current forest road design criteria. Prairie Creek is drained at the 100 Road through a wood stave culvert (~2.1m diameter). The culvert appears to be functional and shows no evidence of instability, however this was based on visual observations at the inlet of the structure.

Deactivated roads on the east side of Prairie Creek are in good condition, waterbars and cross ditches are effective and access is limited to 4x4/ATV only.

Channels - The lower reaches of Prairie Creek have riffle pool morphologies, and are generally stable with gravel bed and bank materials. Downstream from the 100 Road, there are beaver dams and multiple channels in places. The low channel gradient (<1%) and the beaver dams have created swampy areas near the mouth of Prairie Creek, which reduces potential sediment delivery from the upper watershed to the Horsefly River. Much of the channel upstream from the 100 Road is also very low gradient with a large swampy floodplain that can also act as a buffer to peak flow responses.

Sawley Creek (refer to Photos 7-10)
Peak Flow - Sawley Creek is 1,171 ha, is 34% harvested and has a current ECA of 25.3%. The 20-year recovery will reduce ECA to 9.7% in 2026. None of the mature forest is pine leading.

Roads - Access to the south side of the sub-basin is via Camp Road. Although sections of the road experience minor surface erosion, the sediment delivery paths are not connected to the stream network. The ditch lines are cut through very rocky material and ditch erosion is minor. Drainage structures in the area appear adequately sized and spaced.

There is a large (approximately 8 m) open bottomed arch culvert at the 100 Road crossing on Sawley Creek. The ditch approaches have been armoured and sumps have been installed to reduce erosion and sediment delivery to the stream.

Channels - The channel upstream from the 100 Road crossing has a cascade pool morphology with a cobble bed. Stone lines in the channel are present and the gravel/cobble banks show no signs of active erosion. The riparian vegetation in the lower reaches was previously harvested, and there is some minor undercut banks. Deciduous vegetation on the lateral bar deposits indicates the channel is recovering.

Harvie Creek (refer to Photos 11-14)
Peak Flow - Harvie Creek is 774 ha and has been 39% harvested. The current ECA is 25.4% and is expected to recover to 6.8% by 2026. None of the mature forest is pine leading.

Roads - The upper stream crossing at the 900 Road may be contributing sediment to the channel. Three culverts drain the creek (pond/marshy area at this location – near the headwaters of the channel), however two of the three have damaged inlets. The roadbed was rutted and the ditches were connected to the channel (refer to Map 2 – Assessment Site #2). Roads in the upper watershed were generally coarse surfaced and well drained and culvert sizing and spacing appeared adequate.

The ditch along the 100 Road is connected to Harvie Creek but sediment production and delivery is low at this site. The creek drains at the 100 Road through a wood stave culvert (~1.8 m diameter). Visual inspection of the culvert did not identify any obvious instability.

Channels - The channel upstream from the road has a stable, very low gradient morphology and flows through a wetland/marshy complex. The creek near the 100 Road has a stable to slightly aggraded cascade pool morphology with cobble and boulder bed materials.

MacKay River (refer to Photos 15-18)
Peak Flow - The MacKay River sub-basin is 14,348 ha, has been 16% harvested and has a current (December, 2006) ECA of 10.4%. Hydrologic recovery over the next 20 years reduces the ECA to 2.3%, excluding proposed development. Forest cover in this basin is dominated by spruce and fir and only 1% of the area is pine leading. Effects of the pine beetle infestation are minimal in this sub-basin, but forest harvesting in this sub-basin (which is primarily within the snow sensitive zone) will have a greater effect on increased peak flows than would development in pine stands.

Roads - Although road related sediment sources did not appear to be a major problem, snow cover affected field observations in the MacKay River basin. Access to the upper watershed was restricted to Hawkley Creek on the north side of the river and approximately the same distance (~7 km) upstream on the south side of the river (refer to Appendix D – Maps). For the roads that were assessed, drainage structure spacing appeared adequate and there was no evidence of excessive running surface erosion.

The MacKay Mainline Bridge across Hawkley Creek appeared to have been recently replaced. Ditches at this site are connected to the creek, but have been armoured to reduce sediment production and delivery, which are considered low at this crossing.

Channels - The lower reaches of both Hawkley and Pegasus creeks have been affected by past riparian harvesting. Previous reports indicate channel instability along the lower reaches of Hawkley and Pegasus creeks. Although channel recovery may be occurring in Pegasus Creek, it was not assessed due to snow cover. The Hawkley Creek channel upstream from the MacKay Mainline is stable. The MacKay River main stem channel also appeared to be stable.

Tributary streams draining north into the MacKay River appeared stable and did not display signs of elevated bedload. Minor bank erosion was noted at two un-named tributary road-crossing locations. One is located one across the river from the Hawkley Creek confluence and the other approximately one km further up the valley (refer to Map 2 – Assessment Site #3). Vegetation regeneration suggests these sites are recovering.

Un-named Creek #1

Peak Flow - This basin is 696 ha, has been 10% harvested and has a current ECA of 10%. Nearly 89% of the mature forest in this basin is non-pine leading.

Roads - Forest development in this area is limited to the upper watershed and there are no road related erosion concerns on the mid and lower slopes.

Channels - The riparian vegetation is intact and the channel remains in a natural state, but actual conditions are unknown, as the channels were not assessed in the field.

Horsefly Residual Above the Falls (refer to Photos 19-28)

ECA - This residual area is 9,825 ha and has been 62% harvested. The current ECA is 28.5% and is expected to recover to 7.6% in 2026. Nearly 95% of the mature forest is non-pine leading.

Whiskey Bridges Area

Roads - There was minor erosion from the upper deactivated road crossing in the Whiskey Bridges area off spur S1262 and the road is impassable beyond the deactivated stream crossing (refer to Map 2 – Assessment Site #4). The soil/debris at the crossing is very coarse textured and minor sediment delivery is only likely to occur during the freshet.

Typically, routine cross drain culverts were 400 mm diameter and were spaced from 50 m to 70 m along the access roads above the Whiskey Bridges. Because of snow cover, not all road sections travelled in this area were assessed.

Channels - The creek at the deactivated road crossing on spur S1262 is a stable cascade pool channel with cobble bed materials. Riparian vegetation on the right bank is mature forest, but left bank riparian vegetation has been harvested, and is currently 0-3 meter pine.

There is a small channel that flows through a partially blocked 36" culvert (refer to Map 2 – Assessment Site #5). This is a stable cascade pool channel with cobble and gravel bed materials.

The main tributary channel in the Whiskey Bridges area is a stable riffle pool channel with gravel and sand bed materials. The riparian vegetation is shrub/herb and the channel flows through a swampy area. The stream passes through two culverts (18" and 24") with partly blocked and/or damaged inlets. The two culverts at this location appear to be undersized (refer to Appendix C, and Map 2 – Assessment Site #6).

100 Road Area
Roads - Flow in the tributary near the 143 km on the 100 Road was turbid. Reconnaissance in the upper watershed failed to identify the source, but it is suspected to be the new block spur roads that were recently constructed. The upper road crossing was not contributing sediment and the water in the 143 km tributary was clear at this location (refer to Map 2 – Assessment Site #7). Silt fencing installations may be appropriate to reduce sediment delivery to streams during road building activities.

A deactivated spur road at approximately 140.8 km on the 100 Road crosses a small stream approximately 250m upstream from the 100 Road crossing. Prior to this road being deactivated (large cross ditches), water flowed down the road and back into the un-named stream. There is a large erosion channel (approximately 2m by 1.5m) through the road. The stream crossing structure on the spur was removed when the road was deactivated, and no further work is required on this road (refer to Map 2 – Assessment Site #8).

Channels - A creek near the 153.25 km on the 100 Road has a slightly aggraded cascade pool channel with cobble and gravel bed material. Small lateral bar deposits were noted behind functioning LWD and sections of the stream banks were undercut. Stumps on the west side of the channel indicate past logging in the riparian area, the east side was intact. The channel is recovering from past disturbance (refer to Map 2 – Assessment Site #9).

The small tributary near the 143 km on the 100 Road is a stable cascade pool channel with cobble bed material. The riparian vegetation on the right bank was high grade logged, but is still intact with mature cedar and spruce. The left bank was logged, but is currently regenerated with 9 meter and taller spruce.

A creek near the 141 km on the 100 Road has a severely degraded cascade pool channel. The channel condition is the result of a failed drainage structure on a spur road approximately 250 m upstream from the 100 Road crossing (referred to in paragraphs above). The problem has been corrected and the stream above the spur road crossing has stable step-pool morphology, with moss on the cobble and LWD steps in the channel (refer to Map 2 – Assessment Site #10).

Sucker Creek (refer to Photos 29-32)
Peak Flow - Sucker Creek is 3,098 ha, has been 25% harvested and the current ECA of 18.2% is expected to recover to 5.2% in 2026. Approximately 50% of the mature forest is >40% pine leading. Field observations confirm much of the mature pine stands remaining in the area are at the red attack phase from the pine beetle. Due to the location in the watershed (low elevation), the gentle/rolling topography and the lake and wetland areas, peak flow increases and increased sedimentation are not likely to be problematic even with the increases in ECA.

Roads - Most roads in this area are low gradient overland type construction (limited cut and fill) and many sections are ditched on both sides. There is no evidence of excessive running surface erosion along any of the roads inspected. Some sections did show evidence of minor sediment production but sediment delivery to the stream network was low to none. Many of the low use roads had grassed running surfaces. Drainage structures appeared adequately sized and spaced and no major sediment input locations were identified.

Channels - Upper Sucker Creek has a stable cascade pool channel and no signs of instability. Lower Sucker Creek is a stable riffle pool channel with occasional LWD and intact mature riparian vegetation (refer to Map 2 – Assessment Sites #11 and #12).

Patenaude Creek (refer to Photo 33)
Peak Flow - Patenaude Creek is 1,007 ha, has been 9% harvested and has a current ECA of 6.1%. Nearly 89% of the mature forest stands are non-pine leading which suggests little hydrological impacts from the pine beetle infestation.

Roads - The bridge crossing at the 100 Road likely allows fine textured sediment to enter the creek, but there is no evidence of extensive surface erosion or sediment deposition at this location.

Channels - The stream reaches above the 100 Road have stable cascade pool morphologies, with functional LWD and intact mature riparian vegetation. The lower reach riparian vegetation has been logged to the banks for agricultural purposes, however The Land Conservancy has purchased this land to help protect fishery resources. Stream bank restoration on the Horsefly River near the mouth of Patenaude Creek is showing signs of success. Several spruce were planted and are beginning to release. Their growth was likely stunted from competition with shrubs and grasses.

Wilmot Creek (refer to Photos 34-35)
Peak Flow - Wilmot Creek is 1,272 ha, has been 5% harvested and has a current ECA of 4.6%. Approximately 70% of the mature forest is non-pine leading.

Roads – There is no indication of road related problems in this sub-basin.

Channels - Access to this creek was limited and very little development has occurred in this sub-basin. The channel at the 100 Road is stable and is drained by two culverts (36" and 18") however the pipe inlets are not well aligned with the creek and the inlets are partly obstructed.

Doreen Creek (refer to Photos 36-39)
Peak Flow - Doreen Creek is 1,920 ha, and has been 40% harvested. The current ECA is 21.4%, and is expected to recover to 3.8% in 2026. Approximately 77% of the mature forest is non-pine leading. The regenerating stands in the lower watershed are typically spruce dominated stands and visual assessments showed no signs of spruce bark beetle infestation.

Roads - The access road to lower Doreen Creek (from Offset Road) has been adequately deactivated. The roads are not well travelled and have dense alder growth along most of the length. The stream crossing at Doreen Creek has been pulled back and is passable by foot traffic only. Deactivated overgrown roads limited access to the upper watershed.

Channels - The lower channels have stable cascade pool morphologies with moss covered cobble and gravel bed and bank materials. Woody debris is present and offers channel control and the riparian vegetation consists of mature cedar and spruce (refer to Map 2 – Assessment Site #13).

McKinley Creek Below the Lake (refer to Photos 40-42)
Peak Flow - This sub-basin is 7,667 ha, has been 25% harvested and the current ECA (15.0%) is expected to recover to 4.2% in 2026. Approximately 75% of the mature forest is non-pine leading.

Roads - The 500 Road in this area did not show signs of excessive running surface erosion and the routine cross drains appeared adequately sized and spaced. Several of the inactive roads were grassed over and in good condition.

Channels - A small tributary channel to McKinley Creek was visited via road RO1350 S451 approximately 3.5 km from the junction of the 500 Road (refer to Map 2 – Assessment Site #14). This site had a stable cascade pool channel with gravel and sand bed material with occasional cobbles. The riparian vegetation was intact mature forest, and the channel control is provided by LWD. There is evidence of an old bank failure, however it appears to have occurred naturally and is not an active sediment source.

Tisdall Creek

Peak Flow - This sub–basin is 7,178 ha and has been 32% harvested. The current ECA is 26.0% and will recover to 11.5% by 2026. Approximately 82% of the mature forest is non-pine leading. Much of the past harvest is on slopes that drain directly into Tisdall Lake. The lake has a buffering effect on peak flows and sediment delivery to the lower reaches.

Roads - Much of the road network in the upper basin has been deactivated and none of the previous reports reviewed indicated significant erosion in these areas.

Channels - The stream channel was not visited in the field, but there are no obvious signs of channel instability noted on aerial images, nor were any problems reported in previous reports. Other than sections of private land on the Horsefly River floodplain, the riparian vegetation is intact.

Un-named Creek #2

Peak Flow - This basin is 1,596 ha and has been 12.5% harvested. The current ECA is 12.5% and is expected to recover to 10% in 2026. Approximately 50% of the mature forest is non-pine leading.

Roads - There is little development in this sub-basin, with only recent harvest near the top of the basin. There are no roads accessing the mid and lower slopes so erosion is not a concern at this time.

Channels - Based on a review of aerial images, the riparian vegetation is intact along the entire mainstem channel, except for the section along cleared private land on the Horsefly River floodplain. Overview photos from 2006 (viewed at Tolko offices) showed patches of red attack pine on the mid slopes in this basin.

Deerhorn Creek

Peak Flow - Deerhorn Creek is 3,678 ha and has been 36% harvested. The current ECA is 22.2% and will recover to 7.4% in 2026. Approximately 66% of the mature forest is non-pine leading.

Roads - Previous reports did not identify any significant road concerns in Deerhorn Creek.

Channels - Many interconnected small lakes characterize the drainage in this basin. The frequent lakes and low gradient channels attenuate any potential increased peak flows and sedimentation.

Horsefly Residual Below Falls (refer to Photos 43-44)
ECA - This unit covers 7,209 Ha, has been 21% harvested and has a current ECA of 19.0%. The 20 year recovery results in an 11.9% ECA in 2026. Approximately 77% of the mature forest in this area is non-pine leading.

Roads - Several sections of the public 100 Road (this road is a public road up to the 126 km mark) contribute sediment to the tributary streams and the Horsefly River. The culvert at Barker Creek (tributary to the Horsefly River) has a partly blocked inlet at 100 Road crossing.

Channels - Bank erosion along private cleared riparian ~150 meters upstream from the 100 Road is contributing to the culvert problem at Barker Creek. The culvert is likely to become blocked with debris during the 2007 freshet and although it is a small stream (approximately 0.8m wide x 0.65m deep) the 100 Road could be damaged and any sediment released would enter the Horsefly River.

7.0 HYDROLOGIC RISK AND FOREST DEVELOPMENT LIMITS

The following section outlines the hydrologic risk ratings and proposed forest development limits for each sub-basin. The potential effects to pine stands from the mountain pine beetle are also provided.

7.1 Hydrologic Risk

The peak flow hazards are based on the sub-basin ECA (0-30% - Low, 31-45% - Moderate, >45% - High). For the upper watershed sub-basins, the ECA above the snowline (1,460 m) and the gross area ECA are both considered. Because the sub-basins in the lower watershed do not significantly affect the peak flows, the ECA for the gross area is used to assign the peak flow hazard in the lower watershed. Road construction can affect the peak flows as well, but if construction includes frequent cross drains and does not divert natural run-off patterns, the road effects on peak flows should be minimized. For this assessment, only the effects of ECA are used for assessing peak flow hazards.

Section 5 identified the reaches that are considered high value salmon spawning reaches, these reaches have a high peak flow consequence, and the remainder have moderate consequence ratings.

The risk is the result of the Hazard and Consequence Matrix (LxL=L, LxM=L, LxH=M, MxM=M, MxH=H and HxH=VH). Table 5 contains the current Hydrologic Risk Ratings for each sub-basin.

Table 5 – Hydrologic Risk Ratings

Upper Horsefly [1]							
Sub-basin	**Sub-basin Area (ha) and ECA(%)**		**Area Above 1,460 m (ha) and ECA(%)**		**Peak Flow Hazard**	**Peak Flow Consequence**	**Hydrologic Risk**
Black Creek	2,184	26.1%	805	39.9%	Moderate	High	**High**
Club Creek	865	37.1%	390	19.6%	Moderate	Moderate	Low
Prairie Creek	3,757	29.5%	1,016	40.7%	Moderate	Moderate	Moderate
Sawley Creek	1,171	25.3%	718	29.9%	Moderate	Moderate	Moderate
Harvie Creek	774	25.4%	291	7.7%	Low	Moderate	Low
MacKay River	14,348	10.4%	10,724	2.7%	Low	High	Moderate
Un-named 1	696	10.0%	244	26.0%	Low	Moderate	Low
Residual Above Falls	9,825	28.5%	1,750	29.4%	Low	High	Moderate
Lower Watershed [2]							
Sucker Creek	3,098	18.2%	45	46.7%	Low	High	Moderate
Patenaude Creek	1,007	6.1%	102	4.9%	Low	Moderate	Low
Wilmot Creek	1,272	4.6%	125	0%	Low	Moderate	Low
Doreen Creek	1,920	21.4%	391	19.5%	Low	Moderate	Low
McKinley Creek	7,667	15.0%	148	14.5%	Low	High	Moderate
Tisdall Creek	7,178	26.0%	745	39.6%	Low	Moderate	Low
Un-named 2	1,596	12.5%	42	0%	Low	Moderate	Low
Deerhorn Creek	3,678	22.2%	0	0%	Low	High	Moderate
Residual below Falls	7,209	19.0%	13	0%	Low	High	Moderate

1. For these basins, the ECA for both the area above 1,460 m and the sub-basin ECA values are referenced. The hazard category is based on the most conservative value, which in some cases is the gross ECA.
2. For these basins, the area above the 1,460 m elevation is a relatively small proportion of the gross area. The peak flow hazards are estimated based on the ECA for the sub-basin area only.

The suggested target hydrologic risk rating for each sub-basin is moderate. Because the peak flow consequence cannot be modified, the hydrologic risk can only be managed by adjusting the peak flow hazard rating, which is ECA dependant. Currently Black Creek exceeds the target risk rating; this can only be reduced through hydrologic recovery in the watershed.

7.2 Suggested Harvest Limits

The proposed harvest limits are based on maintaining no greater than a moderate hydrologic risk for the sub-basins. Table 6 shows the current and proposed maximum ECA's. Table 7 shows the maximum available harvest in hectares and Appendix C contains additional GIS data for the current ECA and future hydrologic recovery.

Table 6 – Current ECA and Proposed Harvest Limits

	2006 Conditions				Proposed Harvest Limit [1]			
Upper Horsefly								
	Sub-basin Area (ha) and ECA (%)		**Area Above 1,460 m (ha) and ECA (%)**		**Max Sub-basin ECA (%) and (ha)**		**Max ECA Above 1,460 m ECA (%) and (ha)**	
Black Creek	2,184	26.1%	805	39.9%	30%	655	30%	241
Club Creek	865	37.1%	390	19.6%	45%	389	45%	176
Prairie Creek	3,757	29.5%	1,016	40.7%	45%	1,690	45%	457
Sawley Creek	1,171	25.3%	718	29.9%	45%	527	45%	323
Harvie Creek	774	25.4%	291	7.7%	45%	348	45%	131
MacKay River	14,348	10.4%	10,724	2.7%	30%	4,304	30%	3,217
Un-named 1	696	10.0%	244	26.0%	45%	313	45%	110
Residual Above Falls	9,825	28.5%	1,750	29.4%	30%	2,947	30%	525
Lower Horsefly								
Sucker Creek	3,098	18.2%	45	46.7%	30%	929	N/A	N/A
Patenaude Creek	1,007	6.1%	102	4.9%	45%	453	N/A	N/A
Wilmot Creek	1,272	4.6%	125	0%	45%	572	N/A	N/A
Doreen Creek	1,920	21.4%	391	19.5%	45%	864	N/A	N/A
McKinley Creek	7,667	15.0%	148	14.5%	30%	2,300	N/A	N/A
Tisdall Creek	7,178	26.0%	745	39.6%	45%	3,230	N/A	N/A
Un-named 2	1,596	12.5%	42	0%	45%	718	N/A	N/A
Deerhorn Creek	3,678	22.2%	0	0%	30%	1,103	N/A	N/A
Residual below Falls	7,209	19.0%	13	0%	30%	2,163	N/A	N/A

1. The proposed maximum harvest is calculated by multiplying the maximum target peak flow hazard (%ECA) by both the sub-basin area and the area above the snow line, (1,460 m).

Table 7 – Area Available for Harvest
(Maximum Proposed ECA, Minus Current ECA)

	Sub-basin Area			Sub-basin Area above 1,460 m		
Sub-basin	**2006 ECA (ha)**	**Max. Proposed ECA (ha)**	**Area Available for Harvest (ha)**	**2006 ECA (ha)**	**Max. Proposed ECA (ha)**	**Max. Area Available for Harvest (ha)**
Upper Horsefly						
Black Creek	569	655	**86**	321	241	**-80**
Club Creek	321	389	**68**	77	176	**99**
Prairie Creek	1,108	1,690	**582**	414	457	**43**
Sawley Creek	296	527	**231**	193	323	**130**
Harvie Creek	196	348	**152**	22	131	**109**
MacKay River	1,487	4,304	**2,817**	290	3,217	**2,817**
Un-named 1	69	313	**244**	64	110	**46**
Residual Above Falls	2,800	2,947	**147**	515	525	**10**
Lower Horsefly						
Sucker Creek	565	929	**364**	21	45	**24**
Patenaude Creek	61	453	**392**	5	102	**97**
Wilmot Creek	58	572	**514**	0	125	**125**
Doreen Creek	412	864	**452**	76	391	**315**
McKinley Creek	1,152	2,300	**1,148**	21	148	**127**
Tisdall Creek	1,863	3,230	**1,367**	295	745	**450**
Un-named 2	199	718	**519**	0	42	**42**
Deerhorn Creek	818	1,103	**285**	0	N/A	**N/A**
Residual below Falls	1,372	2,163	**791**	0	13	**13**
Watershed			**10,159**			**4,447**

The data in the above table is based on 2006 ECA values. The maximum available harvest will increase as ECA values recover.

The total area available for harvest is 10,159 ha of which 4,447 ha are above the 1,460 m elevation. This value will change with changes in hydrologic recovery. Recovery in Black Creek above the snow line should occur before any additional harvest above the snow line is scheduled.

7.3 Mountain Pine Beetle and Hydrologic Risk

The mountain pine beetle is affecting mature pine in the watershed. The stand composition is highly variable throughout the watershed but several of the areas in the lower watershed have a significant proportion of >40% pine leading stands. Table 8 contains the details for the change in peak flow hazard ratings with the harvest of all the mature forest with >40% pine leading.

Table 8 – Change in Target Peak Flow Hazard with Harvest of Mature Pine

	Gross Sub-basin Area			Sub-basin Area above 1,460 m		
Sub-basin	**Max. Area Available for Harvest (ha)**	**Area Pine Leading (ha)**	**Exceeds P.F. Hazard Rating (Y/N)**	**Max. Area Available for Harvest (ha)**	**Area Pine Leading (ha)**	**Exceeds P.F. Hazard Rating (Y/N)**
Upper Horsefly						
Black Creek	86	380	**Y**	-80	57	**Y**
Club Creek	68	11	N	99	0	N
Prairie Creek	582	129	N	43	8	N
Sawley Creek	231	0	N	130	0	N
Harvie Creek	152	0	N	109	0	N
MacKay River	2,817	149	N	2,817	121	N
Un-named 1	244	69	N	46	12	N
Residual Above Falls	147	204	**Y**	10	36	**Y**
Lower Horsefly						
Sucker Creek	364	1,134	**Y**	24	7	N
Patenaude Creek	392	100	N	97	41	N
Wilmot Creek	514	364	N	125	101	N
Doreen Creek	452	261	N	315	93	N
McKinley Creek	1,148	1,450	**Y**	127	26	N
Tisdall Creek	1,367	845	N	450	64	N
Un-named 2	519	693	**Y**	42	19	N
Deerhorn Creek	285	802	**Y**	N/A	0	N
Residual below Falls	791	1,280	**Y**	13	5	N

Table 8 outlines the conditions assuming 100% of the stands with >40% pine leading have been harvested (worst case scenario). Because targeting 100% of the stands with >40% pine leading for harvest is not likely, the actual effects on the peak flow hazards (ECA) will likely be less than indicated in the table.

In addition, these values are based on a scenario with all the pine being harvested immediately. Because there is hydrologic recovery in all basins over the next five years (and beyond), and the fact that it will take several years for the pine beetle to kill the pine the actual conditions will likely be more favourable than indicated.

As discussed previously, the dead standing pine has a residual hydrologic function and is only considered a 50% ECA, vs. 100% if harvested. Furthermore, loss of forest cover in the lower Horsefly sub-basins is not likely to have a significant effect on peak flows in the main stem channels.

There are many "what if" harvest scenarios in the watershed. The complexity of these scenarios is beyond the scope of this report, but each of these must be studied individually and there may be cases where flexibility is required on the suggested peak flow hazard ratings.

8.0 CONCLUSIONS

- The Horsefly River watershed provides important habitat for Pacific salmon and other resident fish species. The most important salmon habitat/reaches are the Horsefly main stem channel between Sucker and Deerhorn creeks, the main stem between the falls and McKinley Creek, Black Creek below the 100 Road and McKinley Creek below McKinley Lake. The MacKay River sub-basin is also important as late season snow melt from this basin cools the water in the lower Horsefly River and enhances conditions for fish survival during the hot summer months.

- The sub-basins studied are divided into two groups referred to as, the "Upper Horsefly" (sub-basins with substantial areas within the snow sensitive zone) and the "Lower Horsefly" (sup-basins with a small proportion of area within the snow sensitive zone).

- The snow sensitive zone is defined as the watershed area above 1,460 m, which is the H_{60} for the combined Horsefly River above the Falls sub-basins.

- Based on recovery from past disturbance in the watershed and current research pertaining to ECA and peak flow increases, the following ECA categories outline the peak flow hazard rating (0-30% ECA Low Hazard, 31-45% ECA – Moderate Hazard and >45% ECA – High Hazard). For the upper Horsefly sub-basins, the ECA targets for both the sub-basin area and the sub-basin area above the snowline are considered. Neither of these areas should exceed the target ECA. For the lower Horsefly sub-basins, the target ECA is based on the entire sub-basin area only.

- The hydrologic risk assessment is based on the above peak flow hazards and the stream reach specific consequences of those hazards. The goal is to manage forest development to not exceed a moderate hydrologic risk rating.

- Black Creek currently has a high hydrologic risk rating due to 40% ECA in the snow sensitive zone (moderate hazard) and the high consequence on the stream. The rest of the study sub-basins have low or moderate risk ratings.

- Loss of forest canopy in pine-dominated stand is occurring because of the pine beetle infestation. The loss of pine whether harvested or not will affect the hydrological risk rating in both the upper and lower watershed sub-basins.

- Each "what if" harvest scenario must be studied individually, and is beyond the scope of this report. In some cases flexibility with the suggested maximum peak flow hazard rating (ECA) may be required, especially in the lower watershed sub-basins.

- Based on the risk ratings and current ECA values, there is potential available harvest throughout the watershed, however due to past disturbance, Black Creek should recover further before additional forest development occurs in that basin.

- Spruce bark beetle is present in the watershed. It is assumed that the spruce beetle is not at epidemic levels at this time. If the spruce bark beetle becomes epidemic in the watershed, further analysis may be required to determine the potential effect on the hydrologic risk.

- Two stream crossing structures that were assessed for flow capacities require attention: Whiskey Field Stops #5 and #6. The inlet of the culvert at the #5 location is partly blocked; otherwise the culvert is adequately sized. The culverts at the #6 location both have partly blocked inlets and are undersized for the estimated peak flows in the channel.

- Wood stave culverts drain both Prairie Creek (~2.1m) and Harvie Creek (~1.8m) at the 100 Road crossings. These culverts are functional and appear intact, but are old and may be decaying.

- None of the other major stream crossing structures was considered to be undersized.

- The public portion of the 100 Road (up to the 126 km mark) contributes fine sediment to the channel network, especially during the snowmelt period and rainy periods.

- The two culverts that drain Wilmot Creek at the 100 Road (public portion) are poorly aligned. Vegetated sediment deposits in the channel immediately upstream from the inlet are contributing to the problem.

- The culvert at Barker Creek and the 100 Road (public portion) is partially blocked and may require maintenance to prevent over topping during the 2007 freshet.

9.0 RECOMMENDATIONS

- Defer harvest in the Black Creek sub-basin until hydrologic recovery reduces the ECA in the snow sensitive zone to 30% or less. In the event other forest management requirements supersede this recommendation more detailed investigation is required.

- For sub-basins that may directly affect the most important salmon habitat/reaches (high consequence reaches) the peak flow hazard should not exceed a low rating. For all other sub-basins, the peak flow hazard should not exceed a moderate rating.

- In situations where peak flow hazard and hydrologic risk may exceed the suggested targets, further detailed hydrologic investigations should be conducted before further development is proposed.

- When targeting pine beetle infested stands, consider maintaining non-merchantable stems (secondary structure) and reserve deciduous stands to help expedite hydrologic recovery.

- Consider completing a total chance plan or retention plan for the watershed. This will help future management decisions, especially if the spruce bark beetle reaches epidemic levels that may result in increased hydrologic risk ratings.

- Clear the partially blocked inlet on the culvert at the Whiskey Field Stop #5 crossing and replace the two undersized culverts at Whiskey Field Stop #6 with a 1100 mm culvert.

- The road surface on the 900 Road at Harvie Creek may require improvements, as this site is possibly causing sediment to enter the creek. This site should be monitored during 2007 as the road may require upgrades (surfacing material at the stream crossing, and ditch line improvements/armouring).

- The wood stave culverts that drain Harvie and Prairie creeks at the 100 Road should be inspected to ensure they are structurally sound.

- Consider contacting the Ministry of Transportation regarding road surface improvements along the portion of the 100 Road, including the partially blocked culvert at Barker Creek and at the Wilmot Creek crossing on the 100 Road. Partial removal of the vegetated sediment accumulation may be required at Wilmot Creek.

Original signed by:

Prepared by G.J. VanEmmerik, AScT.

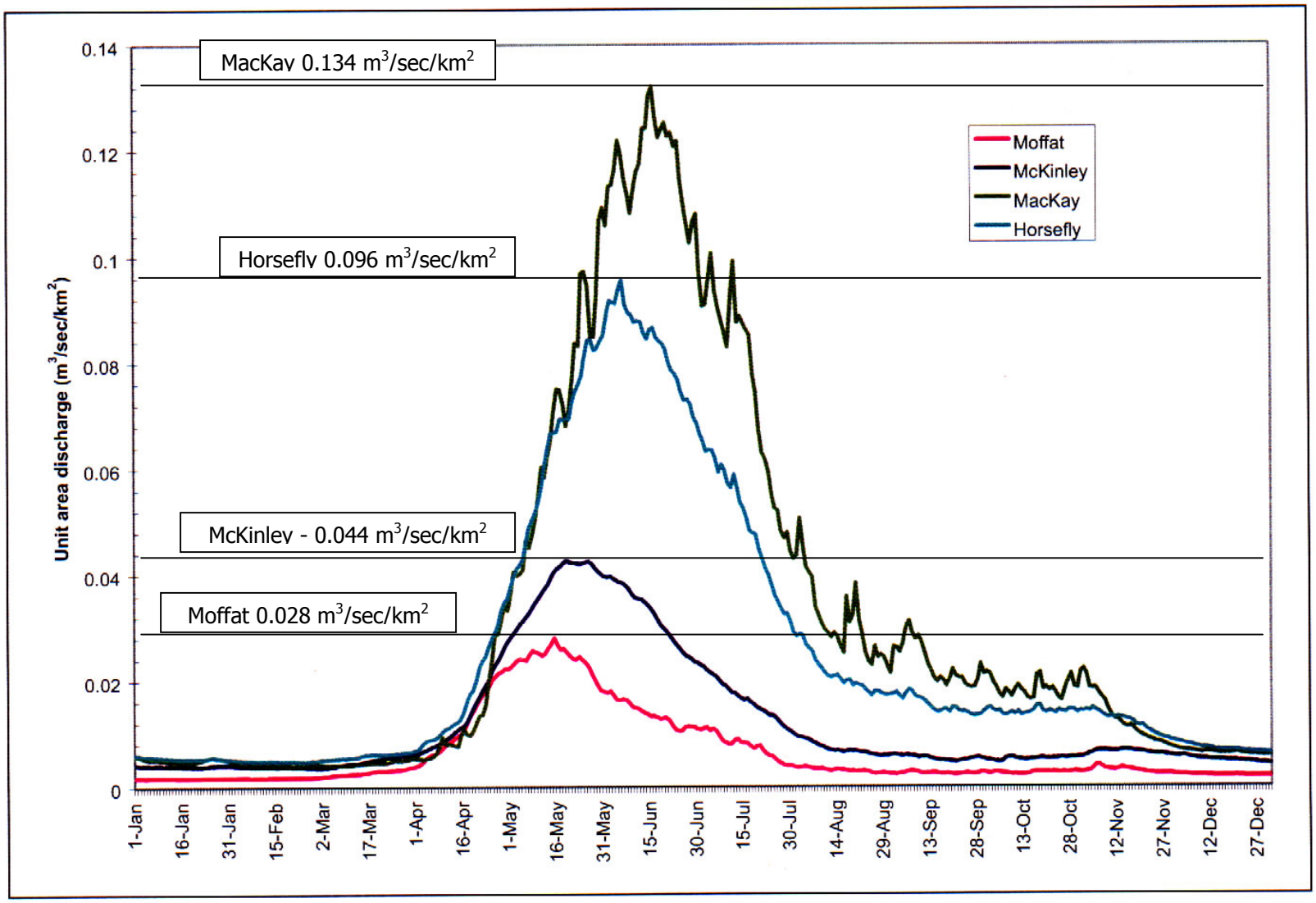
Original signed by:

Reviewed by D.A. Dobson, P.Eng.

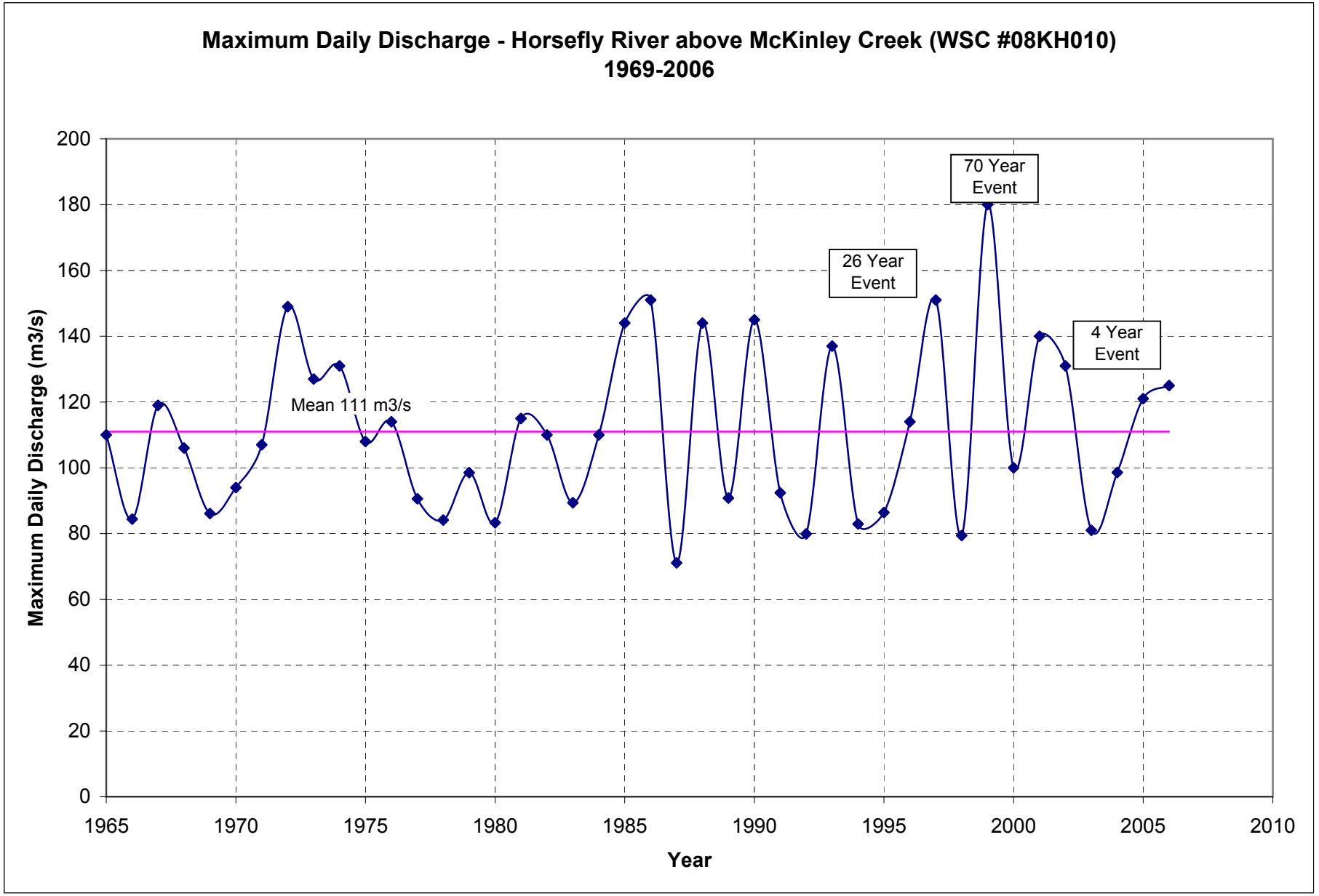
Appendix A

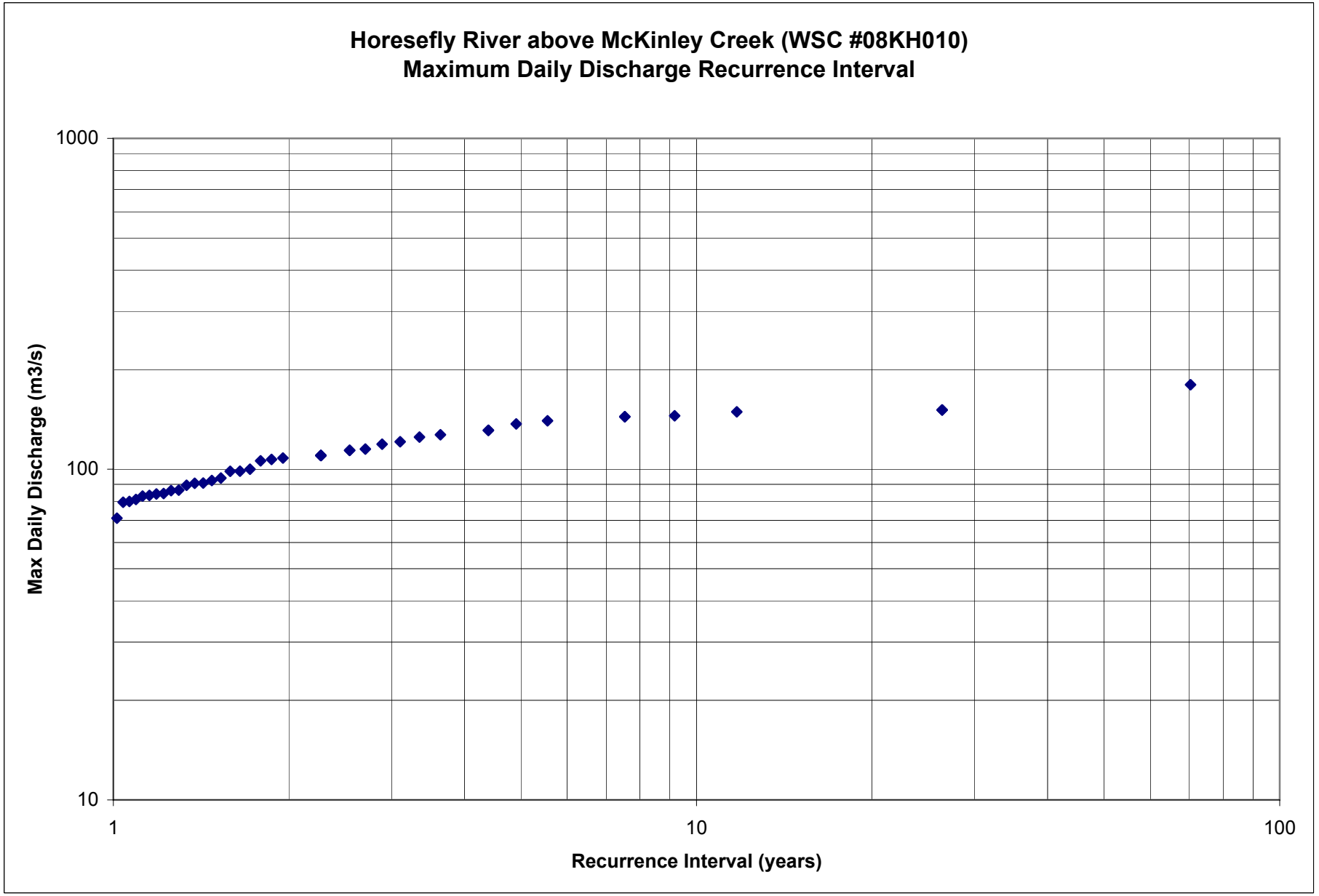
Hydrometric Data

Mean Annual Unit Area Discharges ($m^3/s/km^2$) for Selected WSC Stations



Adapted from; *Interior Watershed Assessment Update for Eight Watersheds Tributary to the Horsefly River., P. Beaudry and Associates Ltd., 2002*


Maximum Daily Discharge - Horsefly River above McKinley Creek (WSC #08KH010)
1969-2006
Maximum Daily Discharge (m3/s)
Year
Mean 111 m3/s
70 Year Event
26 Year Event
4 Year Event
0
20
40
60
80
100
120
140
160
180
200
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010


Horesefly River above McKinley Creek (WSC #08KH010)
Maximum Daily Discharge Recurrence Interval
1000
100
10
Max Daily Discharge (m3/s)
1
10
100
Recurrence Interval (years)

Appendix B

GIS Data

*Watershed Report Card for Horsefly River 2006**

Basin	*Gross Area ha*	*Total Harvested Area ha %*	*ECA ha %*	*ECA below Snowline ha %*	*Area Above Snowline ha*	*ECA Above Snowline ha %*
MacKay River	14,347.9	2,246.3 15.7	1,486.7 10.4	1,196.9 33.0	10,724.3	289.8 2.7
Club Creek	865.2	728.9 84.2	321.2 37.1	244.7 51.5	389.9	76.5 19.6
Prairie Creek	3,757.1	2,895.3 77.1	1,107.7 29.5	693.8 25.3	1,016.2	413.9 40.7
Sawley Creek	1,170.6	402.3 34.4	296.2 25.3	102.9 22.7	717.8	193.3 26.9
Harvie Creek	773.6	303.8 39.3	196.3 25.4	173.9 36.0	290.6	22.4 7.7
Doreen Creek	1,920.0	772.6 40.2	411.6 21.4	335.4 21.9	391.4	76.2 19.5
Horsefly River Residual Above Falls	9,825.3	6,038.4 61.5	2,799.8 28.5	2,285.3 28.3	1,750.2	514.5 29.4
Sucker Creek	3,098.3	772.0 24.9	564.7 18.2	543.5 17.8	45.4	21.2 46.7
Patenaude Creek	1,006.7	88.4 8.8	61.3 6.1	56.3 6.2	101.5	5.0 4.9
Wilmot Creek	1,271.6	58.0 4.6	58.0 4.6	58.0 5.1	124.6	0.0 0.0
Black Creek	2,184.2	693.2 31.7	569.1 26.1	247.7 18.0	804.5	321.3 39.9
McKinley Creek	7,667.0	1,927.7 25.1	1,152.4 15.0	1,130.9 15.0	148.1	21.4 14.5
Tisdall Creek	7,178.4	2,327.1 32.4	1,863.2 26.0	1,568.5 24.4	744.5	294.7 39.6
Unnamed Creek 2	1,595.7	199.2 12.5	199.2 12.5	199.2 12.8	42.1	0.0 0.0
Unnamed Creek 1	695.9	69.4 10.0	69.4 10.0	5.9 1.3	243.9	63.5 26.0
Deerhorn Creek	3,678.1	1,326.4 36.1	817.5 22.2	817.5 22.2	0.0	0.0 0.0
Horsefly River Residual Below Falls	7,209.4	1,480.6 20.5	1,371.7 19.0	1,371.7 19.1	12.8	0.0 0.0
Watershed	68,245.2	22,329.7 32.7	13,345.9 19.6	11,032.1 21.8	17,547.6	2,313.8 13.2

** Includes all blocks cut or projected to be cut in 2006*

Horsefly River 20 year ECA Report

Values in ha and %

Basin	*Area*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*	*2023*	*2024*	*2025*	*2026*
McKay River	14,347.9	1,486.7	1,384.3	1,314.4	1,202.6	1,138.9	1,082.8	1,005.5	915.2	833.8	770.0	715.6	662.1	644.8	593.6	523.5	467.2	435.0	394.3	379.9	352.8	322.9
		10.4	9.6	9.2	8.4	7.9	7.5	7.0	6.4	5.8	5.4	5.0	4.6	4.5	4.1	3.6	3.3	3.0	2.7	2.6	2.5	2.3
Club Creek	865.2	321.2	310.7	299.3	295.9	274.0	272.5	272.5	239.2	237.9	237.8	230.0	223.7	206.5	206.5	192.0	190.3	188.8	158.9	157.1	149.7	141.5
		37.1	35.9	34.6	34.2	31.7	31.5	31.5	27.6	27.5	27.5	26.6	25.9	23.9	23.9	22.2	22.0	21.8	18.4	18.2	17.3	16.4
Prairie Creek	3,757.1	1,107.7	1,084.8	1,070.8	1,042.9	1,038.9	971.4	886.1	866.1	849.4	832.8	823.4	799.0	789.9	780.0	774.0	737.7	711.6	692.0	668.0	653.9	650.5
		29.5	28.9	28.5	27.8	27.7	25.9	23.6	23.1	22.6	22.2	21.9	21.3	21.0	20.8	20.6	19.6	18.9	18.4	17.8	17.4	17.3
Sawley Creek	1,170.6	296.2	292.8	292.5	282.2	274.3	250.0	236.2	214.8	213.4	208.7	193.3	190.3	185.3	153.9	142.0	134.3	131.3	131.3	130.9	125.0	113.7
		25.3	25.0	25.0	24.1	23.4	21.4	20.2	18.4	18.2	17.8	16.5	16.3	15.8	13.1	12.1	11.5	11.2	11.2	11.2	10.7	9.7
Harvie Creek	773.6	196.3	195.5	190.2	142.6	142.0	142.0	139.4	139.1	121.1	118.4	98.3	97.5	97.4	84.7	80.4	76.8	76.3	76.3	68.6	52.5	52.5
		25.4	25.3	24.6	18.4	18.4	18.4	18.0	18.0	15.6	15.3	12.7	12.6	12.6	10.9	10.4	9.9	9.9	9.9	8.9	6.8	6.8
Doreen Creek	1,920.0	411.6	392.1	343.1	342.4	312.1	280.5	272.8	254.0	251.3	223.8	191.8	181.9	166.4	166.4	151.8	135.5	101.3	99.7	88.3	82.4	73.8
		21.4	20.4	17.9	17.8	16.3	14.6	14.2	13.2	13.1	11.7	10.0	9.5	8.7	8.7	7.9	7.1	5.3	5.2	4.6	4.3	3.8
Horsefly River Residual Above Falls	9,825.3	2,799.8	2,711.7	2,551.6	2,414.8	2,237.0	2,082.8	1,993.6	1,887.6	1,768.4	1,646.4	1,528.0	1,475.9	1,379.3	1,325.4	1,225.9	1,130.7	1,047.9	956.6	903.2	796.3	743.9
		28.5	27.6	26.0	24.6	22.8	21.2	20.3	19.2	18.0	16.8	15.6	15.0	14.0	13.5	12.5	11.5	10.7	9.7	9.2	8.1	7.6
Sucker Creek	3,098.3	564.7	519.8	501.7	495.3	483.8	463.6	429.9	401.0	381.5	364.8	338.7	310.6	295.0	267.4	265.5	249.2	234.2	195.2	194.8	182.3	160.3
		18.2	16.8	16.2	16.0	15.6	15.0	13.9	12.9	12.3	11.8	10.9	10.0	9.5	8.6	8.6	8.0	7.6	6.3	6.3	5.9	5.2
Patenaude Creek	1,006.7	61.3	61.3	61.3	61.3	61.3	61.3	61.3	61.3	61.3	61.3	51.9	51.9	51.9	51.9	51.9	51.9	42.5	42.5	42.5	42.5	42.5
		6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	5.2	5.2	5.2	5.2	5.2	5.2	4.2	4.2	4.2	4.2	4.2
Wilmot Creek	1,271.6	58.0	58.0	58.0	58.0	58.0	58.0	58.0	58.0	58.0	58.0	58.0	58.0	58.0	58.0	58.0	58.0	58.0	58.0	58.0	58.0	58.0
		4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6
Black Creek	2,184.2	569.1	537.0	526.7	516.8	506.2	500.4	487.2	479.8	476.1	440.4	424.2	400.0	399.9	384.3	367.4	355.1	328.1	290.4	274.2	261.5	246.9
		26.1	24.6	24.1	23.7	23.2	22.9	22.3	22.0	21.8	20.2	19.4	18.3	18.3	17.6	16.8	16.3	15.0	13.3	12.6	12.0	11.3
McKinley Creek	7,667.0	1,152.4	1,126.2	1,067.2	1,002.0	972.8	932.2	885.9	817.0	780.9	745.7	700.9	666.9	593.8	567.1	517.8	464.4	451.1	412.9	381.4	341.9	318.2
		15.0	14.7	13.9	13.1	12.7	12.2	11.6	10.7	10.2	9.7	9.1	8.7	7.7	7.4	6.8	6.1	5.9	5.4	5.0	4.5	4.2
Tisdall Creek	7,178.4	1,863.2	1,854.8	1,811.1	1,741.1	1,658.9	1,635.9	1,622.6	1,590.4	1,558.5	1,446.1	1,404.0	1,361.2	1,272.6	1,241.4	1,205.7	1,098.5	1,032.2	1,000.3	961.9	870.1	823.1
		26.0	25.8	25.2	24.3	23.1	22.8	22.6	22.2	21.7	20.1	19.6	19.0	17.7	17.3	16.8	15.3	14.4	13.9	13.4	12.1	11.5
Unnamed Creek 2	1,595.7	199.2	188.8	188.8	188.8	188.8	181.2	178.5	178.5	178.1	178.1	170.5	167.7	167.7	167.3	162.7	161.8	160.1	160.1	159.7	159.7	158.8
		12.5	11.8	11.8	11.8	11.8	11.4	11.2	11.2	11.2	11.2	10.7	10.5	10.5	10.5	10.2	10.1	10.0	10.0	10.0	10.0	10.0
Unnamed Creek 1	695.9	69.4	69.4	69.4	69.4	69.4	66.2	66.2	66.2	66.2	66.2	63.0	63.0	63.0	61.7	61.7	58.5	58.5	58.5	57.3	57.3	55.4
		10.0	10.0	10.0	10.0	10.0	9.5	9.5	9.5	9.5	9.5	9.0	9.0	9.0	8.9	8.9	8.4	8.4	8.4	8.2	8.2	8.0
Deerhorn Creek	3,678.1	817.5	803.5	788.9	771.4	749.2	733.3	679.4	650.8	627.0	601.4	590.1	537.4	516.7	477.3	452.9	418.8	380.4	355.4	319.6	297.5	272.9
		22.2	21.8	21.4	21.0	20.4	19.9	18.5	17.7	17.0	16.3	16.0	14.6	14.0	13.0	12.3	11.4	10.3	9.7	8.7	8.1	7.4
Horsefly River Residual Below Falls	7,209.4	1,371.7	1,339.8	1,323.5	1,307.4	1,281.6	1,254.8	1,239.1	1,210.0	1,144.0	1,131.4	1,100.8	1,067.3	1,040.6	991.3	977.2	969.6	946.0	921.8	885.6	872.5	859.3
		19.0	18.6	18.4	18.1	17.8	17.4	17.2	16.8	15.9	15.7	15.3	14.8	14.4	13.8	13.6	13.4	13.1	12.8	12.3	12.1	11.9
Watershed	68,245.2	13,345.9	12,930.4	12,458.6	11,935.0	11,447.2	10,968.9	10,514.2	10,029.0	9,606.8	9,131.2	8,682.5	8,312.1	7,926.4	7,569.5	7,201.7	6,746.1	6,364.9	5,985.6	5,712.5	5,335.3	5,065.8
		19.6	18.9	18.3	17.5	16.8	16.1	15.4	14.7	14.1	13.4	12.7	12.2	11.6	11.1	10.6	9.9	9.3	8.8	8.4	7.8	7.4

Horsefly River Above Snow Sensitive Zone 20 year ECA Report

Values in ha and %

Basin	*Area*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*	*2023*	*2024*	*2025*	*2026*
McKay River	5,784.9	289.8	281.5	274.7	250.2	230.4	212.8	211.4	203.0	195.7	184.4	162.7	1.3	137.9	130.0	120.2	119.6	108.8	98.2	90.2	76.0	68.3
		2.7	2.6	2.6	2.3	2.1	2.0	2.0	1.9	1.8	1.7	1.5	1.3	1.3	1.2	1.1	1.1	1.0	0.9	0.8	0.7	0.6
Club Creek	389.9	76.5	76.5	67.5	64.6	55.9	54.3	54.3	52.3	52.3	52.3	52.0	11.7	36.7	36.7	35.0	33.5	33.5	33.4	32.3	24.9	24.0
		19.6	19.6	17.3	16.6	14.3	13.9	13.9	13.4	13.4	13.4	13.3	11.7	9.4	9.4	9.0	8.6	8.6	8.6	8.3	6.4	6.2
Prairie Creek	1,016.2	413.9	409.9	399.9	397.8	395.3	369.7	338.7	327.1	325.0	322.5	315.4	30.8	305.5	299.9	294.7	288.3	276.3	264.6	258.0	248.9	245.6
		40.7	40.3	39.4	39.1	38.9	36.4	33.3	32.2	32.0	31.7	31.0	30.8	30.1	29.5	29.0	28.4	27.2	26.0	25.4	24.5	24.2
Sawley Creek	717.8	193.3	190.3	190.0	190.0	185.4	169.3	155.6	136.2	135.0	130.7	125.2	17.2	119.7	90.2	78.5	74.2	72.8	72.8	72.8	70.7	59.4
		26.9	26.5	26.5	26.5	25.8	23.6	21.7	19.0	18.8	18.2	17.4	17.2	16.7	12.6	10.9	10.3	10.1	10.1	10.1	9.9	8.3
Harvie Creek	290.6	22.4	21.6	21.6	21.6	21.6	21.6	19.2	18.9	18.9	18.9	18.9	6.2	18.0	18.0	16.4	16.0	15.5	15.5	15.5	15.5	15.5
		7.7	7.4	7.4	7.4	7.4	7.4	6.6	6.5	6.5	6.5	6.5	6.2	6.2	6.2	5.6	5.5	5.3	5.3	5.3	5.3	5.3
Doreen Creek	391.4	76.2	76.2	68.9	68.9	54.4	52.4	52.4	45.0	45.0	30.6	29.3	7.5	24.3	24.3	15.7	15.7	15.5	14.3	14.2	14.1	10.8
		19.5	19.5	17.6	17.6	13.9	13.4	13.4	11.5	11.5	7.8	7.5	7.5	6.2	6.2	4.0	4.0	4.0	3.6	3.6	3.6	2.8
Horsefly River Residual Above Falls	1,750.2	514.5	509.4	492.0	479.0	467.6	443.2	439.5	430.2	420.8	410.7	381.4	21.5	365.4	364.5	350.0	334.0	321.4	303.6	288.5	276.1	266.0
		29.4	29.1	28.1	27.4	26.7	25.3	25.1	24.6	24.0	23.5	21.8	21.5	20.9	20.8	20.0	19.1	18.4	17.3	16.5	15.8	15.2
Sucker Creek	45.4	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2	46.7	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2
		46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7
Patenaude Creek	101.5	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
		4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9
Wilmot Creek	124.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Black Creek	804.5	321.3	290.7	280.8	270.8	268.1	266.1	265.0	265.0	261.3	230.9	221.4	25.9	208.7	194.6	188.0	185.9	184.6	154.3	140.2	128.1	126.9
		39.9	36.1	34.9	33.7	33.3	33.1	32.9	32.9	32.5	28.7	27.5	25.9	25.9	24.2	23.4	23.1	23.0	19.2	17.4	15.9	15.8
McKinley Creek	148.1	21.4	20.7	15.0	13.9	13.9	12.5	12.5	6.9	6.9	6.8	6.8	4.6	3.5	3.4	3.4	3.4	3.3	3.3	3.3	3.3	1.1
		14.5	14.0	10.1	9.4	9.4	8.4	8.4	4.7	4.6	4.6	4.6	4.6	2.4	2.3	2.3	2.3	2.3	2.3	2.3	2.3	0.7
Tisdall Creek	744.5	294.7	294.7	294.5	277.5	277.5	270.5	270.5	262.7	252.8	243.5	235.7	29.6	219.8	215.9	215.9	206.2	197.6	188.3	185.1	165.7	162.8
		39.6	39.6	39.6	37.3	37.3	36.3	36.3	35.3	34.0	32.7	31.7	29.6	29.5	29.0	29.0	27.7	26.5	25.3	24.9	22.3	21.9
Unnamed Creek 2	42.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unnamed Creek 1	243.9	63.5	63.5	63.5	63.5	63.5	60.3	60.3	60.3	60.3	60.3	57.1	23.4	57.1	55.9	55.9	52.7	52.7	52.7	51.5	51.5	49.5
		26.0	26.0	26.0	26.0	26.0	24.7	24.7	24.7	24.7	24.7	23.4	23.4	23.4	22.9	22.9	21.6	21.6	21.6	21.1	21.1	20.3
Deerhorn Creek	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Horsefly River Residual Below Falls	12.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Watershed	12,608.3	2,313.8	2,261.2	2,194.6	2,123.9	2,059.8	1,959.0	1,905.6	1,833.9	1,800.3	1,717.8	1,631.9	8.9	1,522.9	1,459.6	1,399.7	1,355.7	1,308.3	1,227.2	1,177.7	1,101.1	1,056.2
		13.2	12.9	12.5	12.1	11.7	11.2	10.9	10.5	10.3	9.8	9.3	8.9	8.7	8.3	8.0	7.7	7.5	7.0	6.7	6.3	6.0

Horsefly River Below Snow Sensitive Zone 20 year ECA Report

Values in ha and %

Basin	*Area*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*	*2023*	*2024*	*2025*	*2026*
McKay River	8,563.0	1,196.9	1,102.8	1,039.7	952.5	908.5	870.0	794.0	712.2	638.1	585.6	552.9	524.2	506.8	463.6	403.4	347.5	326.2	296.1	289.7	276.9	254.6
		33.0	30.4	28.7	26.3	25.1	24.0	21.9	19.7	17.6	16.2	15.3	14.5	14.0	12.8	11.1	9.6	9.0	8.2	8.0	7.6	7.0
Club Creek	475.3	244.7	234.2	231.8	231.3	218.1	218.1	218.1	186.8	185.6	185.5	178.1	178.1	169.8	169.8	156.9	156.8	155.4	125.4	124.8	124.8	117.4
		51.5	49.3	48.8	48.7	45.9	45.9	45.9	39.3	39.0	39.0	37.5	37.5	35.7	35.7	33.0	33.0	32.7	26.4	26.3	26.3	24.7
Prairie Creek	2,740.9	693.8	674.9	670.9	645.1	643.5	601.7	547.4	539.0	524.4	510.3	508.0	485.9	484.5	480.1	479.3	449.5	435.4	427.4	410.0	405.0	404.9
		25.3	24.6	24.5	23.5	23.5	22.0	20.0	19.7	19.1	18.6	18.5	17.7	17.7	17.5	17.5	16.4	15.9	15.6	15.0	14.8	14.8
Sawley Creek	452.9	102.9	102.5	102.5	92.2	88.9	80.6	80.6	78.7	78.4	78.1	68.1	67.0	65.7	63.7	63.5	60.0	58.5	58.5	58.2	54.3	54.3
		22.7	22.6	22.6	20.4	19.6	17.8	17.8	17.4	17.3	17.2	15.0	14.8	14.5	14.1	14.0	13.3	12.9	12.9	12.8	12.0	12.0
Harvie Creek	483.0	173.9	173.9	168.5	121.0	120.4	120.4	120.3	120.3	102.2	99.5	79.4	79.4	79.3	66.6	64.0	60.7	60.7	60.7	53.1	37.0	37.0
		36.0	36.0	34.9	25.1	24.9	24.9	24.9	24.9	21.2	20.6	16.4	16.4	16.4	13.8	13.2	12.6	12.6	12.6	11.0	7.7	7.7
Doreen Creek	1,528.7	335.4	315.8	274.2	273.6	257.6	228.1	220.4	209.0	206.3	193.3	162.5	152.7	142.0	142.0	136.2	119.9	85.8	85.5	74.1	68.3	63.0
		21.9	20.7	17.9	17.9	16.9	14.9	14.4	13.7	13.5	12.6	10.6	10.0	9.3	9.3	8.9	7.8	5.6	5.6	4.8	4.5	4.1
Horsefly River Residual Above Falls	8,075.1	2,285.3	2,202.3	2,059.6	1,935.8	1,769.4	1,639.6	1,554.1	1,457.4	1,347.6	1,235.7	1,146.6	1,099.9	1,013.9	961.0	876.0	796.7	726.6	653.0	614.7	520.2	477.9
		28.3	27.3	25.5	24.0	21.9	20.3	19.2	18.0	16.7	15.3	14.2	13.6	12.6	11.9	10.8	9.9	9.0	8.1	7.6	6.4	5.9
Sucker Creek	3,052.9	543.5	498.6	480.5	474.1	462.6	442.4	408.7	379.8	360.3	343.7	317.5	289.4	273.8	246.2	244.3	228.0	213.1	174.0	173.7	161.1	139.1
		17.8	16.3	15.7	15.5	15.2	14.5	13.4	12.4	11.8	11.3	10.4	9.5	9.0	8.1	8.0	7.5	7.0	5.7	5.7	5.3	4.6
Patenaude Creek	905.1	56.3	56.3	56.3	56.3	56.3	56.3	56.3	56.3	56.3	56.3	46.9	46.9	46.9	46.9	46.9	46.9	37.5	37.5	37.5	37.5	37.5
		6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	5.2	5.2	5.2	5.2	5.2	5.2	4.1	4.1	4.1	4.1	4.1
Wilmot Creek	1,147.0	58.0	58.0	58.0	58.0	58.0	58.0	58.0	58.0	58.0	58.0	58.0	58.0	58.0	58.0	58.0	58.0	58.0	58.0	58.0	58.0	58.0
		5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1
Black Creek	1,379.7	247.7	246.3	245.9	245.9	238.1	234.3	222.2	214.8	214.8	209.4	202.8	191.3	191.2	189.7	179.5	169.2	143.5	136.1	134.0	133.4	120.0
		18.0	17.9	17.8	17.8	17.3	17.0	16.1	15.6	15.6	15.2	14.7	13.9	13.9	13.8	13.0	12.3	10.4	9.9	9.7	9.7	8.7
McKinley Creek	7,518.9	1,130.9	1,105.5	1,052.2	988.1	958.9	919.7	873.4	810.0	774.0	738.8	694.1	660.1	590.3	563.7	514.4	461.0	447.7	409.5	378.0	338.6	317.1
		15.0	14.7	14.0	13.1	12.8	12.2	11.6	10.8	10.3	9.8	9.2	8.8	7.9	7.5	6.8	6.1	6.0	5.4	5.0	4.5	4.2
Tisdall Creek	6,433.9	1,568.5	1,560.1	1,516.7	1,463.6	1,381.4	1,365.4	1,352.1	1,327.7	1,305.7	1,202.6	1,168.4	1,141.2	1,052.8	1,025.5	989.7	892.2	834.5	812.0	776.8	704.4	660.3
		24.4	24.2	23.6	22.7	21.5	21.2	21.0	20.6	20.3	18.7	18.2	17.7	16.4	15.9	15.4	13.9	13.0	12.6	12.1	10.9	10.3
Unnamed Creek 2	1,553.7	199.2	188.8	188.8	188.8	188.8	181.2	178.5	178.5	178.1	178.1	170.5	167.7	167.7	167.3	162.7	161.8	160.1	160.1	159.7	159.7	158.8
		12.8	12.2	12.2	12.2	12.2	11.7	11.5	11.5	11.5	11.5	11.0	10.8	10.8	10.8	10.5	10.4	10.3	10.3	10.3	10.3	10.2
Unnamed Creek 1	452.0	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.8	5.8	5.8	5.8	5.8	5.8
		1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
Deerhorn Creek	3,678.1	817.5	803.5	788.9	771.4	749.2	733.3	679.4	650.8	627.0	601.4	590.1	537.4	516.7	477.3	452.9	418.8	380.4	355.4	319.6	297.5	272.9
		22.2	21.8	21.4	21.0	20.4	19.9	18.5	17.7	17.0	16.3	16.0	14.6	14.0	13.0	12.3	11.4	10.3	9.7	8.7	8.1	7.4
Horsefly River Residual Below Falls	7,196.6	1,371.7	1,339.8	1,323.5	1,307.4	1,281.6	1,254.8	1,239.1	1,210.0	1,144.0	1,131.4	1,100.8	1,067.3	1,040.6	991.3	977.2	969.6	946.0	921.8	885.6	872.5	859.3
		19.1	18.6	18.4	18.2	17.8	17.4	17.2	16.8	15.9	15.7	15.3	14.8	14.5	13.8	13.6	13.5	13.1	12.8	12.3	12.1	11.9
Watershed	55,636.9	11,032.1	10,669.2	10,264.0	9,811.1	9,387.4	9,009.9	8,608.5	8,195.1	7,806.5	7,413.4	7,050.6	6,750.0	6,403.5	6,109.8	5,802.0	5,390.4	5,056.6	4,758.4	4,534.8	4,234.2	4,009.6
		21.8	21.0	20.2	19.4	18.5	17.8	17.0	16.2	15.4	14.6	13.9	13.3	12.6	12.1	11.4	10.6	10.0	9.4	8.9	8.4	7.9

Appendix B – Forest Cover Distribution

	Forest Cover Distribution Above H60							Forest Cover Distribution Below H60							Above and Below
Pine Leading Category	**ha <40**	**ha >70**	**ha 40-50**	**ha 51-60**	**ha 61-70**	**ha Logged**	**ha No Pine**	**ha <40**	**ha >70**	**ha 40-50**	**ha 51-60**	**ha 61-70**	**ha Logged**	**ha No Pine**	**% Non-Pine Leading**
Sub-Basin															
Black Creek	69.0	15.2	37.0	0.9	3.7	395.5	283.2	540.3	112.0	71.4	41.4	98.2	297.7	218.8	**74.5%**
Club Creek	0.0	0.0	0.0	0.0	0.0	325.1	64.8	9.2	0.0	0.0	8.4	2.5	403.8	51.4	**92.0%**
Prairie Creek	36.4	0.0	7.9	0.0	0.0	568.4	403.5	17.2	7.7	91.7	22.1	0.0	2327.0	275.3	**85.0%**
Sawley Creek	32.8	0.0	0.0	0.0	0.0	225.7	459.2	81.4	0.0	0.0	0.0	0.0	176.6	194.9	**100%**
Harvie Creek	40.3	0.0	0.0	0.0	0.0	22.5	227.9	56.3	0.0	0.0	0.0	0.0	281.3	145.3	**100%**
MacKay River	79.0	0.0	113.8	0.0	7.1	352.1	10172.3	42.8	12.2	15.9	0.0	0.0	1894.3	1658.3	**98.8%**
Un-named 1	32.6	0.0	8.5	3.3	0.0	63.5	136.0	149.6	9.5	19.6	14.3	13.9	5.9	239.2	**89.0%**
Residual Above Falls	85.8	2.9	33.0	0.0	0.0	695.2	933.3	483.7	32.6	113.8	1.1	20.4	5371.9	2051.6	**94.6%**
Sucker Creek	17.6	0.0	6.5	0.0	0.0	21.2	0.0	790.6	640.0	255.4	176.6	54.9	750.9	384.5	**51.3%**
Patenaude Creek	31.9	12.3	28.2	0.0	0.0	5.0	24.1	523.4	4.0	44.2	7.7	3.8	83.4	238.6	**89.1%**
Wilmot Creek	13.8	44.4	22.9	29.8	3.3	0.0	10.3	493.2	87.0	72.8	66.0	37.7	58.0	332.3	**70.0%**
Doreen Creek	95.0	69.8	8.2	14.6	0.0	111.1	92.6	221.8	146.6	16.1	5.6	0.0	661.6	477.0	**77.3%**
McKinley Creek	17.9	0.7	14.8	4.6	6.0	49.9	54.2	1493.6	701.1	398.2	136.3	188.1	1901.9	2699.6	**74.6%**
Tisdall Creek	88.8	0.3	56.6	6.7	0.0	310.7	281.5	1627.4	241.3	246.4	156.8	136.8	2023.6	2001.5	**82.6%**
Un-named 2	23.4	16.1	0.4	2.2	0.0	0.0	0.0	582.8	267.0	217.3	158.5	31.5	199.2	97.3	**50.4%**
Deerhorn Creek	0.0	0.0	0.0	0.0	0.0	0.0	0.0	848.2	218.5	325.3	128.8	129.8	1326.4	701.1	**65.9%**
Residual below Falls	7.4	0.0	0.0	5.3	0.0	0.0	0.0	1494.7	403.9	456.6	264.8	149.3	1511.8	2915.4	**77.5%**
Watershed	671.7	161.7	337.9	67.5	20.1	3145.7	13143.0	9456.3	2883.4	2344.8	1188.6	867.0	19275.1	14682.3	**82.8%**

Appendix C

Selected Structure Size and Capacity

Appendix C – Selected Structure Size and Capacity

Water Survey of Canada Stations - Unit Area Discharge Data

WSC Station	2-Year Peak Unit Area Discharge $m^3/sec/km^2$
Moffat - 08KH019	**0.028**
McKinley – 08KH020	**0.044**
Horsefly - 08KH010	**0.096**
MacKay – 08KH022	**0.134**

The unit area discharges are based on information provided in Appendix A, and are based on the mean annual peak flow, or the 2-year peak flow event.

Culvert Sizes and Capacities

Culvert Size (mm)	Culvert Capacity (m^3/s)	Culvert Size (mm)	Culvert Capacity (m^3/s)	Culvert Size (mm)	Culvert Capacity (m^3/s)
400	0.09	1100	1.50	1800	5.50
500	0.17	1200	1.85	1900	6.50
600	0.28	1300	2.20	2000	7.50
700	0.43	1400	2.80	2100	8.50
800	0.60	1500	3.40	2200	9.50
900	0.85	1600	4.00	2300	10.7
1000	1.13	1700	4.70	2400	12.5

The culvert size and capacities were derived from the nomogram in the Handbook of Steel Drainage & Highway Construction Products, Canadian Edition – American Iron and Steel Institute, 1984 pg 181

Selected Drainage Structures – Flow Capacities

Location	Unit Area Discharge ($m^3/sec/km^2$)	Structure Drainage Area (km^2)	2-Year Peak Discharge (m^3/sec)	100-Year Peak Discharge (m^3/sec)	Structure Size(s)	Structure Capacity (m^3/sec)	Structure Meets 100-Year Size
Black Cr at 100 Rd	0.044	21.8	0.959	2.88	2000 mm arch culvert	7.5	Yes
MacKay (Assessment Site 3)	0.134	4.44	0.595	1.78	700mm, 900mm and 1200mm culverts	3.13	Yes
S. Trib MacKay	0.134	4.65	0.623	1.87	2x900mm and 1600mm culverts	5.7	Yes
Club Creek at 100 Rd	0.096	8.6	0.826	2.48	800mm and 1200mm culverts	2.45	Yes
Prairie Cr at 100 Rd[1]	0.096	37.5	3.600	10.8	2200mm wood culvert	9.5	Yes
Sawley Cr at 100 Rd	0.096	11.7	1.123	3.37	~8 meter open bottom culvert	>5	Yes
Harvie Cr at 100 Rd	0.096	7.7	0.739	2.22	1800mm culvert	5.5	Yes
Whiskey (Assessment Site 5)	0.096	2.34	0.225	0.68	900mm culvert	0.85	Yes
Whiskey (Assessment Site 6)	0.096	4.73	0.454	1.36	500mm and 600mm culverts	0.45	No
153.25 km Trib (Assessment Site 9)	0.096	3.91	0.375	1.13	2400mm culvert	12.5	Yes
141 km Trib (Assessment Site 10)	0.096	2.38	0.228	0.68	1200mm culvert	1.85	Yes

The 100-Year peak discharge is estimated by multiplying the 2-Year peak discharge by three, as per the procedures outlined in the 1995 BC Forest Road Engineering Guidebook. If the structure does not accommodate 3x the estimated 2-Year peak discharge, then it may be undersized.

[1]Prairie Creek drains through a marshy area at this location and there was no field evidence of the current structure being undersized. The unit area discharge for the Horsefly River above McKinley is likely an over-estimate for the actual unit area discharge for this area, and the current structure is likely adequately sized.

The Whiskey Field Stop 6 structures are undersized at this location. The estimated 100-year discharge is 3 x 0.454 = 1.36 m^3/s. A 1100mm culvert would accommodate this flow.

Appendix D

Maps

Appendix E

Photographs

Photo 1 – Club Creek upstream from 100 Road

Photo 2 – Club Creek upstream from 100 Road

Photo 3 – Prairie Creek/eroded trib. Channel at 6500 Road

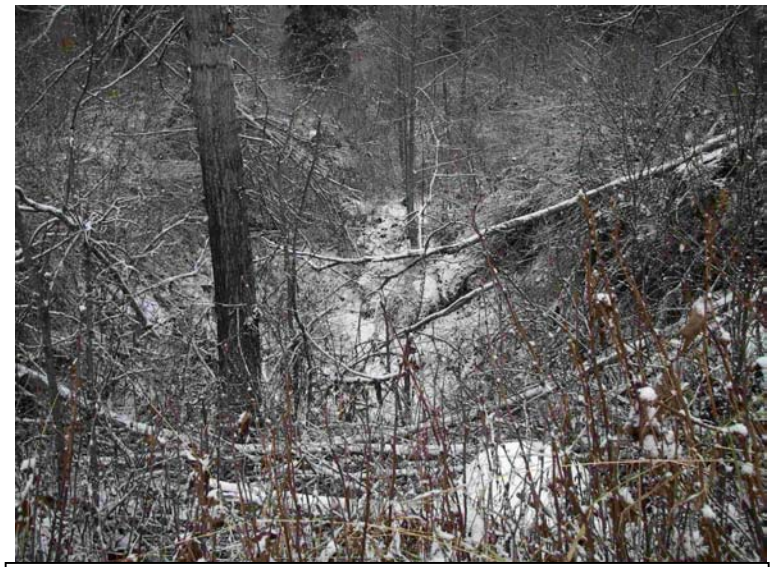


Photo 4 – Eroded trib. Channel below 1000 mm culvert

Photo 5 – Prairie/Deactivated HoChiMin Trail and regen.

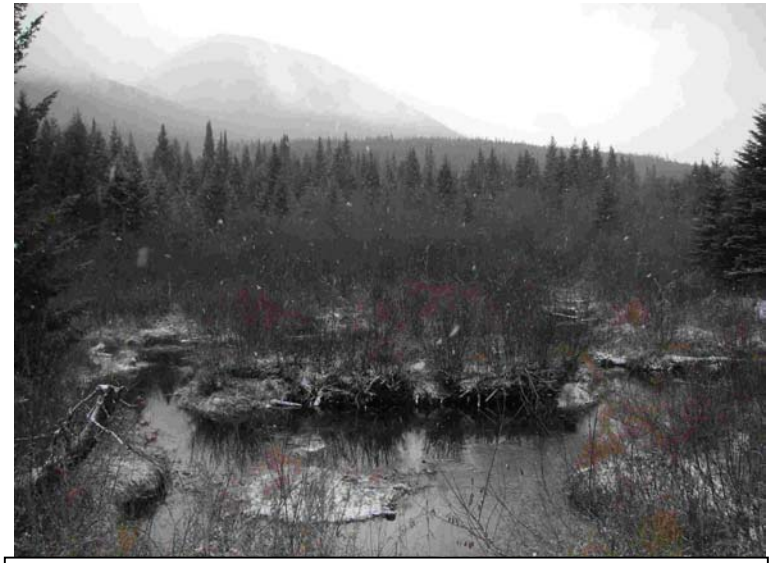


Photo 6 – Prairie Creek upstream from 100 Road.

Photo 7 – Sawley Creek/2.5 km up Camp Road.

Photo 8 – Sawley Creek below 100 Road.

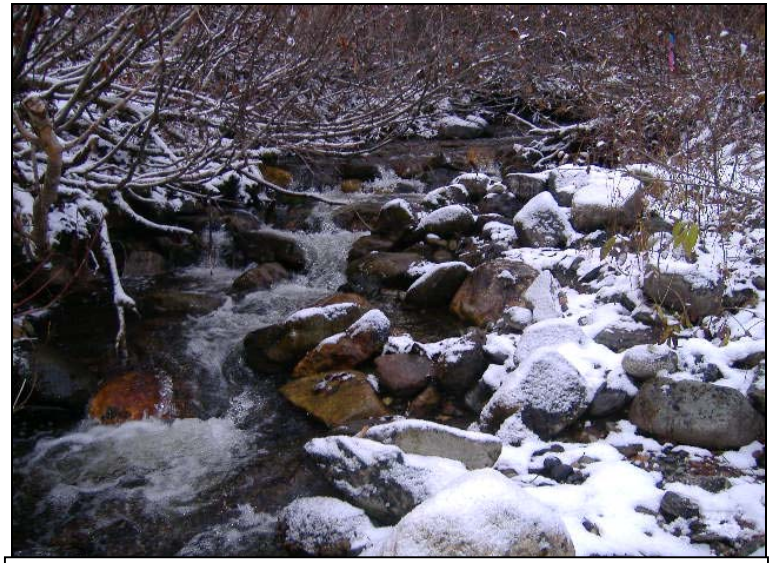


Photo 9 – Sawley Creek ~120 m above the 100 Road.

Photo 10 – Sawley Creek at the Horsefly River.

Photo 11 – Harvie Creek at the 900 Road.

Photo 12 – Harvie Creek below the 900 Road.

Photo 13 – Harvie Creek/wood stave culvert at the 100

Photo 14 – Harvie Creek~100 m above the 100 Road.

Photo 15 – Hawkley Creek above the MacKay Mainline.

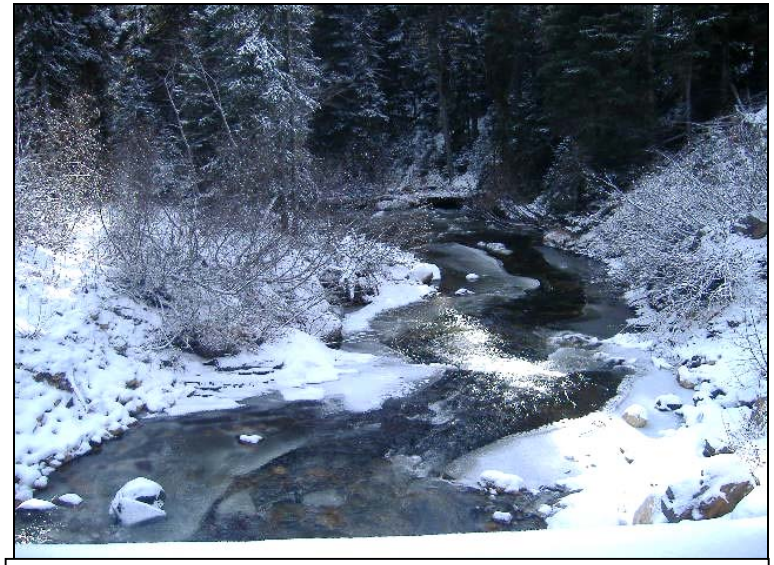


Photo 16 – Hawkley Creek below the MacKay Mainline.

Photo 17 – MacKay River below the MacKay Mainline at 7km.

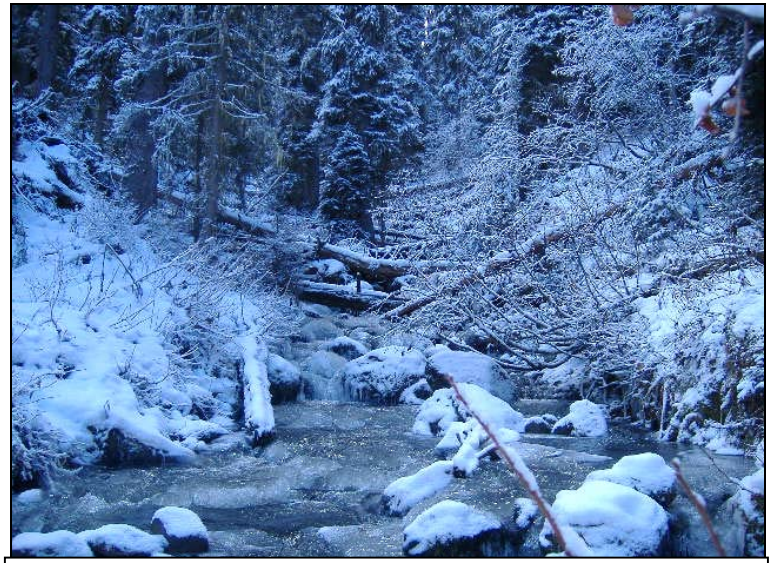


Photo 18 – MacKay River un-named trib. draining north.

Photo 19 – Whiskey Bridge area, upper deactivated crossing.

Photo 20 – Whiskey Bridge area, trib. with 36" culvert.

Photo 21 – Whiskey Br. area, trib. with 18" & 24" culverts.

Photo 22 – 18" and 24" culverts outlets.

Photo 23 – Camp Road crossing on 143 km tributary.

Photo 24 – Deactivated spur road on 141 km tributary.

Photo 25 –153.25 km tributary ~100m above 100 Road.

Photo 26 –143 km tributary ~100m above 100 Road.

Photo 27 –141 km tributary above 100 Road.

Photo 28 –141 km tributary above spur road.

Photo 29 – Sucker Creek area, typical road.

Photo 30 – Sucker Creek area, typical new road.

Photo 31 – Upper Sucker Creek.

Photo 32 – Lower Sucker Creek.

Photo 33 – Patenaude Creek at the 100 Road.

Photo 34 – Wilmot Creek culverts at 100 Road.

Photo 35 – Wilmot Creek above the 100 Road.

Photo 36 – Doreen Creek lower road conditions.

Photo 37 – Doreen Creek lower deactivated roads.

Photo 38 – Doreen Creek at lower road crossing.

Photo 39 – Doreen Creek at lower road crossing.

Photo 40 – McKinley Creek old spur roads.

Photo 41 – McKinley Creek tributary channel.

Photo 42 – McKinley Creek tributary, old bank failure.

Photo 43 – Barker Creek partially blocked culvert at 100 Rd.

Photo 44 – Barker Creek ~100m above the 100 Road.