Interior Watershed Assessment Update for Eight Watersheds Tributary to the Horsefly River

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December, 2002

ACKNOWLEDGEMENTS

I would like to thank several staff members of *P. Beaudry and Associates Ltd*. who helped with the data processing, the field work and the reporting: Mr. Bill Floyd, F.I.T., Ms. Becky L'Hirondelle, Biologist and Ms. Leisbet Beaudry, R.P.F. I would also like to express my sincere gratitude to Mr. E. Schmid from Weldwood and Mr. J. Liscomb from Lignum who took a lead role on behalf of the forest licencees throughout this watershed assessment process. Finally, I would like to thank all of the members of the Watershed Advisory Committee (WAC) for their diligence in reviewing the various drafts of the WAP document and their continuous commitment throughout the assessment process

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1.0 INTRODUCTION

In a letter dated December 20, 2000, the District Manager (DM) of the Horsefly Forest District provided instructions to all licensees operating in the Horsefly watershed to update the Interior Watershed Assessment Procedure (IWAP) for eight (8) tributary watersheds of the Horsefly River (Figure 1). Section 14(1) of the Operational Planning Regulation calls for an IWAP to be redone every three years. The initial eight IWAPs were submitted to the DM on April 30, 1998 and consequently an update was required by the spring of 2001. It was identified in the letter that the update is the responsibility of all licensees operating in the watershed, including SBFEP. The consortium of licencees was directed to hire a qualified hydrologist to complete the eight assessments. The "consortium" includes: 1) MoF Small Business Program, 2) Lignum Ltd., 3) Welwood of Canada Ltd., 4) Riverside Forest Products Ltd., 5) West Fraser Mils Ltd., 6) Ainsworth Lumber Co. Ltd.

In June of 2001, the consortium retained the services of *P. Beaudry and Associates Ltd.* to complete the eight IWAP updates. An initial draft of the updates was submitted to the Watershed Advisory Committee in October of 2001. For the initial phase of the IWAP updates no field work or air-photo interpretations were proposed or undertaken. The initial update focused predominantly on the re-calculation of hazard indices (e.g. ECA and road density), the review of recent watershed related studies and the assessment of risk. I felt that this would be the most efficient way to initiate the update. The consortium of licensees agreed that, depending on recommendations provided in the initial report, helicopter or ground based field assessments may be initiated at a later date to complete the IWAP updates for specific high risk areas.

The Watershed Advisory Committee met in the fall of 2001 to discuss the initial draft update and collectively they identified numerous shortcomings of the update procedure and the report submitted in October 2001. One of the biggest problems identified was the lack of effective communications between the consortium of licensees, the watershed advisory committee and P. Beaudry and Associates Ltd.. The IWAP document (Government of BC, 1999) does not provide clear direction about the required content of an IWAP update and unfortunately the Watershed Advisory Committee never formally met prior to the initiation of the update to agree on the required content. In the spring of 2002 the Watershed Advisory Committee met several times and agreed on the required content of the IWAP update for the eight watersheds that are tributary to the Horsefly River.

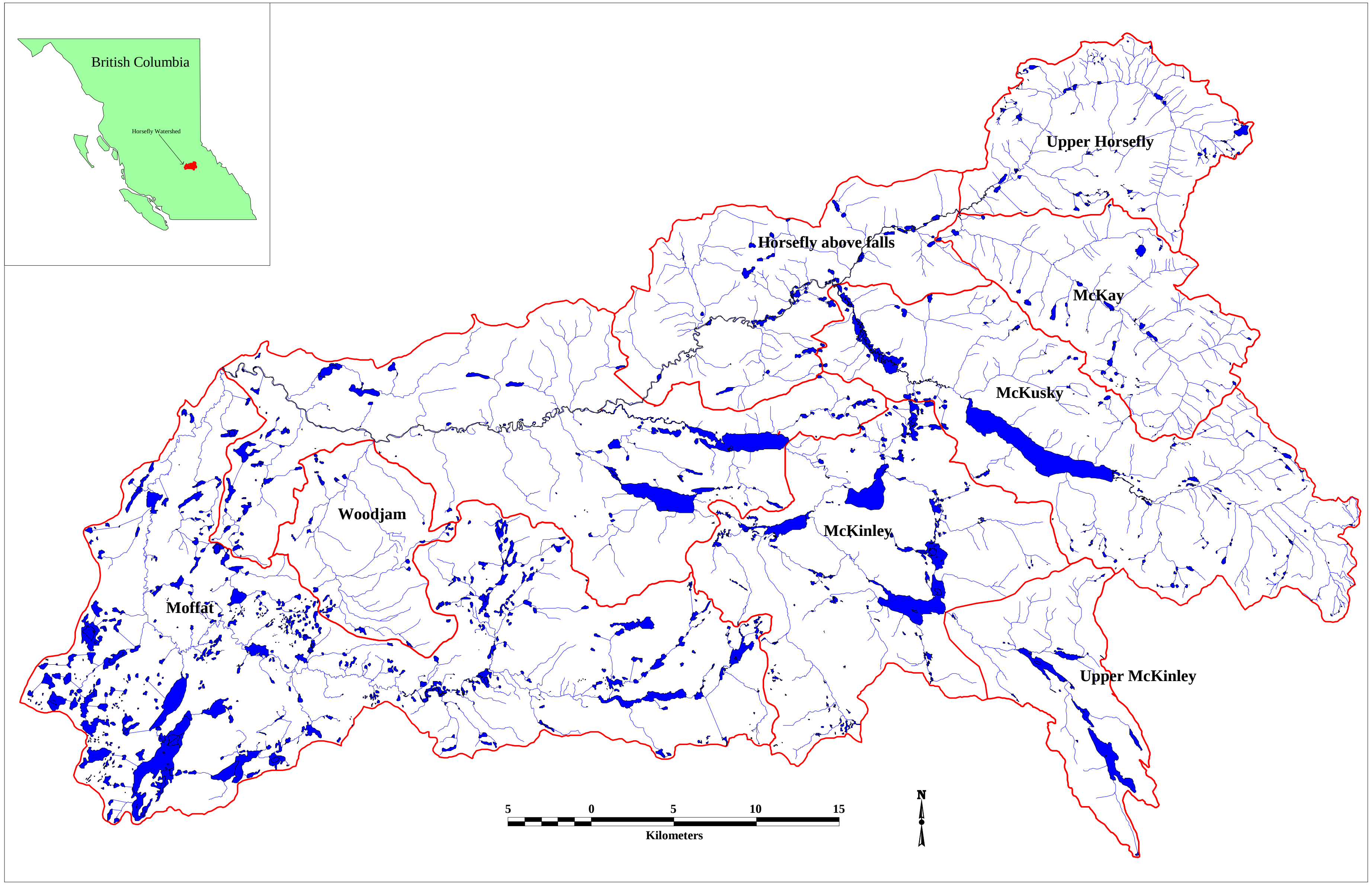

Figure 1. Map of the eight watersheds where IWAPs are required.

The final agreement amongst the members of the Watershed Advisory Committee was that the IWAP updates required pretty well all of the inventories and analysis required for a full watershed assessment as identified in the second edition of the Watershed Assessment Guidebook (Government of BC, 1999). This was primarily because the initial IWAPs were done according to the first edition of the guidebook and It was felt that new IWAP should be completed as per the guidelines of the second edition.

The eight watershed assessments presented in this report can be considered as full assessments and they follow closely the guidelines and the intent of the 1999 IWAP procedure. This report presents the inventories, field assessments and analysis that were completed in 2002 for each of the eight watersheds that required IWAP updates. This satisfies requirements for the six fundamental WAP components (see page 2 of guidebook). :

1. Descriptions of watershed characteristics, stream networks and provision of hydrographs where available.

2. Calculations of all GIS based indicators such as Equivalent Clearcut Area (ECA), Peak flow Index (PFI), road densities, extent of harvesting activities on unstable slopes, etc.

3. Review of recent air-photos to identify the extent of riparian harvesting, and large sediment sources such as landslides and massive streambank erosion.

4. Overview helicopter flight to: A) classify stream reaches and assess channel stability, B) ground-truth and update the inventory of large sediment sources, and C) become more familiar with landforms, topography and surficial geology of the watersheds.

5. Two weeks of field assessments to identify, classify and evaluate the smaller sources of sediment that are directly connected to stream channels (i.e. surface erosion hazard).

6. Summarize the GIS and field inventory data and provide these in a tabular format (i.e. watershed report card).

7. Develop a hazard classification and designate hazard classes for each of the following IWAP indicators: A) peak flow hazard, B) riparian hazard, C) surface erosion hazard, D) hazard associated with large sediment sources and E) hazard associated with accelerated mass wasting.

8. Analyse the data and provide recommendations to the licensees relative to the forest development plan (FDP). I provided recommendations for both the landscape (or watershed) scale and the more specific site level.

The Watershed Advisory Committee agreed that the objective of this IWAP is as stated in the WAP guidebook i.e., “ to provide watershed-level recommendations for forest development plans, based on an assessment of the potential for cumulative hydrological effects from past and proposed forest harvesting and road building”

The Cariboo-Chilcotin Land Use Plan (CCLUP) provides the following objectives relative to protection of the Fisheries Resources: 1) ECA should be utilized as a coarse filter to assist in the identification of watersheds with risks to fisheries and which therefore require further assessment, restoration, and mitigation. 2) Risks to fisheries targets are to be mitigated through long term forest development planning and FPC requirements including riparian management, road construction practices, controls on the rate of harvest, and watershed assessment procedures. 3) Other mitigative processes (including constraints to achieving other targets) may be required based on the results of watershed assessments (http://www.luco.gov.bc.ca/regional/carichil/6.htm#d).

2.0 METHODOLOGY

This section of the report provides an explanation of the methodology used to collect and analyse the watershed information for each of the indicators for each of the eight watersheds.

2.1 Watershed and Stream Characteristics

Most of the watershed and stream characteristics were measured from BC Environment 1:20,000 digital TRIM maps. The TRIM maps were analysed with *MapInfo Professional* and *Vertical Mapper* GIS computer software. The watershed boundaries for each of the eight sub-basins were digitized by *P. Beaudry and Associates Ltd.* (PBA) based on the TRIM contours and stream network. The stream characteristics were defined by using a combination of digital air-photos (ortho-photos), helicopter reconnaissance flight and ground based assessment.

2.2 Harvesting and Land-use History

The harvesting and natural disturbance history, in each of the analysed watersheds, was obtained from digital Forest Cover maps (Ministry of Forest FC1 and FIP files) provided by Inland Timber Management Ltd (ITM) of Williams Lake. The Equivalent Clearcut Area (ECA) was calculated from the information provided in the FIP files. The information about the level of planned harvest in the next five years was obtained from the digital forest development plan provided by ITM. The proposed blocks included category “A”, “P” and “I” blocks. All of these blocks were considered as one category and were all grouped under the classification “proposed blocks”. It was agreed upon by the licensees that no separate analysis was required to evaluate individually the different categories of proposed blocks, i.e. Category “A”, “P” and “I”. This results in conservative ECA numbers because not all blocks will be approved and harvested. However, it was decided that this would be consistent with the methodology of the previous IWAP. In many cases the “Wildlife Tree Patches” and the “Partial Cutting” blocks were considered simply as clear-cuts. This is the way the digital cut-block data were provided and consequently there was no way of accounting for these practices and the possible ECA reductions. This also contributes to slightly inflated ECA values (i.e. conservative estimates).

The location of the roads was obtained from the digital Forest Cover maps and development plans provided to ITM by the licensees. The distribution of slope gradients within the watershed and the H_{60} for each watershed was calculated using digital elevation modelling software (i.e. *Vertical Mapper*).

The equivalent clearcut area (ECA) is defined as the area that has been disturbed (i.e. logging, wildfire, right of ways), with a reduction factor to account for the hydrological recovery due to forest regeneration. The watershed assessment document (BC Government 1999) provides a hydrological recovery table which indicates a recovery factor for different heights of a forest. For example, a stand that has a height between 5 and 7 metres, has a recovery factor of 50% and a nine metre stand has a recovery factor of 90%. The value for the stand height was obtained from the forest cover inventory database (i.e. FIP files).

The “H_{60}” is the elevation in a watershed (expressed in metres above m.s.l.) above which there is 60% of the watershed area. Forest harvesting above the H_{60} line is considered to have a greater effect on peak flows (compared to below the H_{60}) because this is considered the “peak flow generating area” for mountainous terrain where the hydrograph is dominated by snowmelt. The “peak flow index” is calculated to provide a numeric value that represents the effect of the ECA that is above the H_{60} line. To calculate this index the ECAs for each of the cutblocks (or proportions of cutblocks) that are located above the H_{60} line are weighted by a factor of 1.5. For example, if all of the cutblocks were located above the H_{60} and the ECA was 30%, then the peak flow index would be 45%. If all of the cutblocks were located below the H_{60} then the ECA value and the peak flow index (PFI) would be identical. The ECA and PFI calculations include all forest harvesting activities, agricultural activities and wildfires. This is why the ECA values for a watershed can be significantly higher than the value for “the total amount harvested” which is also provided in each report

The stream density, road density and stream crossing density are indices that relate to both the potential for peak flow increases and increases in the supply of sediment to the stream system. A high value does not necessarily mean that there is a surface erosion problem in the watershed, but it does indicate that the potential for problems is present and that a field survey may be required. These values were calculated from the road information provided by ITM, using the GIS software. The road and stream crossing density information was sorted into three categories to better evaluate the potential impacts. The categories included: 1) existing roads and crossings, 2) proposed roads and crossings and 3) de-activated roads and crossings which includes the category "proposed de-activation" as provided by the licensees.

The values for ECA, PFI, stream density, road density and stream crossing density are provided in Tables 2 and 3 for each of the watershed assessment reports.

2.3 Extent of Riparian Removal

The extent of riparian removal in each of the watersheds was determined from digital air photographs (orthophotos). The mapping included all disturbed streams sections in the watershed, both the mainstem and all tributaries. The mapped stream sections included all areas where the riparian forest was removed completely to the stream edge, either one side or both. The mapping including all forms of land-use related riparian removal, e.g. agriculture, forest harvesting, mining or right of ways. The mapping was done using *Mapinfo* GIS software and an associated database was created providing descriptive information for each of the mapped sections of riparian removal. The database includes the following information:

1. ID of the disturbed riparian area
2. Channel width (1= >20 metres wide, 2=5 to 20 metres, 3= 1.5 to 5 metres and 4 = less tham 1.5 metres)
3. Stream type (1= mainstem, 2=tributary to mainstem, 3= tributary to tributary)
4. One or two sided riparian removal (1= removal on only one side, 2= removal on both sides)
5. Length of the riparian disturbance
6. Type of landuse that created the disturbance (1= clearcut, 2=agriculture, 3=road or other right of way)

The complete database for the disturbed riparian areas is provided in Appendix 1 of each of the watershed assessment reports. The disturbed riparian areas are mapped and identified on the maps provided in the report.

Channel width is an estimate of the width of the stream channel based on orthophotos. Since it is done from ortho-photos the estimate may not be very accurate (compared to field measurement). The objective here was to provide an indication of the extent of riparian removal on small and intermediate sized streams vs. the large streams.

2.4 Survey of Large Sediment Sources

Large sediment sources that were identified and mapped for this project include: A) landslides and debris flows larger than 0.05 ha, B) torrented stream channels, C) gullies or deeply incised stream channels with evidence of sidewall or channel failure, or D) large ravelling streambank terraces. The sediment sources were identified on orthophotos and plotted on TRIM base maps using *Mapinfo* GIS software. A database was created to provide descriptive information about each of the plotted sediment sources. The database includes the following information:

1. ID of sediment source
2. Type (1= falls, 2=creep, 3=slumps and earth flows, 4= debris avalanches, 5=debris torrent, 6= unknown, 7= torrented channel or accelerated bank erosion, 8= snow avalanche, 9= mine excavation)
3. Probable cause (1= road or trail, 2= clearcut, 3=open slope-natural, 4= eroding bank – natural, 5= Gully erosion – natural, 6= Burn, 7=Placer mining, 8= Alpine – natural, 9= riparian harvesting, 10 = agriculture, 11= open pit mine)
4. Deliverability (1= source is far removed from stream, 2= source is indirectly connected to stream, 3= source is directly connected to stream channel).
5. Revegetation (1= low, 2= moderate, 3= high, 4= can't determine)
6. Activity level (1= low delivery, 2= moderate delivery, 3= high delivery, 4= can't determine)

The complete database for the large sediment sources is provided in Appendix 2 of each of the watershed assessment reports. The large sediment sources are mapped and identified on the maps provided in the report.

2.5 Sediment Hazards from Roads (i.e. Surface Erosion Hazard)

The inventory of sources of road related surface erosion is a field-based exercise. This cannot be done with the use of maps or airphotos. Erosion from roads can include one or several of the following sources: a) road running surface, b) eroding ditch, c) eroding cutbank, d) eroding fill and e) road sections encroaching on stream channel. For the purposes of this inventory, only sediment sources that are connected to stream channels and have the potential to deliver sediment to a stream are relevant (WAP guidebook page 37). To complete the WAP inventory of road related sediment hazards, as required y the guidebook, we used a methodology that I developed for Canadian Forest Products in 2001 called the Stream Crossing Quality Index (SCQI). This procedure focuses on erosion and sediment delivery at stream crossings. It is my opinion that almost all of the road related surface erosion that reaches a water course does so at a stream crossing (especially areas with low to moderate topography). Thus a survey that focuses on stream crossings should do a good job in characterising road related surface erosion problems.

The SCQI procedure is based on the concept of the stream crossing density index used in the watershed assessment procedure. In the WAP each stream crossing that is identified on a map is counted and divided by the watershed area which produces the index of number of crossing per square kilometer. Of course not all of these crossings produce and deliver sediment. The SCQI is a field based assessment that actually evaluates erosion and sediment delivery problems for each stream crossing. The SCQI procedure scores each crossing on a scale of 0 to 1. A score of 0 means that no sediment is being delivered to the stream from the crossing, while a score of 1.0 means that there are significant sediment delivery problems. After each crossing is assessed, the scores can be summed up to produce a total watershed score. The score can then be divided by the watershed area to produce an "equivalent stream crossing density index" for the watershed. This process is analogous to the ECA concept. If all the stream crossings receive a score of one, then the equivalent stream crossing density will equal the traditional crossing density calculated on the maps (this of course assumes that the crossings indicated on a map are the same as those in the field). If all of the scores are zero then the "equivalent" density will equal 0 crossings/km^2.

To obtain an accurate "equivalent stream crossing density" for a watershed it is necessary to inventory 100% of the stream crossings in the watershed. However, for the watershed assessment procedure a 100% sampling is not a requirement. The guidebooks states "It is not necessary to field survey all roads-only portions of the stream network- to confirm the sediment hazard". Unfortunately, the guidebook does not provide any direction or suggestions relative to an appropriate survey intensity. For this project, it was agreed with the Watershed Advisory Committee that a survey intensity of about 30% of stream crossings identified on TRIM maps would be adequate. We completed this survey between July 15 and July 27, 2002. The actual intensity of the survey was about 50% of stream crossing identified on TRIM maps.

Each crossing that was surveyed received a score between 0.0 and 1.0. We have defined four "water quality concern ratings (WQCR)" to cover the range of scores as follows:
SCQI score less than 0.02= WQCR of "None"
SCQI score between 0.02 and 0.40= WQCR of "Low"
SCQI score between 0.41 and 0.80 = WQCR of "Medium"
SCQI score greater than 0.80 = WQCR of "High"

Since we did not have a 100% sampling of stream crossings in each watershed, we pro-rated the total number of crossing identified on the TRIM maps by the percentage of crossings that we surveyed in each category (None, L, M or H). These were then compiled to provide the "equivalent" stream crossing density for the watershed. An example of this calculation is provided in the table below for a watershed that has a total of 100 crossings identified on TRIM maps and 50 crossings were sampled (size of watershed = 25 km^2).

Table 1. Example of equivalent stream crossing calculations for Horsefly assessment

WQCR	Stream crossings sampled in each category (total n=50)		Pro-rated number of crossings in each category (total = 100 crossings on TRIM)	Median SCQI score for each WQCR	"equivalent" number of stream crossings
	number	%			
None	15	30	30%X100=30	0	30 X 0 = 0
Low	20	40	40%X100=40	0.2	40 X 0.2 = 8
Medium	10	20	20%X100=20	0.6	20 X 0.6 = 12
High	5	10	10%X100=10	0.9	10 X 0.9 = 9
"equivalent" number of stream crossings for watershed =					29
"equivalent" stream crossing density for watershed =					1.16

Each of the stream crossings surveyed was plotted on the watershed map and identified with a color coded star representing it's WQCR (blue = none, green = low, yellow= medium and red=high). The database containing all of the information associated with each survey point is provided in Appendix 3 of each watershed report. The following information is provided in this database:

1. Watershed name
2. Crossing ID
3. Easting
4. Northing
5. Structure type
6. Size of culvert
7. SCQI score
8. Water Quality Concern Rating
9. Stream width class
10. Stream gradient class

The stream width class used in this section is a measure of the bank full width at the stream crossing (measured in the field). The stream width class has one additional class, compared to the channel width used in the riparian assessment (i.e. less than 0.5 m in width). I wanted to identify the very small streams (i.e. less than 0.5m in width) in the field in a class of their own, which cannot be done on the ortho-photos when doing the riparian assessment.

The SCQI methodology is described in detail in Appendix A. This appendix also provides an example of the field data sheets and all of the data collected during the field survey. Definitions for all of the data entry fields and for the database are provided in this Appendix.

The SCQI methodology is a snapshot qualitative evaluation of the potential for eroded material to be delivered to the stream at a road crossing. The evaluation system searches for and identifies the extent of erosion from cutbanks, road ditches and road running surfaces and the potential for delivery of the eroded material to the stream. If there is good drainage, erosion and sediment control (DESC) at the site, then the evaluation is pretty well independent of when the survey was done. This is simply because the potential for sediment to get to the stream would be low no matter when it is evaluated. If there are long, bare ditches that flow directly into a stream, then the potential for sediment delivery would be very high and this would be identified as such no matter when the survey was done. The SCQI was designed as a method that would generally be independent of when the survey was completed. Of course a very large rainstorm may cause extensive erosion and change the results of the assessment a little bit, but I think that it would not significantly change the score because if there was good DESC at the site than the large rainstorm would not effect that.

2.6 Land-use Activities on Unstable Terrain

One of the WAP indicators required for the watershed report card is “length of road on unstable slopes”. This information is used to help define the hazard for accelerated mass wasting. The guidebook suggests that the measurement of this indicator should be based on the length of road on terrain stability class 4 or 5, for detailed terrain stability maps, or classes P (potentially unstable) or U (Unstable) for reconnaissance maps. For this report we used detailed maps and reconnaissance maps wherever they were available. However, there has not been any significant terrain stability mapping for most of the watersheds in the study area, simply because the relatively gentle terrain does not justify it. For areas where terrain mapping was not available we defined unstable terrain as slopes greater than 60%.

I used a digital elevation model built from the 1:20,000 TRIM elevation points to define the 60% slopes. This of course is not as accurate as a site map that could be constructed from 1:5,000 scale information with contour intervals at 5m. However, the use of the 1:20,000 TRIM information meets with the intent and the requirements of the IWAP guidebook. The 1:20,000 TRIM information is usually not accurate enough to identify very short sections of steep slopes such a steep streambanks or valley walls of incised streams or gullys.

Section 5.0 of each of the watershed reports presents a summary of the extent of land-use activities on unstable terrain. The summaries also indicate how “unstable terrain” was determined for that particular watershed. There is no significant amount of activity (either roads or cutblocks) on unstable terrain in any of the eight watersheds assessed for this project.

2.7 Stream Channel Conditions.

The lower mainstem reaches of all eight watersheds were assessed for disturbance levels and indicators of channel instability. This was done by using a combination of air-photo review, helicopter reconnaissance (June 24 and 25, 2002) and reference to past channel assessments completed within the watershed. (Chew 1998, Dobson Engineering 1996). I did not complete a historical analysis of the air-photos because I felt that the information provided by the other sources was enough to assess channel disturbances. In the Moffat and Woodjam watersheds the disturbance caused by extensive riparian agriculture is very obvious and has been identified in numerous previous reports. The lower mainstem reaches of all of the other watersheds are generally very stable with the exception of a few localized areas.

A summary of the extent of disturbed channel length by reach is provided in Section 7 of each watershed report. Each disturbed section is plotted and identified on the maps. The accompanying database is provided in Appendix 4 of each watershed report. The following information is provided in the accompanying database:

1. Disturbance ID
2. Length disturbed
3. Instability level (Low, Moderate or High)
4. Source of the disturbance (1= clearcut, 2=agriculture, 3=roads, 4=unclear/unknown, 5=natural).
5. Reach ID where the disturbance occurs.

As per the directions in Appendix 4 of the IWAP (second edition), the following steps were taken to complete the assessment of channel stability:

1) The mainstem stream channel and major tributaries were broken down into reaches and identified on maps.
2) The major characteristics of the stream reach were identified (i.e. width, length and slope)
3) We identified the extent of riparian removal (i.e. riparian disturbance) along the length of each reach.
4) We identified the number, location and types of large sediment sources that could be contributing coarse sediments to the stream reach (i.e. landslide disturbance). This exercise also identified the extent of logging vs. natural sources.
5) We identified on the aerial photographs (ortho-photos) reaches or sections of reaches that appeared to be disturbed or "unstable". This was done considering disturbance indicators such as a)extent of riparian removal, b) extent of land-use related large sediment sources, c) significant changes in width and channel pattern in disturbed sections (compared to undisturbed sections), and d) significant changes in sediment accumulations and patterns in disturbed sections (compared to undisturbed sections).
6) The indicators of channel disturbance were field-checked during the helicopter overview flight. Some of the disturbance levels were changed as a result of the overview flight.
7) The "channel state" or overall level of reach disturbance, based on the disturbance indicators, and my professional judgement for that reach were identified and provided in each of the watershed reports (Table 7.1). The disturbance classes ranged from "undisturbed" through "Low" disturbance, "Moderate" disturbance,

and "severe" disturbance. This classification is as suggested in Appendix 4 of the IWAP guidebook.

Based on the results of previous CAP assessments, the obvious disturbance indicators in some of the watersheds (and the absence of any in other watersheds) and my professional judgement, I did not feel that a review of the historical air-photographs was necessary to identify channel disturbance. It is my opinion that Moffat and Woodjam are obviously disturbed, while the 6 other watersheds show indications of only localized minor or moderate disturbance in the lower reaches of the mainstems (based on extent of riparian logging, large sediment sources, ECA levels, and channel disturbance indicators).

3.0 HAZARD ASSESSMENTS

The WAP guidebook provides the following directive: "The hydrologist will use the report card, together with the field assessment maps, to develop hazard rating for peak flow, sediment sources, riparian function and channel stability. He or she will then use these ratings in making specific recommendations for the forest development plan (FDP)" (Government of BC, 1999). This WAP requirement has been met and I have developed hazard ratings for each of the eight watersheds and 5 sub-basins included in this project. Table 2 summarizes these hazard ratings. The hazard ratings were determined by using the descriptive data collected for each watershed, which are presented in each individual watershed report. An explanation of how the hazards were determined in provided in sections 3.1 to 3.5 of this report. Note that many of the hazard ratings were adapted from the information provided in the first edition of the watershed assessment guidebook.

Table 2. Summary of hazard ratings for 8 watersheds and 5 sub-basins.

Water-shed	Hazard Ratings[2]						Generalized channel disturbance[1]
	Increases in peak-flows (Current/ Proposed)	Reduction in riparian functions	Large logging related sediment sources	Road related sediment sources (field work)	Accelerated surface erosion from GIS (Current/ proposed)	Accelerated mass wasting	
Moffat	L/M	VH	VL	M	M/M	VL	5
Woodjam	VL/M	VH	VL	M	M/H	VL	4
McKinley above Lake	L/M	L	H	H	M/M	VL	3
McKinley above Bosk	VL/VL	L	VL	M	M/M	VL	1
McKuskey	VL/L	L	H	L	M/M	VL	1
MacKay at mouth	VL/VL	L	VH	H	VH/VH	L	4

Water-shed	Hazard Ratings[2]						Generalized channel disturbance[1]
	Increases in peak-flows (Current/ Proposed)	Reduction in riparian functions	Large logging related sediment sources	Road related sediment sources (field work)	Accelerated surface erosion from GIS (Current/ proposed)	Accelerated mass wasting	
Upper Horsefly	VL/VL	VL	VL	M	M/H	L	2
Horsefly above falls	L/L	M	M	H	H/VH	L	4
Sub-basins							
Upper Moffat	L/H	M	VL	L	L/M	VL	1
Molyb-denite	L/M	M	VH	M	M/M	VL	4
Upper MacKay	VL/VL	VL	VL	M	M/H	L	4
Club	VH/VH	VH	VL	N/a	VH/VH	VL	3
Doreen	H/VH	VH	VL	N/a	H/H	VL	1

[1] Note: Generalized channel disturbance codes: 1 = no disturbance identified, 2 = localized channel disturbance, 3 = minor localized land-use related disturbance, 4 = moderate land-use related channel disturbance, 5 = extensive land-use related channel disturbance.

[2] Note: Hazard ratings: VL=very low, L=low, M=moderate, H=high, VH=very high (definitions for the ratings are provided in attached tables).

3.1 Increases in Peak Flow Hazard

The hazard caused by “increases in peak flows” was determined by using the Peak Flow Index value which is presented in Section 2 of each watershed report (Table 2.1 or 2.2 or 2.2.). This value is shaded in Table 2.x of each watershed report to facilitate locating it. The other values presented in Tables 2.x are presented either because they are required by the guidebook or as additional descriptive information. The formal hazard classification (i.e Very Low to Very High) is based solely on the peak flow index because this is the value that I believe is most relevant to establishing this hazard. The development of an algorithm that includes several other values would be complex and would make it more difficult to understand where the hazard rating actually comes from. The use of the peak flow index is simple, straightforward and I believe meaningful. Table 3 provides the range of peak flow index values for the five different hazard ratings. For example if the peak flow index is between 35 and 44.9% than the hazard rating is Moderate.

Table 3. Determination of Peak flow hazard rating (from GIS)

Hazard Rating	Peak Flow Index
Very Low	Less than 25%
Low	25 to 34.9%
Moderate	35 to 44.9%
High	45 to 54.9%
Very High	Greater than 55%

3.2 Reduction in Riparian Functions Hazard

The hazard caused by a “reduction in riparian functions” was determined by using a combination of the “percent riparian removal of mainstem” and the “percent removal of all tributaries” which are presented in Section 3 of each watershed report (Table 3.1 or 3.2 or 3.2.). This value is shaded in Table 3.x of each watershed report to facilitate locating it. The other values presented in Tables 3.x are presented either because they are required by the guidebook or as additional descriptive information. The formal hazard classification (i.e Very Low to Very High) is based solely on these two variables because these are the values that I believe are most relevant to establishing this hazard. Table 4 provides the ranges of the two variables for different values for the five different hazard ratings. As an example, the hazard rating will be Moderate if less than 5% of the mainstem is logged and 12 to 20% of the tributaries are logged (see Table 4 below).

Table 4. Determination of riparian hazard rating (both condition must apply) (from airphotos and overview flight)

Hazard Rating	Scenario	% of mainstem logged	% of tributary logged
Very Low	1	Less than 5	Less than 6
Low	2	Less than 5	6-12
Moderate	3	Less than 5	12-20
High	4	Less than 5	20-30
Very High	5	Less than 5	Greater than 30
Low	6	5 to 10	Less than 6
Moderate	7	5 to 10	6-12
High	8	5 to 10	12-20
Very High	9	5 to 10	Greater than 20
Moderate	10	10 to 20	Less than 6
High	11	10 to 20	6-12
Very High	12	10 to 20	Greater than 12
High	13	20 to 30	Less than 6
Very High	14	20 to 30	Greater than 6
Very High	15	Greater than 30	Greater than 0

3.3 Large Logging Related Sediment Sources Hazard

The hazard caused by “large logging related sediment sources” was determined by using the “density of large land-use related sediment sources that are directly connected to a stream (#/km^2)” which is presented in Section 4 of each watershed report (Table 4.1 or 4.2 or 4.2.). This value is shaded in Table 4.x of each watershed report to facilitate locating it. The other values presented in Tables 4.x are presented either because they are required by the guidebook or as additional descriptive information. The formal hazard classification (i.e Very Low to Very High) is based solely on this variable because I believe that it relates well to the increase in sediment input to streams caused by land-use activities. Table 5 provides the range of values that generate one of the five different hazard ratings. For example, if the density of large[1] land-use related sediment sources that are directly connected to a stream is greater than 0.005 and less or equal to 0.01 sources/km^2 than the hazard rating is Moderate.

Table 5. Determination of hazard associated with logging related large sediment sources (from air photos and overview flight)

Hazard Rating	Density of large[1] land-use related sediment sources that are directly connected to a stream (#/km^2)
Very Low	0
Low	Greater than 0 and less or equal to 0.005
Moderate	Greater than 0.005 and less or equal to 0.01
High	Greater than 0.01 and less or equal to 0.02
Very High	Greater than 0.02

[1] Note: “Large” sediment sources are defined as being larger than 0.05 ha in area.

3.4 Hazard Associated with Road Related Sediment Sources

The hazard associated with road related sediment sources was determined in two ways: 1) by the use of GIS information only and 2) by doing field work to establish how much erosion is actually occurring on the ground. The GIS index provides a coarse evaluation of the potential for increased delivery of fine sediment to stream channels, while the field work actually assesses the extent of real problems on the ground. The GIS index can be useful to help determine if there is any potential for problems and if field work is warranted. In sections 3.4.1 and 3.4.2 of this introduction, I provide the information on how the hazard level was determined.

3.4.1 Hazard Associated with Road Related Sediment Sources (field work)

The hazard caused by “road related sediment sources” was determined on the ground by using the “Equivalent Stream Crossing Density” which is presented in Section 6 of each watershed report (Table 6.5 or 6.10). This value is shaded in Table 6.5 or 6.10 of each watershed report to facilitate locating it. The other values presented in Tables 6.x are presented either because they are required by the guidebook or as additional descriptive information about that particular hazard. The formal hazard classification (i.e. Very Low to Very High) is based on this variable because it relates well to the potential for increases in fine sediment input to streams caused by road activities. Table 6 provides the range of values that generate one of the five different hazard ratings. For example, if the equivalent stream crossing density is greater than 0.20 and less or equal to 0.29 crossings/km^2 than the hazard rating is Moderate.

Table 6. Determination of hazard associated with road related sediment sources (from SCQI field work)

Hazard Rating	Equivalent stream crossing density (xings/km^2)
Very Low	Less than 0.07
Low	0.07 – 0.19
Moderate	0.20 – 0.29
High	0.30 – 0.39
Very High	Greater than 0.39

3.4.2 Hazard Associated with Road Related Sediment Sources (GIS)

The hazard caused by “road related sediment sources” was determined on digital maps by using the “Density of active stream crossings within a watershed as mapped on TRIM (#/km^2)” which is presented in Section 2 of each watershed report (Table 2.1 or 2.2 or 2.3). This value is shaded in Table 2.x of each watershed report to facilitate locating it. The other values presented in Tables 2.x are presented either because they are required by the guidebook or as additional descriptive information about that particular hazard. The formal hazard classification (i.e. Very Low to Very High) is based on this variable because it theoretically relates to the potential for increases in fine sediment input to streams caused by road activities. Table 7 provides the range of values that generate one of the five different hazard ratings. For example, if the active stream crossing density is greater than 0.25 and less or equal to 0.4 crossings/km^2 than the hazard rating is Moderate. The term “active” relates to the information in the GIS database provided by the licensees. Any stream crossing that is located along a segment of road that is identified as “active” is considered as “active”.

Table 7. Determination of hazard associated with road related sediment sources (from GIS map based work)

Hazard Rating	Density of active[1] stream crossings within a watershed as mapped on TRIM (#/km^2)
Very Low	Less than or equal to 0.1
Low	Greater than 0.1 and less or equal to 0.25
Moderate	Greater than 0.25 and less or equal to 0.4
High	Greater than 0.4 and less or equal to 0.6
Very High	Greater than 0.6

[1] Note: "Active" road crossings are those identified as such in the GIS database provided by the forest licencees.

3.5 Hazard Associated with Accelerated Mass Wasting

The hazard caused by "Accelerated Mass Wasting" was determined on the ground by using the "density of active roads on unstable terrain within a watershed (km/km^2)" which is presented in Section 5.0 of each watershed report (Table 5.1 or 5.2 or 5.3). This value is shaded in Table 5.x of each watershed report to facilitate locating it. The other values presented in Tables 5.x are presented either because they are required by the guidebook or as additional descriptive information about that particular hazard. The formal hazard classification (i.e. Very Low to Very High) is based on this variable because it relates best to the potential for increased mass wasting caused by forestry activities. Table 8 provides the range of values that generate one of the five different hazard ratings. For example, if the "density of active roads on unstable terrain within a watershed" is greater than 0.03 and less or equal to 0.10 km/km^2 than the hazard rating is Moderate (see Table 8 below).

Table 8. Determination of hazard associated with forestry activities on unstable slopes. (from GIS)

Hazard Rating	Density of active[1] roads on unstable terrain within a watershed (km/km^2)
Very Low	Less than or equal to 0.0
Low	Greater than 0.0 and less or equal to 0.03
Moderate	Greater than 0.03 and less or equal to 0.1
High	Greater than 0.1 and less or equal to 0.3
Very High	Greater than 0.3

[1] Note: "Active" roads are those identified as such in the GIS database provided by the forest licencees.

4.0 REGIONAL PHYSIOGRAPHY AND HYDROLOGY OF THE STUDY AREA

4.1 Physiography

The Moffat and Woodjam Creek watersheds are located in the Fraser Plateau physiographic areas as described by Holland (1976). This area is characterized by flat and gently rolling country having large areas of undissected upland lying between 1200 and 1500 m in elevation. The other six watersheds are located in the Quesnel Highlands which lie on the western side of the Cariboo Mountains (Holland 1976). This area is characterized by a highly dissected plateau of moderate relief. These highlands rise gradually from an elevation of about 1500 m on the western edge to over 2000 m on the eastern edge, which become progressively more dissected.

4.2 Natural Disturbance Types

The Moffat and Woodjam watersheds are dominated by areas classified as NDT3 (Natural Disturbance Types). These areas have frequent stand initiating events (about 125 year return interval) which means that historically large fires have played an important role in the forest ecology of the area (Government of BC, 1995). The McKinley watershed is dominated by the Natural Disturbance Type #2, which is defined as having infrequent stand initiating events. Wildfires were of moderate size with a return interval of about 200 years (Government of BC, 1995). The remainder of the study area (i.e. Horsefly above the falls) is dominated by the Natural Disturbance Type #1, which is defined as ecosystems with rare stand initiating events. The disturbances in NDT3 (fires, wind and landslides) were usually small in size and occurred on an average return interval of about 300 years (Government of BC, 1995).

4.3 Hydrology

There have been four Water Survey of Canada stream guaging stations located in the study area. These are Moffat at the mouth (8KH019), McKinley Creek (8KH020), MacKay River (8KH022) and Horsefly River above McKinley Creek (8KH010). The station on Mackay River only operated between 1971 and 1985. Average daily streamflow data for the entire period of record (up to 2001) were purchased from the Water Survey of Canada. In order to get a visual representation of the streamflow regime for these watersheds, I plotted the average daily unit area discharge for the period of record for each station (Figure 2).

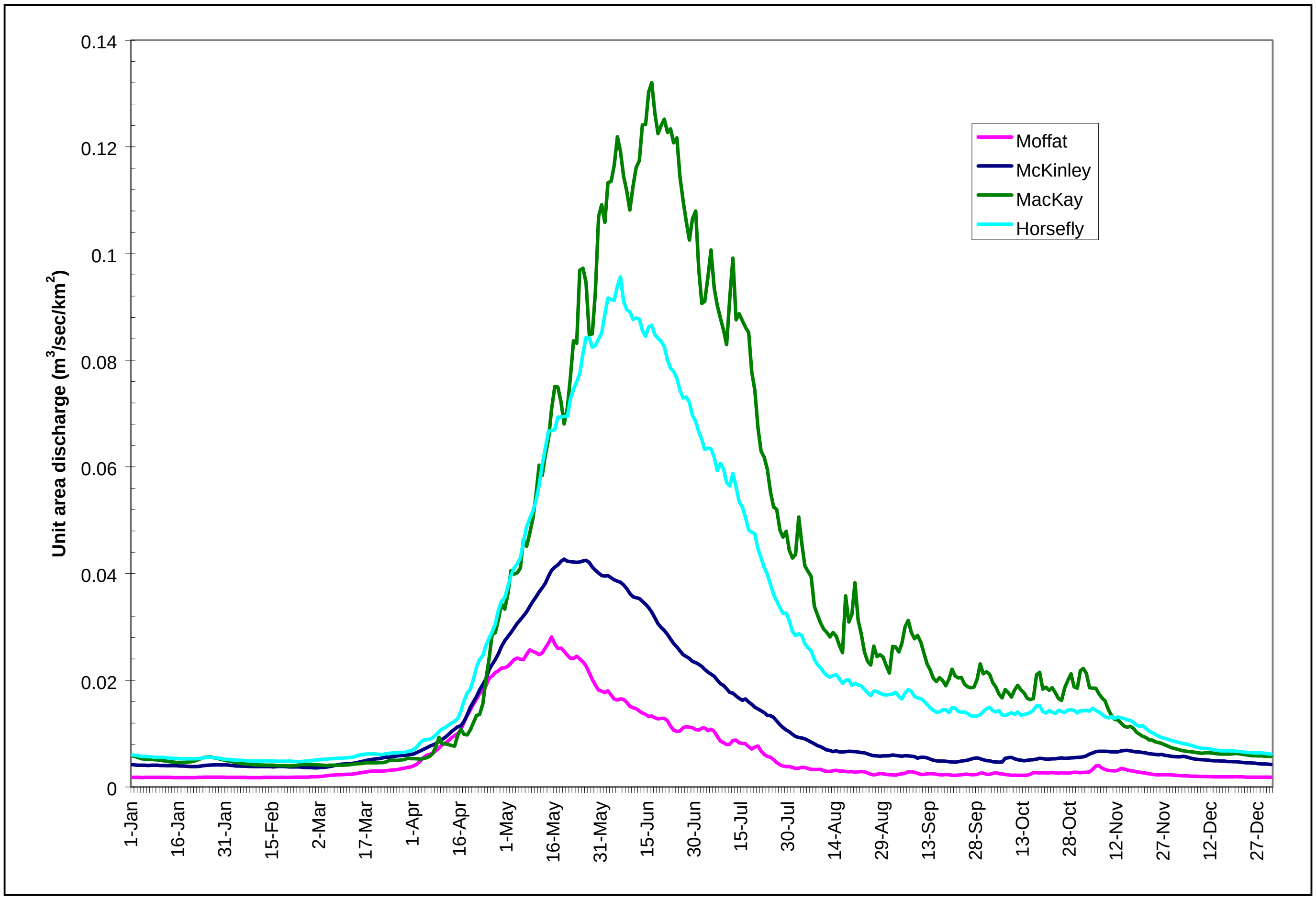

Figure 2. Mean annual unit area discharge for four guaged stations located in the study area.

The hydrology of the area is clearly dominated by the snowmelt hydrograph. On average streamflows begin to rise in mid-April and peak in early to mid-May. The watersheds that are located further to the east with higher elevations peak later (mid-June) than those located to the west (early May). For the McKinley and Moffat watersheds, low flow periods begin as early as late August , while low flows do not occur until mid-November for the watershed further east. It is interesting to note that the peak unit area discharge is about 5 times greater for the MacKay watershed compared to the Moffat watershed (Figure 2). Obviously, the climate is much wetter as you go east, which is in large part responsible for the changes in natural disturbance types and lower frequency of large stand initiating fires.

In Figures 3 to 5, I plotted the average daily streamflows for three of the gauged watersheds (average, minimum and maximum for period of record). Streamflow gauging was discontinued in the MacKay River in 1985 and consequently there are no recent records. These clearly indicate that there is a large annual variation in peak flows in each watershed . In Moffat Creek, for example, annual peak flows have ranged from 10m^3/sec to 45 m^2/sec (a difference of almost 5 fold). The trends are similar in the other watersheds.

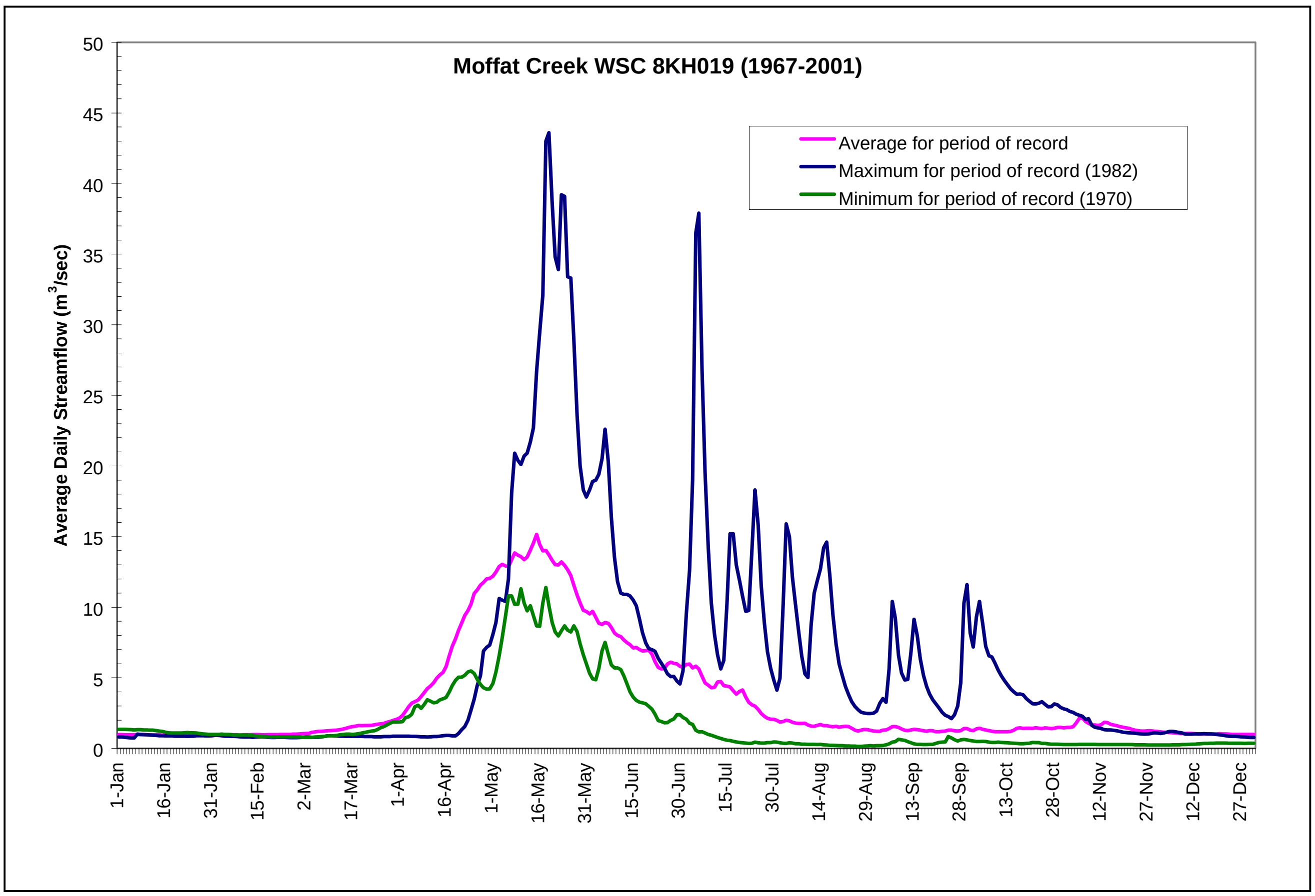

Figure 3. Average daily streamflows in Moffat Creek

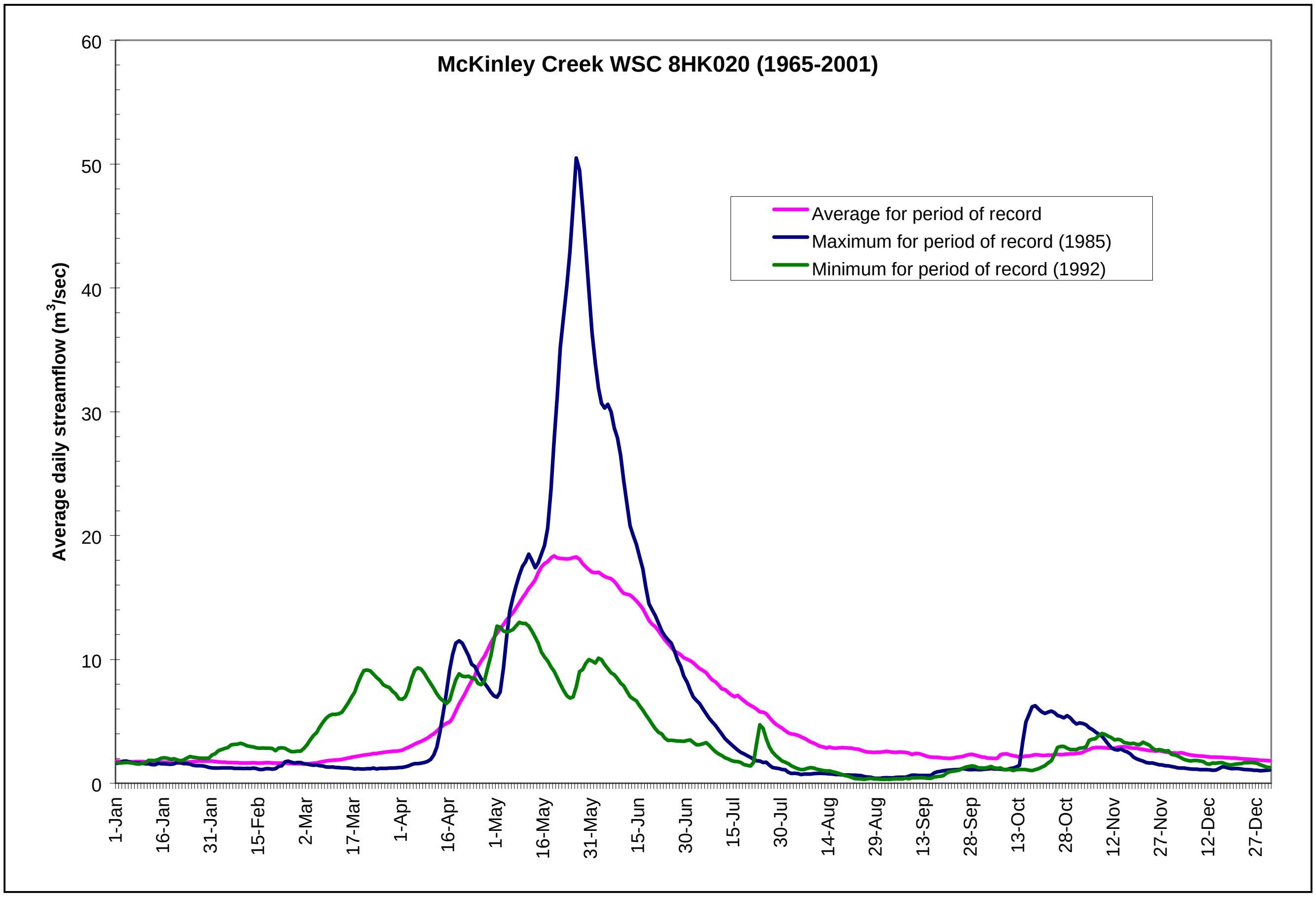

Figure 4. Average daily streamflows in McKinley Creek

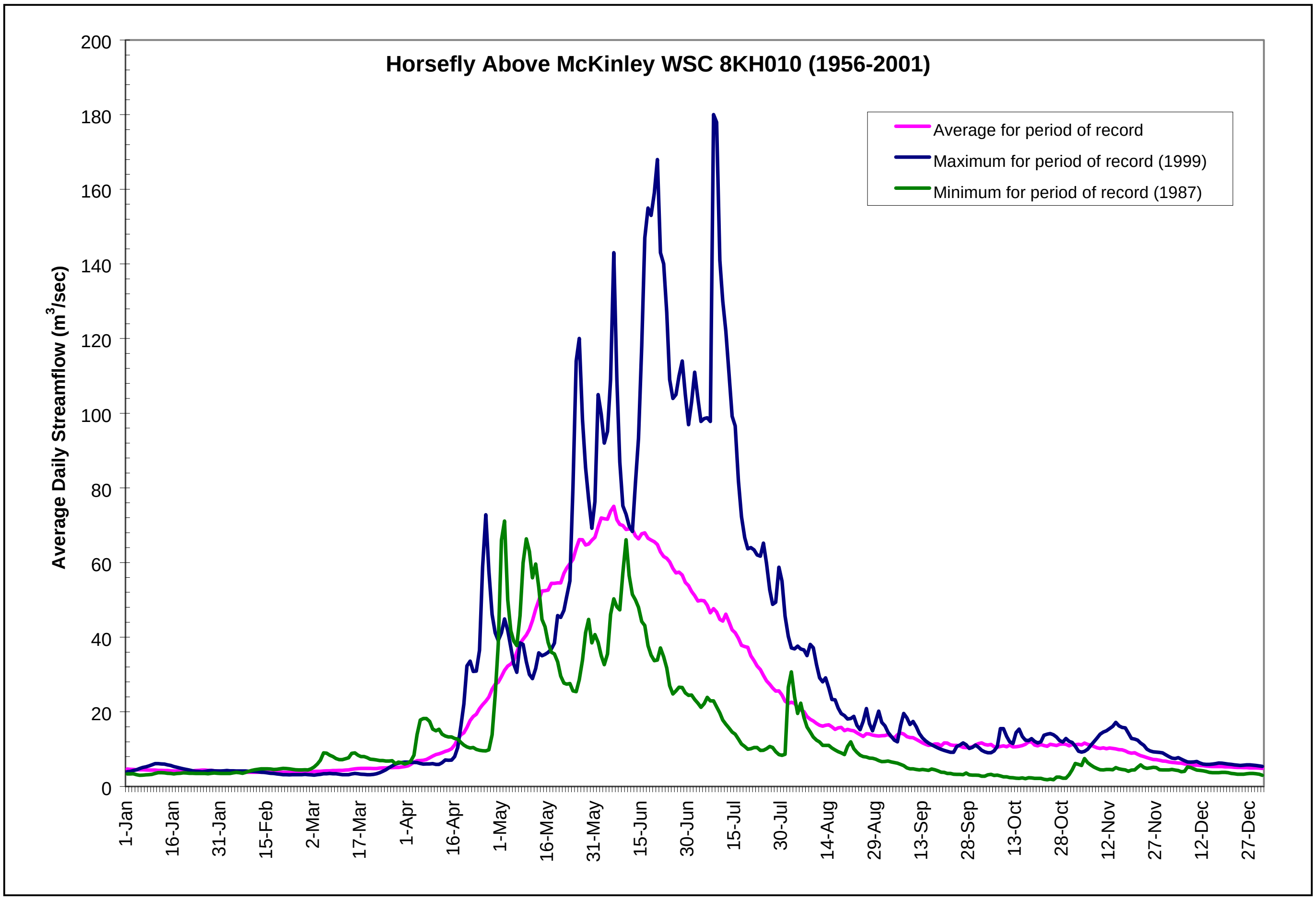

Figure 5. Average daily streamflows in the Horsefly above McKinley Creek.

5.0 CONTENTS OF WATERSHED REPORTS AND HOW TO USE THEM

Watershed assessment updates were required by the District Manager for eight individual watersheds that are tributary to the Horsefly River. This document provides the eight separate assessment reports, one for each watershed. Several of the watersheds were divided into sub-basins by the Watershed Advisory Committee. Consequently, there are four reports that also contain information about the sub-basins, although the main focus of the work remains at the watershed level. Each report is laid out in an identical fashion and includes the following sections:

1. Section 1 contains the watershed descriptive information
2. Sections 2 to 7 contain the summary of the GIS, air photo and field assessments. These are the data that form the basis of the analysis and recommendations. These sections should be considered as the “watershed report card” referred to in the WAP guidebook.

3. Section 8 is a summary of the fisheries resources present in the watershed.
4. Section 9 presents the hazard ratings for each of the WAP indicators.
5. Section 10 presents the interpretations of the data.
6. Section 11 provides ideas and recommendations that can be incorporated into the FDP.
7. Appendices 1 to 4 provide the databases for the mapped information
8. Appendix 5 provides a collection of selected photographs that represent the condition of the watershed. Some of the photographs were taken during the overview flight and others were taken during the field work.

It is important to note that each watershed report contain two very distinct components. The first one is the presentation of the data that provides a description of the condition of the watershed (or watershed health). There is a good deal of information here and it is presented in detail so that everyone can obtain the "facts" of the watershed condition. The second component is the interpretation of the data and the development of recommendations. This is a much more subjective component of the process and the data can be interpreted in several ways by different people.

I believe that, along with the hydrologist, there is an important role to be played here by the Watershed Advisory Committee and the licencees. In each report, I have provided some ideas and recommendations, but I do not think that these are to be viewed as the only possible ways to deal with the specific hazards identified for each watershed. Others in this process may have different ideas and different perspectives that I have not considered. I believe that these ideas should be brought forward to the meetings of the Watershed Advisory Committee and discussed. If they make sense they should be incorporated into the FDP process. It is very difficult for me (if not impossible) to be aware of all of the possibilities, limitations and legal challenges (technical, social and economic) that are involved in the preparation of any specific FDP. Consequently, any recommendations that I provide must be considered by the licensees in the context of the broader forest planning process and it is quite possible that different or complimentary solutions can be developed. The recommendations that I have provided are meant to be considered and implemented wherever practicable.

6.0 SUGGESTIONS FOR THE NEXT IWAP UPDATE

As per the requirements of the IWAP guidebook (page 12) I am providing the Watershed Advisory Committee with some ideas about how to deal with the next 3 year update and what it should focus on.

1. I do not think that the next **update** should focus on fulfilling all of the suggested "first time" requirements of the WAP guidebook. I believe that this process has been implemented in it's entirety at least once and that is enough.

2. Rather than collecting a plethora of data to develop broad watershed hazard ratings, I believe that the evaluation and monitoring of specific activities that create that hazard is more important. I believe that collectively we know what

practices are needed to properly manage the watershed. It is simply a matter of evaluating those practices to see if they are being adequately implemented in the field. For example, the SCQI procedure could be used to evaluate if erosion and sediment control practices around small streams is improving.

3. I think that it would be useful in three years to re-calculate a few simple indices such as ECA and PFI to evaluate how fast forest development is progressing in the watershed. This is especially important for the Moffat and Woodjam watersheds where the peak flow hazard is already elevated. I do not believe that re-doing most of the other calculations assessments completed for this report would provide any significant contribution to the next IWAP update.

4. I believe that the role of the Watershed Advisory Committee should change from one of directing a process (i.e. the WAP guidebook process) to one of reviewing, considering, discussing and agreeing on alternative management strategies to meet both the broader regional land-use plans and site specific objectives that may be raised by different agencies.

5. The objectives of the next WAP update should be clearly established by the Watershed Advisory Committee prior to the commencement of any assessment work. The requirements and the content of the update should also be clearly established. This should be done before any consultants are asked to bid on the project.

6. I think that there are three main watershed management issues in these eight watersheds. The next update should focus on these and drop the other assessment components of the IWAP. The focus should also be directed at field work rather than GIS based calculations. The three issues are as follows:

    - For the Moffat and Woodjam watersheds I believe that a rate-of cut issue is developing. It is not so much that the level of harvest is unreasonably high by itself, but that the lower reaches are so unstable due to past activities in the riparian zone. The next update could focus on evaluating the implementation of peak flow management strategies recommended in this report.

    - For many of the watersheds, road related surface erosion is currently a moderate to high hazard. The next update could focus on field evaluations of erosion and sediment control at stream crossings for those watersheds with the moderate to high hazards. I recommend that there be no more calculations of sediment hazards using GIS methods (e.g. road density, road crossing density etc.). I believe that their usefulness has a limit and that limit has been reached.

- Riparian management around small streams remains a controversial issue throughout North America. This issue is not explicitly addressed in the current WAP procedure. I believe that the next update should focus some efforts on evaluating the effectiveness of riparian management regimes adjacent to small streams.

7. I believe that the next round of watershed assessments in this area should focus on smaller sub-basins where a moderate amount of stress is perceived. I think that these assessments should focus on watersheds in the size range of about 50 to 100 km^2 .The selection of these watersheds would have to be discussed during an initial Watershed Advisory Committee meeting.

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