Peak Flows Risk Assessment for the 71 Watersheds in the 100 Mile House Forest District

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100 Mile House
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1.0 INTRODUCTION

The BC Ministry of Forests - 100 Mile House Forest District have undertaken this watershed planning process in an effort to better consider potential watershed level impacts of new harvesting proposals on associated hydrologic resources. The entire Forest District has been divided into 71 individual “watershed” planning units. There are 60 individual true watersheds and 11 residual areas. The objective of this project was to identify the potentials risks associated with increased peak flows, in each of the 71 planning units. These risk assessments will then be used as a planning tool to help in the decision making for future harvesting and Mountain Pine Beetle (MPB) salvage operations in the 100 Mile House Forest District.

1.1. Definition of Risk

Risk can be defined as the probability of harmful consequences resulting from interactions between natural or human-induced hazards and the sensitivity of a particular environment to a given hazard (or set of hazards). Risk is conventionally expressed by the relation:

Risk = Hazard * Sensitivity

where:

Hazard = a source of potential danger, and

Sensitivity = the responsiveness of a system to a particular hazard.

The objective of this watershed planning project is to provide a hydrologic risk rating for each of the individual watersheds within the 100 Mile Forest District. These risks are defined relative to the possible harmful consequences of increased peak flows that can occur as a result of extensive forest harvesting activities in a watershed. These harmful consequences could include reduction in the quality of fish habitat, damage to human habitation, and negative impacts on road infrastructure. For this project, the peak flow “**hazard**” will be defined by the extent of forest harvesting operations within the watershed (i.e. the human-induced hazard) in addition to the extent of the pine beetle infestation (i.e. the natural-induced hazard).

The “**sensitivity**” of the watersheds to increased peak flows (i.e. the hazard) will be defined by the bio-physical characteristics of each individual watershed included in this planning process. These characteristics include such variables as: 1)Rosgen stream classification type 2) general topography, 3) location and size of wetlands and lakes, 4) size and gradient of lower reaches of mainstem river, 5) morphology of lower reaches of mainstem river, 6) general stability of lower reaches of mainstem river, 7) dominant natural disturbance types within the watershed, and 8) fish species present in watershed.

The **hazards** tend to be defined by disturbances within the watershed that occur on a relatively rapid timeframe and which can have a direct or indirect influence on fish habitat, e.g. extent of MPB kill or the presence of stream crossings. In contrast, the watershed **sensitivity** is defined by variables that are inherent to the watershed and do not typically change rapidly over time, e.g. location of large lakes, watershed topography and fish species present.

Detailed descriptions of how the variables are measured and scored and how the final evaluations are made are provided in the following sections of this report. The watershed risk ranking was determined, for each watershed, by using the cross-matrix provided below (Table 1).

Table 1. Risk assessment matrix for watershed planning for 100 Mile House Forest District

Watershed Peak Flow Risk Ratings		**Hydrologically Equivalent Disturbed Areas in the Watershed (% of Watershed)**						
		<15% (None)	**15 to 25% (Very Low)**	**25 to 35% (Low)**	**35 to 45% (Moderate)**	**45 to 55% (High)**	**55 to 65% (Very High)**	**>65% (Extreme)**
Sensitivity of watershed and stream channel to peak flow increases	None	**None**	**None**	**None**	**None**	**None**	**None**	**None**
	Very Low	**None**	**Very Low**	**Very Low**	**Very Low**	**Low**	**Moderate**	**High**
	Low	**None**	**Very Low**	**Very Low**	**Low**	**Moderate**	**High**	**Very High**
	Moderate	**None**	**Low**	**Low**	**Moderate**	**High**	**Very High**	**Very High**
	High	**None**	**Low**	**Moderate**	**High**	**Very High**	**Very High**	**Extreme**
	Very High	**None**	**Moderate**	**High**	**Very High**	**Very High**	**Extreme**	**Extreme**
	Extreme	**None**	**Moderate**	**High**	**Extreme**	**Extreme**	**Extreme**	**Extreme**

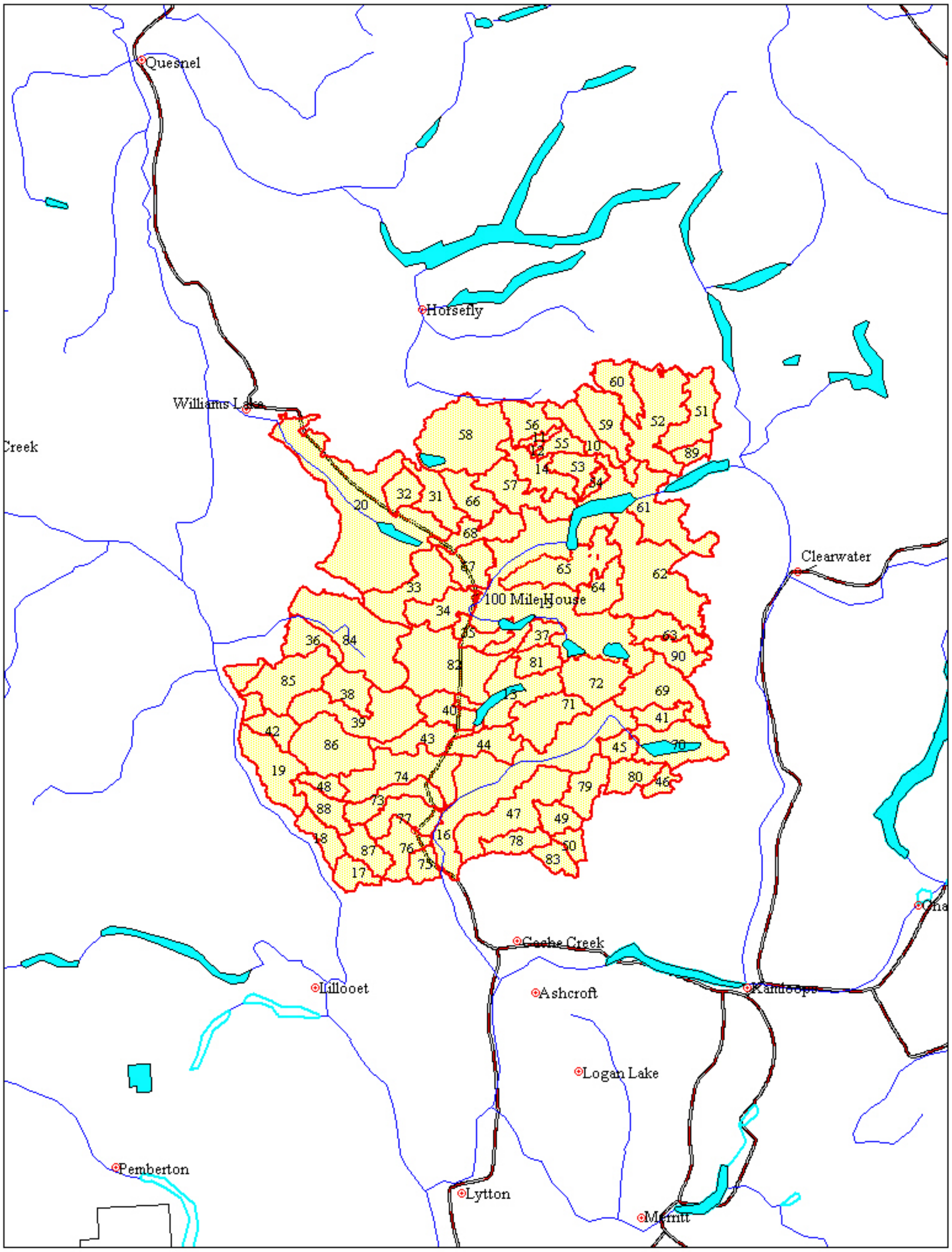


Figure 1. Watersheds and residual areas that were analysed within the 100 Mile House Forest District.

2.0 METHODOLOGY

A total of 71 watersheds or residual areas have been identified in the 100 Mile House Forest District and are considered by the Forest Service as the hydrological planning units (Figure 1). The individual characteristics of each of these 71 watershed planning units have been reviewed and given a hydrological sensitivity rating. Peak flow hazard assessments have also been completed for the 71 watershed planning units, thus enabling the determination of a peak flow risk for watersheds in the 100 Mile House Forest District. This report provides the results of the risk assessment for those 71 watersheds (detailed results provided in Appendix 1).. The following section summarizes the steps we took to complete this project.

2.1 Determination of Watershed Sensitivity Rating

For this procedure, six variables are used to determine watershed sensitivity (i.e. place the watershed into one of five sensitivity classes). They are as follows:

1. The Rosgen stream channel sensitivity rating, applied to the lower reaches of the watershed (Rosgen 1996).
2. The watershed peak flow buffer factor (related to the number, size and location of lakes and wetlands in the watershed).
3. The apparent geomorphic stability of the lower reaches.
4. The dominant natural disturbance type in the watershed.
5. The general topography, shape and connectivity of the watershed.
6. The main fish species found in the watershed.

The first five variables are used to determine the "physical" sensitivity of the watershed, while variable number 6 is used to determine the "biological" sensitivity of the watershed. The most appropriate value for each of these variables is selected from a pre-defined list based on the review of the maps and the air-photos, and professional judgment. It is not an automated GIS procedure, but rather a structured, transparent, objective and repeatable "manual" procedure. This methodology provides me with a structured and transparent approach, yet provides some flexibility for professional judgment. A description of the methodology used to derive values for each of the variables is provided in the sub-sections below.

2.1.1 Determination of the Physical Sensitivity

There are no specific research results that can provide exact numbers or methodologies to determine watershed sensitivities or peak flow thresholds. However, extensive professional experience in the central interior and several related published methodologies have been used to guide me in the development of this procedure (Rosgen 2001, Pfankuck 1978, Church 1992, Rosgen 1994, Leopold 1994, Knighton 1998). This watershed sensitivity classification is based solely on the inherent physical characteristics of the watershed and the stream channel to large scale disturbances in the watershed. The Rosgen stream channel sensitivity rating (Rosgen 1996) is the cornerstone of this procedure. The other four variables are used as sensitivity modifiers to account for specific watershed attributes that contribute to the sensitivity of a stream channel and consequently to fish habitat.

The physical sensitivity score for the watershed is computed using the equation below:

PhS = RS*PFBf*GSf*NDf*TOPf, where:

PhS = Physical sensitivity score for the watershed
RS = Rosgen sensitivity score
PFBf = Peak Flow Buffer factor
GSf = Geomorphic Stability factor
NDf = Natural Disturbance factor
TOPf = Watershed Topography factor

The physical sensitivity score for the watershed (PhS) is used to classify the watershed into one of five sensitivity classes according to the ranking provided in Table 2.

Table 2. Determination of physical sensitivity class based on PhS score

Overall physical stream sensitivity to extensive disturbance	PhS Score
Extreme	greater than or equal to 5.5
Very High	4.5 to 5.49
High	3.5 to 4.49
Moderate	2.5 to 3.49
Low	1.5 to 2.49
Very Low	less than 1.49

The methodology used to determine the values for each of the factors listed above is provided below. It is important to note that this exercise is based on a review of the maps and the digital orthophotos available for each of the watersheds analysed, which focuses on stream channel conditions.

2.1.1.1 The Rosgen Stream Channel Sensitivity Score (RS)

The Rosgen Stream channel classification system (Rosgen 1996) divides stream channels into 8 basic stream types based on: a) single or multi-thread channels, b) the entrenchment ratio of the channel, c) the width/depth ratio and d) the sinuosity of the channel. The system further classifies channels into 96 sub types based on the dominant channel material. Figure 2, extracted from the book *Applied River Hydrology* (Rosgen 1996), provides an illustration of the primary delineative criteria for the major stream types. Although most of the criteria are meant to be measured in the field, it is relatively easy (based on extensive professional experience) to infer the approximate values of the delineative criteria from digital orthophotos, maps, a personal familiarity with the study areas and a helicopter overflight.

Rosgen (1996) also supplies management interpretations for each of the stream types included in the classification system (Figure 3, extracted from Rosgen 1996). The column labeled "Sensitivity to disturbance" was used to provide the basis for a sensitivity score for those channel reaches located at the lower end of a given watershed. The sensitivity scores, for each of the stream sensitivity classes identified by Rosgen (1996), are provided in Table 3.

The USEPA has developed a watershed assessment model based on the concepts of the Rosgen channel classification system (http://www.epa.gov/warsss). This model is called the Watershed Assessment of River Stability and Sediment Supply (WARSSS). It is a comprehensive model that investigates watershed processes at a variety of scales and levels and is used to assess the risks to stream channels caused by land-use activities in the watershed. Although it is more comprehensive then the approach used for this project, it has a lot of similarities. It uses the Rosgen stream types as the basic building blocks of the assessment and defines the risk of outcomes like channel enlargement and bank erosion based on the type and activity level of different hazards in the watershed (e.g. forest removal, roads and riparian logging). This is very similar to the approach used for this project. Figures 4 and 5, which have been extracted from the WARSSS procedural handbook, illustrate how the different stream types are used to define risk relative to ECA and Roads (Figure 4) and . It is obvious from these graphs that A1, A2, B1, B2 are the least sensitive channel types, while the G3-G6 and F3-F6 are the most sensitive channel types. The WARSSS system, much like the system used for this project, will identify a larger risk as the condition of a particular channel type deteriorates (e.g. reduced riparian function or geomorphic instability). The RS for the whole watershed is usually determined by the most sensitive reach, i.e. the "weak link".

Table 3. Rosgen channel sensitivity score based on Rosgen stream sensitivity classes and the concepts provided in the WARSS. The RS for the whole watershed is usually determined by the most sensitive reach, i.e. the "weak link".

Rosgen Stream Type	Stream Sensitivity Class	Channel Sensitivity Score (RS)
A3 to A6 F3 to F6, G3 to G6	Very High	5
C3 to C6 D3 to D6	High	4
E3 to E6	Moderate	3
C1 and C2 B3 to B6	Low	2
A1, A2, B1, B2 F1, F2, G1, G2	Very Low	1

2.1.1.2 Peak Flow Buffer Factor (PFBf)

It is considered here that a watershed that has numerous lakes and swamps near the mouth of the river will have more of a buffering capacity for peak flows than a watershed that does not have any lakes or swamps. Consequently, a watershed with no lakes or swamps is considered as being more sensitive to increased peak flows. As the area of lakes/swamps increases throughout the watershed, the sensitivity is considered to decrease. This is an important factor that has the potential to decrease the sensitivity of a watershed substantially. The peak flow buffer factors used to "modify" the Rosgen channel sensitivity score are provided in Table 4.

Table 4. Peak Flow Buffer factors used to "modify" the Rosgen channel sensitivity score.

Description of Watershed Characteristics relative to abundance of lakes and wetlands	PeakFlow Buffer factor (PFBf)
Numerous lakes, or one big lake, near outlet (big reduction in sensitivity)	0.6
Numerous lakes that are scattered throughout watershed	0.8
Moderate amount of lakes scattered throughout watershed	0.9
Few lakes that are scattered throughout watershed	0.95
No lakes (no reduction in sensitivity)	1

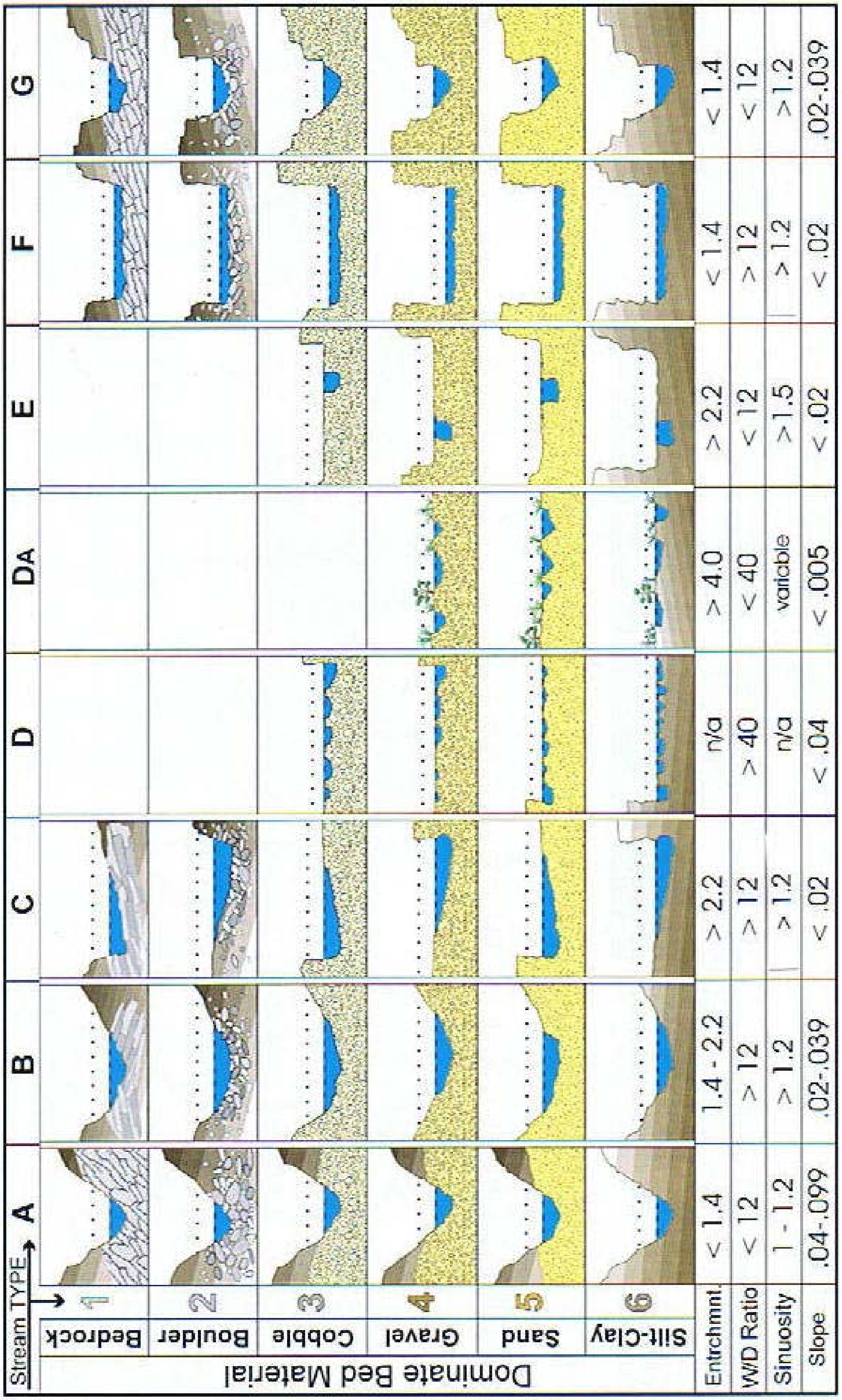


Figure 2. Primary delineative criteria for Rosgen's major stream types

Stream type	Sensitivity to disturbance[a]	Recovery potential[b]	Sediment supply[c]	Streambank erosion potential	Vegetation controlling influence[d]
A1	very low	excellent	very low	very low	negligible
A2	very low	excellent	very low	very low	negligible
A3	very high	very poor	very high	very high	negligible
A4	extreme	very poor	very high	very high	negligible
A5	extreme	very poor	very high	very high	negligible
A6	high	poor	high	high	negligible
B1	very low	excellent	very low	very low	negligible
B2	very low	excellent	very low	very low	negligible
B3	low	excellent	low	low	moderate
B4	moderate	excellent	moderate	low	moderate
B5	moderate	excellent	moderate	moderate	moderate
B6	moderate	excellent	moderate	low	moderate
C1	low	very good	very low	low	moderate
C2	low	very good	low	low	moderate
C3	moderate	good	moderate	moderate	very high
C4	very high	good	high	very high	very high
C5	very high	fair	very high	very high	very high
C6	very high	good	high	high	very high
D3	very high	poor	very high	very high	moderate
D4	very high	poor	very high	very high	moderate
D5	very high	poor	very high	very high	moderate
D6	high	poor	high	high	moderate
Da4	moderate	good	very low	low	very high
DA5	moderate	good	low	low	very high
DA6	moderate	good	very low	very low	very high
E3	high	good	low	moderate	very high
E4	very high	good	moderate	high	very high
E5	very high	good	moderate	high	very high
E6	very high	good	low	moderate	very high
F1	low	fair	low	moderate	low
F2	low	fair	moderate	moderate	low
F3	moderate	poor	very high	very high	moderate
F4	extreme	poor	very high	very high	moderate
F5	very high	poor	very high	very high	moderate
F6	very high	fair	high	very high	moderate
G1	low	good	low	low	low
G2	moderate	fair	moderate	moderate	low
G3	very high	poor	very high	very high	high
G4	extreme	very poor	very high	very high	high
G5	extreme	very poor	very high	very high	high
G6	very high	poor	high	high	high

a Includes increases in streamflow magnitude and timing and/or sediment increases.
b Assumes natural recovery once cause of instability is corrected.
c Includes suspended and bedload from channel derived sources and/or from stream adjacent slopes.
d Vegetation that influences width/depth ratio-stability.

Figure 3. Management interpretations of various stream types (extracted from Rosgen 1996).

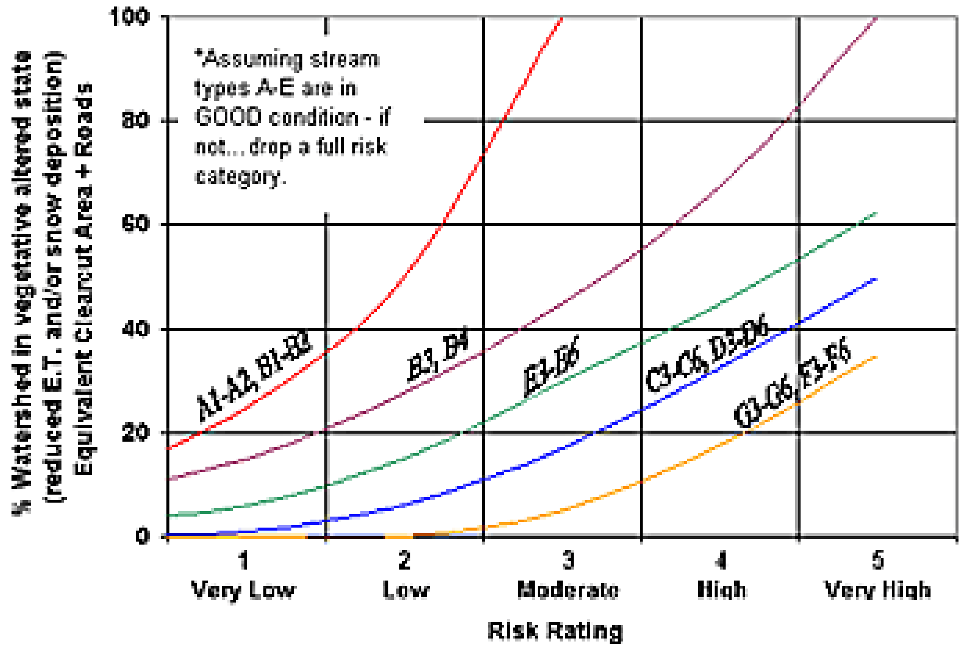
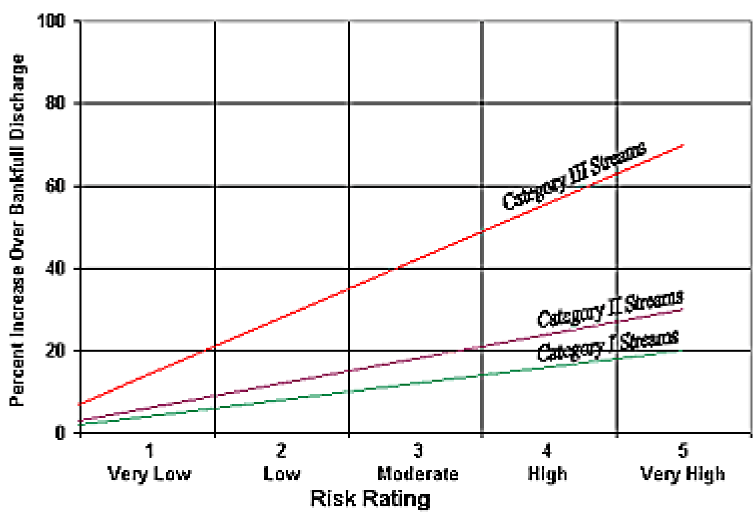


Figure 4. Risk of channel enlargement and accelerated bank erosion associated with increases in equivalent clearcut area (ECA), for different stream types. The channel types on the left of the graph are the least sensitive, while the channel types on the right of the graph are the most sensitive (extracted from http://www.epa.gov/warsss)



Stream Type Category	Stream Types
Category I (Entrenched)	A3-A6, F3-F6, G3-G6
Category II	E3-E6
Category III	A1-A2, B1-B6, C1-C2, F1-F2, G1-G2

* If duration in days area doubled, then for Category I and II stream types = HIGH – VERY HIGH depending on extent of duration in days

Figure 5. Risk of channel adjustment/sediment supply due to increases in bankfull discharge, by stream category. The channel types on the top of the graph are the least sensitive (Category 3), while the channel types on the bottom of the graph are the most sensitive (Category 1) (extracted from http://www.epa.gov/warsss)

2.1.1.3 Geomorphic Stability Factor (GSf)

The geomorphic stability of the lower reaches is assessed by visually evaluating the extent of the stream channel that appears to be unstable, based on the concepts provided in the Reconnaissance Channel Assessment Procedure or Re-CAP (Government of BC 1999). The underlying principle here is that a stream channel will be much more sensitive to increases in peak flows if it is already highly unstable. The assessment is based on the review of the digital orthophotos. The geomorphic stability factors used to "modify" the Rosgen channel sensitivity score are provided in Table 5 (i.e. the greater the instability the greater the increase in sensitivity).

Table 5. Geomorphic stability factors used to "modify" the Rosgen channel sensitivity score.

Apparent geomorphic stability of lower reaches	**Geomorphic Stability factor (GSf)**
Very unstable throughout lower reaches (substantial increase in sensitivity)	1.5
Generally unstable	1.4
Frequent localized instability	1.2
Minor localized instability	1.1
All stable (no increase in sensitivity)	1.0

2.1.1.4 Natural Disturbance Factor (NDf)

The assumption here is that a lower sensitivity rating will be given to those watersheds where large natural disturbances are frequent and the biological communities may be better adapted to frequent natural changes caused by large disturbances (e.g. wildfires, insect infestations and possibly clearcutting). The natural disturbance factors used to "modify" the Rosgen channel sensitivity score are provided in Table 6.

Table 6. Natural disturbance factors used to “modify” the Rosgen channel sensitivity score.

Dominant NDT Type in watershed	Natural Disturbance factor (NDf)
NDT 5 - Alpine tundra and subalpine park land (less sensitive because better adapted to being disturbed)	0.85
NDT 4 - Frequent stand maintaining fires, (less sensitive because better adapted to frequent disturbance)	0.9
NDT 3 - Frequent stand initiating fires, (a bit less sensitive)	0.92
NDT 2 - Infrequent stand-initiating events (minor reduction in sensitivity)	0.98
NDT 1 - Rare stand initiating events (no reduction in sensitivity)	1

2.1.1.5 Watershed Topography Factor (WTf)

It is considered here that a watershed that has a very gentle topography will have a slower “time to peak”, compared to a watersheds that is steep with the hill slopes tightly coupled to the stream network. Consequently, a watershed with a gentle topography is considered as less sensitive to increased peak flows and large scale disturbances compared to a very steep watershed that is highly coupled to the hillslopes. The assessment is based on the review of the digital orthophotos and the topographic maps. The watershed topography factors used to “modify” the Rosgen channel sensitivity score are provided in Table 7.

Table 7. Watershed topography factors used to “modify” the Rosgen channel sensitivity score.

General topography of the watershed	Watershed Topography factor (TOPf)
Gently rolling with very wide uncoupled floodplains (small reduction in sensitivity)	0.9
Hilly, gentle mountains, generally uncoupled.	0.92
Mountainous with localized steepness	0.95
Generally steep and coupled	0.98
Very steep and tightly coupled (no reduction in sensitivity)	1

2.1.2 Determination of Biological Sensitivity (BS)

The biological sensitivity is based on the fish species present in a given watershed, as provided by the Fish Information Summary System (FISS). No field sampling is involved in this determination. Biological sensitivity ratings are defined as follows: a) **low** means there are no fish present in the watershed, b) **moderate** means there are provincially significant fish in the watershed, but no anadromous salmonids or blue or red listed fish species and c) **high** means there are anadromous salmonids or blue or red listed fish species in the watershed. If there are no fish data available for a given watershed, then the sensitivity rating defaults to moderate. The database for each watershed includes a listing of the major fish species found in the watershed and the associated biological sensitivity rating for that particular watershed. For the purposes of this project the biological sensitivity scores are provided in Table 7.

2.1.3 Determination of Overall Watershed Sensitivity

The overall watershed sensitivity was based on the combination of the physical and biological sensitivities determined for each watershed (Table 8).

Table 8. Determination of Watershed Sensitivity

WATERSHED SENSITIVITY		Biological Sensitivity of Watershed		
		Low	**Moderate**	**High**
Physical Sensitivity	**Very Low**	Very Low	Very Low	Low
	Low	Very Low	Low	Moderate
	Moderate	Very low	Moderate	High
	High	Low	High	Very High
	Very High	Moderate	Very High	Very High

2.2: Determination of watershed hazard rating.

The watershed hazard rating is a direct function of the extent of disturbance within the watershed. This hazard relates directly to the potential of the disturbances to alter peak flow regimes and thus possibly impair fish habitat or cause flooding and road management problems. Disturbances include all land-use disturbances in the watershed and the disturbance caused by the Mountain Pine Beetle (MPB). The calculation of the "Hydrologically Equivalent Disturbed" area (HEDA) is done by adding up all of the hydrologically equivalent areas in the watershed as per the example provided in Table 9. The equivalency factors for the disturbed stand were obtained from the Watershed Assessment Procedure guidebook (Government of BC, 1999), while those for the Mountain Pine Beetle affected stands were obtained from the snow survey work completed in 2006 and 2007 (Beaudry P., 2006, 2007).

Table 9. Example of the calculation of the "Hydrologically Equivalent Disturbed" area (HEDA) in a hypothetical watershed of 1500ha in size.

Stand Type	Stand Area in Hectares (a)	Multiplication factor (b)	"Hydrologically Equivalent Disturbed" area (ha) (a) X (b)
Recent Clearcut or other non-recovered land-use related disturbance with a stand height of less than 3 m.	125	1.0	125
Land-use related disturbance with a stand height greater or equal to 3 m and less than 5 m.	85	0.75	63.75
Land-use related disturbance with a stand height greater or equal to 5 m and less than 7 m.	92	0.50	46
Land-use related disturbance with a stand height greater or equal to 7 m and less than 9 m.	65	0.25	16.25
All non-pine stands greater than 9 m in height	390	0.0	0
Mature pine-leading stands (greater or equal to 70% pine composition)	180	0.5	90
Mature pine-mixed stands (pine composition is between 31 and 69%)	78	0.2	15.6
Mature pine-minor stands (pine composition is 30% or less)	132	0.0	0
Other areas in watershed (e.g. lakes, alpine, rivers, swaps, grasslands etc)	353	0.0	0
Total hydrologically equivalent disturbed area (ha)			**356.6**
Total hydrologically equivalent disturbed area (% of watershed)			**23.8**

The "stand type" data are obtained from the Vegetation Resource Inventory (VRI) files and the recent cutblock files are obtained from the BC Data Warehouse. Each polygone within a given watershed is queried to determine the type of disturbance and current stand height.

If desired, the forester can include all of the areas that are proposed for harvesting to generate the "future" or "planned" equivalent disturbed area. The hazard ratings are defined in Table 10 below: The watershed hazard rating is determined by using the computed values of the equivalent disturbed area (Table 9) and Table 10 below.

Table 10. Definition of hazard levels relative to the potential for increased peak flows.

Hazard rating	**Hydrologically Equivalent Disturbed Area in a watershed (expressed as a percentage of entire watershed)**	**Hazard Score**
None	<15% of watershed area	1
Very Low	15 to 25 of watershed area	2
Low	25 to 35% of watershed area	3
Moderate	35 to 45% of watershed area	4
High	45 to 55% of watershed area	5
Very High	55 to 65% of watershed area	6
Extreme	>65% of watershed area	7

2.3 Determine the baseline risk class for a particular watershed.

Based on the sensitivity of the watershed (fixed value) and the hazard level (depends on extent of disturbance), the current baseline risk rating for that particular watershed is determined (Table 11).

Table 11. Risk assessment matrix for watershed planning for 100 Mile House Forest District

Watershed Peak Flow Risk Ratings		**Hydrologically Equivalent Disturbed Areas in the Watershed (% of Watershed)**						
		<15% (None)	**15 to 25% (Very Low)**	**25 to 35% (Low)**	**35 to 45% (Moderate)**	**45 to 55% (High)**	**55 to 65% (Very High)**	**>65% (Extreme)**
Sensitivity of watershed and stream channel to peak flow increases	None	**None**	**None**	**None**	**None**	**None**	**None**	**None**
	Very Low	**None**	**Very Low**	**Very Low**	**Very Low**	**Low**	**Moderate**	**High**
	Low	**None**	**Very Low**	**Very Low**	**Low**	**Moderate**	**High**	**Very High**
	Moderate	**None**	**Low**	**Low**	**Moderate**	**High**	**Very High**	**Very High**
	High	**None**	**Low**	**Moderate**	**High**	**Very High**	**Very High**	**Extreme**
	Very High	**None**	**Moderate**	**High**	**Very High**	**Very High**	**Extreme**	**Extreme**
	Extreme	**None**	**Moderate**	**High**	**Extreme**	**Extreme**	**Extreme**	**Extreme**

It is very important to note that there is no unique "recommended" hazard or risk level provided for any particular watershed. The selection of an acceptable risk level, for a particular watershed, depends on the risk tolerance of the particular prescribing forester or a given company or District objective. The database tables, associated with each of the watersheds, provide information about the watershed sensitivity, the current hazard level and the current hydrological risk (Appendix 1). If the prescribing forester is willing to accept a greater risk then the current baseline risk provided (or increase the risk within the current risk class), then there is an opportunity for further harvesting in the watershed. Any further harvesting will be directly added to the "hydrologically equivalent disturbed area" and will have a multiplication factor of 1.0. The new total area may or may not be enough to raise the total into a new risk class.

3.0 HYDROLOGICAL IMPLICATIONS OF DIFFERENT RISK LEVEL.

There are no textbook definitions for the different risk levels provided in this planning exercise. However, it is important that the prescribing forester has a general idea about the implications of a particular decision and the selection of a particular “tolerable” risk level. The definitions below should be considered as broad concepts and not scientifically defensible precise definitions, because such a thing simply does not exist.

Very Low Risk:

The combination of the extent of disturbances (i.e. the hazard) and the sensitivity of this particular watershed is very unlikely to generate any kind of fish habitat degradation caused by the increases in peak flows.

Low Risk:

The combination of the extent of disturbances (i.e. the hazard) and the sensitivity of this particular watershed is unlikely to generate any kind of fish habitat degradation caused by the increases in peak flows.

Moderate Risk:

The combination of the extent of disturbances (i.e. the hazard) and the sensitivity of this particular watershed is likely to generate localized, but not extensive, fish habitat degradation caused by the increases in peak flows

High Risk:

The combination of the extent of disturbances (i.e. the hazard) and the sensitivity of this particular watershed is likely to generate extensive fish habitat degradation caused by the increases in peak flows

Very High Risk:

The combination of the extent of disturbances (i.e. the hazard) and the sensitivity of this particular watershed is very likely to generate extensive fish habitat degradation caused by the increases in peak flows.

4.0 DETERMINATION OF THE HAZARD LEVEL BY LOOKING AT THE RELATIONSHIPS BETWEEN DISTURBANCE LEVELS AND FLOWS

The scientific literature does not provide one specific "disturbance level" threshold value that is appropriate for all watersheds. The summary presented in Bosch and Hewlett (1982) suggests that significant changes to water yield begin at approximately 20% reduction in cover. Jones and Grant (1996) suggested that a roaded watershed with a 25% ECA resulted in a 22% increase in rain-on-snow peak discharges for the first 10 years after harvest. A subsequent analysis of the same data suggested that the peak flow changes were not as significant as reported (Thomas and Megehan 1998). Beschta et al. (2000) show that peakflow increases following forest harvesting were dependant upon peakflow magnitude. They suggested that the changes were greatest for storms with small recurrence intervals. Harr (1980) reported no changes in peak flow after harvesting 25% of a 71 hectare watershed. A recent study by McFarlene (2001) failed to provide any clear statistical "threshold" ECA value for changes to peak flows, although he did clearly demonstrate that changes in peak flows do occur. Consequently, determining a threshold disturbance value for forest harvesting remains extremely controversial. This particular issue has been investigated since the early 1900's (Bates and Henry 1928) and continues to create heated discussions within the hydrological community.

An issue that is even less well understood is the impact that increases in peak flow have on the biological and physical components of a watershed. Although hydrologists can generally agree that changes in peak flows will occur if there is a "substantial amount" of forest harvesting within a watershed, they cannot agree as to what the impacts might be (and they disagree on what is considered a "substantial amount"). One fact that is clear, however, is that the level and type of impact can change dramatically depending on the type of watershed that is harvested (Grant and Hayes 2001). Different watershed types have different "sensitivities" to increases in peak flows. For example, a watershed with a flat topography which is dominated by swamps, lakes and wetlands would generally be less "sensitive" than one that has a steeper topography and is not buffered by lakes and wetlands and has an alluvial fan. Also, a stream channel that has been recently de-stabilized by a large flood event will remain sensitive to increased peak flows until the stream channel has recovered and returns to relative stability (a process that can take several decades). Consequently, it is our belief that the risks of negative impacts, caused by land-use disturbances, must take into consideration the type of watershed and fluvial system that is potentially being impacted (i.e. the sensitivity) along with the extent and distribution of land-use activities (i.e. the hazard).

4.1 Increases in Peak Flow Hazard

Increases in peak flows are a potential hazard because they can cause accelerated bank erosion and deterioration of fish habitat. However, it is very difficult to measure this particular hazard. The extent of disturbance within a watershed is often used as a surrogate measure of increased peak flows because of the generally accepted relationship that exists between this variable and increases in peak flows. For this particular project the extent of disturbance is determined by using the Mountain Pine Beetle adjusted ECA (or the " Hydrologically Equivalent Disturbed Area"). Table 12 provides the criteria used to determine the Peak Flow hazard rating for each watershed. It is important to note that the Hydrologically Equivalent Disturbed Area is only a coarse indicator of possible increases in peak flows.

Table 12. Determination of peak flow hazard rating by using the Mountain Pine Beetle adjusted ECA (or the "Hydrologically Equivalent Disturbed Area")

Hazard Rating	Hydrologically Equivalent Disturbed Area
None	<15%
Very Low	15-25%
Low	25-35%
Moderate	35-45%
High	45-55%
Very High	55-65%
Extreme	>65%

The peak flow hazard ratings provided in Table 12 are based on a variety of scientific papers that have reported on this subject over the last several decades. No single research paper could provide recommended biological or physical threshold values. Consequently, the values provided in Table 12 are derived from the information provided in the papers and three decades of personal watershed management experience. We have provided a list below of "considerations" that went into the development of the hazard ratings. It is important to note that the ratings are meant to be fairly conservative and used as a component of a complete SFMP that has other indicators to address aquatic values related to riparian management, management of landslide prone terrain, management of erosion and sediment delivery, fish passage and water temperature. It is important to realize that this indicator is not designed to be a stand-alone indicator representing watershed health. This indicator along with others provided in the SFMP can be used as a trigger to initiate more detailed, field based watershed reviews.

The following are considerations that went into the setting of the ECA hazard levels:

- Many investigators have reported that measurable increases to peak flows begin to occur at about 25% ECA.
- These measurable increases (that occur at 25% ECA) do not necessarily mean that there are immediate negative impacts to the aquatic values in all watersheds. However, a conservative approach suggests that the most sensitive watersheds should be protected at levels when increases begin to be measurable.

- Stednick (1996) reported that in areas of low topography (i.e. central plains and eastern coastal plains) there was no measurable increase in streamflows until an ECA of 45 to 50% was reached. Consequently, the watersheds with low relief and the lowest sensitivity class (i.e. 1) were assigned moderate hazard ratings in the 45-50% ECA range and 57-67% PFI range.
- Hazard classes for the three intermediary sensitivity classes were simply distributed between the two extreme classes.

5.0 LITERATURE CITED

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APPENDIX 1: RISK ASSESSMENT DATABASE FOR ALL 71 WATERSHEDS IN THE 100 MILE FOREST DISTRICT

APPENDIX II. CD ROM WITH ALL DIGITAL FILES

APPENDIX III. MAP OF 71 WATERSHED PLANNING UNITS IN THE 100 MILE HOUSE FOREST DISTRICT