Interior Watershed Assessment Update

Moffat Creek Watershed

1.0 WATERSHED DESCRIPTIVE INFORMATION

Table 1.1 Summary information – Biophysical

Size (km^2)	BEC Zones	Elevation Range (m)	H_{60} Elevation (m)	Stream Density km/km^2	Distribution of slope gradients within the watershed (% of watershed)			
					<10% slope	10 to 30% slope	30 to 60% slope	>60%slope
531.80	SBPSmk ESSFwk1 SBSmc1	726 - 2141	1108	1.06	88.5	10.3	0.4	0.0

Table 1.2. Characteristics of main stream reaches – assessment is based on a combination of air-photo interpretations, helicopter overflight and various reports

Reach ID	Minimum Elevation (m)	Maximum Elevation (m)	Reach Length (m)	Reach Gradient (%)	Stream Disturbance Assessment
Main-R1	782.77	800.008	1414	1.2	RPg- Unstable - agriculture and cattle
Main-R2	800.008	819.767	2780	0.7	RPg- Unstable – agriculture and cattle
Main-R3	819.767	891.06	5848	1.2	RPg- Unstable – riparian agriculture
Main-R4	891.06	919.987	3439	0.8	RPg- Unstable – riparian agriculture
Main-R5	919.987	940.714	4840	0.4	RPg- Unstable – riparian agriculture
Main-R6	940.714	979.572	5257	0.7	RPg- Unstable in lower reach – riparian agriculture
Main-R7	979.572	1019.98	5658	0.7	RPg- Localized instability (photo – 1091)
Main-R8	1019.98	1035.62	6231	0.2	RPg- Instability in lower reach
Main-R9	1035.62	1047.2	4020	0.3	RPg – Minor localized instability
Main-R10	1047.2	1059.99	5687	0.2	RPg- Localized instability
Main-R11	1059.99	1140.1	7023	1.1	RPg- Extensive natural instability (photo 1075).
Main-R12	1140.1	1180.06	9094	0.4	Sinuous – stable
Main-R13	1180.06	1219.99	6890	0.6	Sinuous - stable

Main-R14	1219.99	1240	3191	0.6	Sinuous – wetlands- stable
Main-R15	1240	1279.89	2678	1.5	Sinuous – wetlands and stable
Main-R16	1279.89	1299.99	3759	0.5	Sinuous – wetlands and stable
Main-R17	1299.99	1299.99	3253	0.00	Sinuous – wetlands and stable
Main-R18	1299.99	1499.98	3468	5.8	Stable

RPg = Riffle-Pool gravel morphology

2.0 WATERSHED HARVESTING, ROADS AND LAND-USE HISTORY

Table 2.1. Moffat Creek Watershed – (entire watershed)

Private	Total harvest 2002 (%)	Current ECA (%)	Planned Harvest (%)	Current ECA below H60 (%)	Current ECA Above H60 (%)	Peak Flow Index		Road Density Active (km/km^2)		Stream Crossing density active ($\#/km^2$)		Road Density De-active (km/km^2)	
						Current (2002) (%)	End of FDP (2007)(%)	Current (2002)	End of FDP (2007)	Current (2002)	End of FDP (2007)	Current (2002)	End of FDP (2007)
2.78%	23.19	24.01	9.31	11.8	12.2	30.1	42.7	0.78	0.86	0.29	0.33	0.57	0.78

Table 2.2. Upper Moffat Sub-basin (sub-basin only)

Private	Total harvest 2002 (%)	Current ECA (%)	Planned Harvest (%)	Current ECA below H60 (%)	Current ECA Above H60 (%)	Peak Flow Index		Road Density Active (km/km^2)		Stream Crossing density active ($\#/km^2$)		Road Density De-active (km/km^2)	
						Current (2002)(%)	End of FDP (2007)(%)	Current (2002)	End of FDP (2007)	Current (2002)	End of FDP (2007)	Current (2002)	End of FDP (2007)
0.00%	21.87	20.77	13.41	5.9	14.9	28.2	45.4	0.52	0.66	0.23	0.31	0.45	0.82

3.0 SUMMARY OF EXTENT OF RIPARIAN REMOVAL (agriculture and forestry)

Table 3.1. Moffat Watershed

Watershed name	Length (km) of riparian removal on small tributaries (<5m in width)	Length (km) of riparian removal on large tributaries (>5m)	% Riparian removal of all tributaries	Length (km) of riparian removal on mainstem	% Riparian removal of mainstem	Total length of all tributaries (from Trim) (km)	Total length of mainstem (km)
Moffat	79.23	0.72	**14.67**	17.80	**24.83**	544.85	71.68

Table 3.2. Upper Moffat sub-basin

Watershed name	Length (km) of riparian removal on small tributaries (<5m in width)	Length (km) of riparian removal on large tributaries (>5m)	% Riparian removal of all tributaries	Length (km) of riparian removal on mainstem	% Riparian removal of mainstem	Total length of all tributaries (from Trim) (km)	Total length of mainstem (km)
Upper Moffat	37.59	0.00	**13.27**	0.72	**2.89**	283.18	24.78

4.0 SUMMARY OF LARGE SEDIMENT SOURCES

Table 4.1. Moffat Watershed

Watershed Name	Large natural sediment sources		Large natural sediment sources directly connected to a stream		Large land-use related sediment sources		Large land-use related sediment sources directly connected to a stream		Large sediment sources	
	number	density (#/km^2)	number	density (#/km^2)	number	density (#/km^2)	number	density (#/km^2)	number	density (#/km^2)
Moffat	43	0.081	43	0.081	0	0.000	0	0.000	43	0.081

Table 4.2. Upper Moffat Sub-basin

Watershed Name	Large natural sediment sources		Large natural sediment sources directly connected to a stream		Large land-use related sediment sources		Large land-use related sediment sources directly connected to a stream		Large sediment sources	
	number	density (#/km^2)	number	density (#/km^2)	number	density (#/km^2)	number	density (#/km^2)	number	density (#/km^2)
Upper Moffat	2	0.008	2	0.008	0	0.000	0	0.000	2	0.008

5.0 SUMMARY OF LAND-USE ACTIVITIES ON UNSTABLE TERRAIN

Table 5.1. Moffat Watershed

Watershed	Length of road on unstable terrain (km)		Area of cut blocks on unstable terrain (km^2)		Road density on unstable terrain (km/km^2)	Source of information for stability assessment
	Active	Proposed	Harvested	Proposed		
Moffat	0	0	0	0	0.0000	slope>60%

Table 5.2 Upper Moffat Sub-basin

Watershed	Length of road on unstable terrain (km)		Area of cut blocks on unstable terrain (km^2)		Road density on unstable terrain (km/km^2)	Source of information for stability assessment
	Active	Proposed	Harvested	Proposed		
Upper Moffat	0	0	0	0	0.0000	slope>60%

6.0 SUMMARY OF ROAD RELATED SOURCES OF SURFACE EROSION

Table 6.1 Moffat Watershed - summary of stream crossing sediment source survey –

Number of crossings surveyed	Estimated total # of crossings (TRIM maps)	Percentage surveyed	Watershed Size (km^2)
43	262	16.4	531.7

Table 6.2 Summary of Water Quality Concern Ratings (WQCR) – Moffat Watershed

No Concern		**Low**		**Medium**		**High**	
Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
5	11.6	26	60.5	7	16.3	5	11.6

Table 6.3 Summary of Water Quality Concern Ratings by Stream Size - Moffat Watershed

Stream Width Class	None		Low		Medium		High		# of streams surveyed per class
	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	
1	0	0.0	0	0.0	0	0.0	0	0.0	0
2	1	100.0	0	0.0	0	0.0	0	0.0	1
3	1	12.5	5	62.5	2	25.0	0	0.0	8
4	1	4.2	14	58.3	5	20.8	4	16.7	24
5	2	20.0	7	70.0	0	0.0	1	10.0	10

Table 6.4 ESC Summary - Moffat

WQCR	"Equivalent" number of stream crossings
No Concern	0.0
Low	47.5
Moderate	29.9
High	30.5
Total	107.8

Table 6.5 Surface erosion hazard – Moffat Watershed

Equivalent stream crossing density (xings/km^2)	Surface Erosion Hazard
0.20	Moderate

Table 6.6 Upper Moffat Sub-basin - summary of stream crossing sediment source survey –			
Number of crossings surveyed	Estimated total # of crossings (TRIM maps)	Percentage surveyed	Watershed Size (km^2)
25	96	26.0	242.8

Table 6.7 Summary of Water Quality Concern Ratings (WQCR) – Upper Moffat Sub-basin							
No Concern		**Low**		**Medium**		**High**	
Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
2	8.0	15	60.0	3	12.0	5	20.0

Stream Width Class	Table 6.8 Summary of Water Quality Concern Ratings by Stream Size – Upper Moffat Sub-basin								# of streams surveyed per class
	None		Low		Medium		High		
	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	
1	0	0.0	0	0.0	0	0.0	0	0.0	0
2	1	100.0	0	0.0	0	0.0	0	0.0	1
3	0	0.0	4	100.0	0	0.0	0	0.0	4
4	1	7.6	5	38.4	3	23.0	4	30.7	13
5	0	0.0	6	85.7	0	0.0	1	14.3	7

Table 6.9 ESC Summary – Upper Moffat

WQCR	“Equivalent” number of stream crossings
No Concern	0.0
Low	17.3
Moderate	8.1
High	19.2
Total	44.5

Table 6.10 Surface erosion hazard – Upper Moffat Sub-basin

Equivalent stream crossing density (xings/km^2)	Surface Erosion Hazard
0.18	Low

7.0 SUMMARY OF MAINSTEM CHANNEL CONDITIONS

Table 7.1. Extent of channel disturbance

Reach ID	Reach Length (m)	Reach Gradient (%)	Length disturbed (m)	% of channel disturbed	Level of channel disturbance	Probable cause of disturbance
Main-R1	1414	1.2	1219	86	Severe	Agriculture
Main-R2	2780	0.7	1346	48	Severe	Agriculture
Main-R3	5848	1.2	336	6	Moderate	Agriculture
Main-R4	3439	0.8	2035	59	Moderate	Agriculture
Main-R5	4840	0.4	4273	90	Severe	Agriculture
Main-R6	5257	0.7	2786	53	Severe	Mostly Agriculture
Main-R7	5658	0.7	288	5	Low	Unkown/ natural
Main-R8	6231	0.2	0	0	Undisturbed	-
Main-R9	4020	0.3	0	0	Undisturbed	-
Main-R10	5687	0.2	1419	25	Low	Unkown/ natural
Main-R11	7023	1.1	1643	23	Low	Unkown/ natural
Main-R12	9094	0.4	0	0	Undisturbed	-
Main-R13	6890	0.6	0	0	Undisturbed	-
Main-R14	3191	0.6	0	0	Undisturbed	-
Main-R15	2678	1.5	0	0	Undisturbed	-
Main-R16	3759	0.5	0	0	Undisturbed	-
Main-R17	3253	0.00	0	0	Undisturbed	-
Main-R18	3468	5.8	0	0	Undisturbed	-

8.0 SUMMARY OF FISHERIES RESOURCES IN THE WATERSHED

Table 8.1. Documented fish species presence

Category	Common Name	Latin Name	Species Code	Reference
Anadromous salmonids	Chinook Salmon	*Oncorhynchu tshawytschas*	CH	Fish Wizard[1]
	Coho Salmon	*Oncorhynchus kisutch*	CO	Fish Wizard[1]
	Sockeye Salmon	*Oncorhynchus nerka*	SK	Fish Wizard[1]
Freshwater game species	Kokanee	*Oncorhynchus nerka*	KO	Fish Wizard[1]
	Rainbow Trout	*Oncorhynchus mykiss*	RB	Fish Wizard[1]
	Mountain Whitefish	*Prosopium williamsoni*	MW	Fish Wizard[1]
Non-game species	Leopard Dace	*Rhinichthys falcatus*	LDC	Fish Wizard[1]
	Longnose Dace	*Rhinichthys* cataractae	LNC	Fish Wizard[1]
	Redside Shiner	*Richardsonius balteatus*	LSU	Fish Wizard[1]
	Sucker (general)	*Catostomus* sp	RSC	Fish Wizard[1]
	Longnose Sucker	*Catostomus catostomus*	LSU	Fish Wizard[1]
	Northern Pikeminnow	*Ptychocheilus oregonensis*	NSC	Fish Wizard[1]

[1]Fish Wizard available at http://pisces.env.gov.bc.ca

9.0 SUMMARY OF HAZARDS FOR THE MOFFAT WATERSHED

Table 8.2. Watershed assessment hazards

Watershed	Sub-basin	**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
	Upper Moffat	L/H	M	VL	L	L/M	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

10.0 INTERPRETATIONS

10.1 Peakflow Hazards

The peak flow hazard for the Moffat Creek watershed is rated as a **Moderate** for the end of the current FDP (peak flow index for 2007 = 43%). For the upper Moffat it is rated as a **High**. This means that there is a good chance that there will be small increases in spring peak flows at the mouth of the Moffat watershed (increases in peak flows begin to be detectable at a peak flow index of about 30%). Another way of considering this is that the return interval of smaller floods will be shortened (e.g. the 5 year flood will occur, say, on average every four and half years). The mitigating factor in this watershed is that the topography is relatively flat and the stream density is relatively low. This means that the efficiency for transport of water to the main stream system is less than is a steeper watershed.

Unfortunately, the main Moffat River is quite unstable for most of the lower reaches (Tables 1.2 and 7.1). This means that increases in peak flows (or decreases in return intervals) could cause further channel instability, bank erosion and channel aggradation in these lower reaches. Consequently, land management strategies must be implemented to deal with this hazard. These are discussed in Section 11 of this report. The High peak flow hazard for the Upper Moffat sub-basin is assessed at the mouth of this basin (i.e. Reach #11). The actual risk to the aquatic system from the high hazard at reach #11 is actually lower than the moderate risk for the entire watershed. This is simply because the stream reaches in the Upper Moffat sub-basin are very stable and minimal land-use activities have occurred in the riparian area. Consequently, they can withstand larger increases in peak flows without causing significant channel erosion.

10.2 Hazards Associated with a loss in Riparian Functions

The riparian hazard is **Very High** for the Moffat watershed and **Moderate** for the upper sub-basin. This is simply because there has been a substantial loss of riparian function in the lower reaches of Moffat Creek. This has been caused by the removal of most of the trees along the mainstem in the agricultural areas (Photo #1091). In the upper Moffat the problem is very limited to short sections of the river. This significant loss of riparian function has most likely reduced the quality of fish habitat in reaches 1 to 10. This could include impacts to both the physical and biological functions of the stream ecosystem. Examples include negative impacts to physical channel stability, stream temperature, inputs of nutrients and invertebrates, reduction in large woody debris and the quality of light.

10.3 Hazards Associated with Large Sediment Sources

There are no large, directly connected, sediment sources (e.g. landslides) that can be attributed directly to forest harvesting activities in either the Moffat watershed or the Upper Moffat sub-basin. Consequently, the hazard is **Very Low** (Table 9.1). However, there are large sources of sediment associated with the agricultural activities in the lower reaches, mostly accelerated erosion of streambanks. This eroded material deposits into the stream channel and in many cases causes significant channel aggradation. This channel aggradation will cause the channel to partly "fill-up" and become shallower. In such a situation the flowing water will move laterally and further erode the streambanks which will in turn cause even greater channel aggradation. This process can theoretically have a significant impact on fish habitat.

10.4 Hazards Associated with Road Related Surface Erosion

The mapping/GIS exercise identified a total of 262 stream crossings in the Moffat watershed (Table 6.1). We believe that this number is much higher that the real number of stream crossings in this watershed. During our field work, we found that the number of streams mapped on TRIM 2 is much higher that the actual number of streams in the field (i.e. many of the mapped streams did not exist). During our "surface erosion" field work we surveyed 43 stream crossings located throughout the Moffat Watershed. We believe that this represents much more than 16.4% of the real stream crossings in the watershed.

Of the 43 crossings surveyed, 31 (72%) had none or low surface erosion concerns (Table 6.2). Most of the problems identified (i.e. medium and high concerns) were located on small streams (less than 5 m in width) (Table 6.3). Based on our field sampling, the calculated "equivalent stream crossing density" was computed as 0.20 crossings/km^2. This includes all active and de-activated stream crossings. This number has generated a **Moderate** hazard value (Table 6.5). If the true value of the number of stream crossings that exist in this watershed was used (value unknown), instead of the GIS number, the equivalent stream crossing density would be much lower and so would be the hazard.

I believe that the surface erosion hazard is in reality relatively low in this watershed, although all stream crossings are certainly not perfect from an erosion and sediment control perspective. Twelve of the stream crossings had a moderate or high concern rating and these should be addressed in the field.

Based on the field work and the TRIM mapping, the surface erosion hazard for the upper sub-basin is **Low**. As for the Moffat watershed, this hazard is in reality lower than this because simply because the number if TRIM crossings is too high.

10.5 Hazards Associated with Accelerated Mass Wasting (from logging on steep slopes).

There is no steep slope logging in this watershed. Consequently, there is no hazard associated with this IWAP indicator.

10.6 Watershed Cumulative Effects and Channel Stability

The main potential cumulative effect in this watershed is associated with the extent of harvest and the extensive channel instability caused by the removal of the riparian forest along the lower reaches. Consequently, I believe that this watershed is more sensitive to the extent of harvest than any of the other watersheds in the Horsefly area included in the IWAP process. Water related land management decisions in this watershed should focus on controlling the effects of forest removal on peak flows and riparian management in the lower reaches (see Section 11 of this report).

11.0 RECOMMENDATIONS

11.1) Recommendations for the Forest Development Plan (landscape level)

The peak flow hazard will reach a Moderate level by the end of the Forest Development plan for the Moffat watershed. Because of the instability in the lower reaches, these increased flows could be detrimental to water quality and fish habitat near the mouth of the Moffat. As an individual, I cannot establish a maximum harvest level for any specific watershed. This is because there are no solid scientific or technical grounds on which to determine a specific threshold harvest level. I believe that establishing an acceptable harvest level is a "negotiated" decision. This is ultimately the responsibility of the regulatory agencies based on a variety of social, economical and technical information. Much of the technical information related to water management is provided in this document. The most relevant information relating to the extent of harvest for the Moffat Watershed is as follows:

1. The lower 8 reaches are currently unstable and an increase in peak flows (or a decrease in return intervals) could aggravate that instability. Most of the instability can be attributed to historical use of the riparian areas for agricultural purposes. Along many of the lower reaches there is limited riparian vegetation and extensive bank erosion associated with this.

2. According to the literature, peak flows will start to increase when a peak flow index reaches a value of about 30% (or ECA of about 25%). It is important to realize that the literature reports a large variation around the 25% ECA value. A recent study by Stednick (1995), present a wide variation for the "threshold of response" required for measurable increase in annual water yield. A summary of his results are as follows:

Hydrological Region	Number of studies reviewed	Average threshold of response (% harvest area)
All studies	95	20
Appalachian Mountains	29	20
Eastern Coastal Plain	7	45
Rocky Mountain and Intermountain	35	15
Pacific Coast	12	25
Central Plains	7	50

3. The threshold of response reported in Stednick (1995) only represents the level at which there is a measurable increase in water yield. It does not address the issue of threshold value for physical or biological impacts to occur. It is quite clear however, that the level and type of impact can change dramatically depending on the type of watershed that is harvested (Grant and Hayes, 2001). In the case of the

Moffat watershed, it is my opinion that it is a “sensitive” watershed to increased peak flows.

4. The peak flow index for the Moffat and Upper Moffat will be 43 and 45% respectively, at the end of the current FDP.

5. The harvest levels in the Moffat watershed is slowly moving from a low hazard to a high hazard where increases in peak flows begin to occur. This situation must be addressed in the development plan. Suggestions and ideas on how to deal with this situation are presented in the following section. These do no represent all possibilities as the licensee or the committee might develop addition ideas. These recommendations should be considered where practicable.

11.2) Recommendations for Site Specific Activities (site level)

The following management strategies could be implemented in the Moffat watershed to address peak flow concerns:

1. Continued effective de-activation of roads in an effort to maintain natural drainage patterns. Long ditch lines and direct delivery of intercepted water to streams increases the speed at which water is delivered to streams and thus can contribute to increased peak flows.

2. Based on the concept of variable source area (Hewlitt 1961), I recommend that future cutblocks not be located near streams, or that the width of buffer strips or riparian retention zones be increased. Cutblocks that do not have streams in them or are located away from streams have less of an impact on increased peak flows, than those located close to streams. This recommendation would target the S6, S4 and S3 streams more specifically because the FPC requirements are less on those streams. This raises the question: how large an increase in stream buffer is recommended? Rather than giving a specific number, you should use soil, plant and terrain indicators that identify the true riparian area (i.e. terrestrial zones that are influenced by the presence of the stream or water body). In most cases it is relatively easy in the field to delineate the true riparian area from the upper terrestrial areas. Because the Moffat watersheds have been identified as Moderate risk for peak flows and unstable channels, it would be a good watershed management strategy to avoid harvesting within the true riparian areas around S5, S4 and S3 type streams.

3. Leave 20-30% canopy cover in partial retention over the block area. This will result in a disproportionately large benefit on controlling increased snow accumulation and melt rates (i.e. the benefit will be more than 20-30% compared to a clearcut). The rational for this recommendation is provided below.

The U.S. Army Corps of Engineers (1956) suggests that snow accumulation in a forest with 30% canopy cover would be about 27% more than in the fully stocked mature forest. The same study suggests that the snow accumulation in a clearcut would be about 54% more than in the mature forest. Thus, this study suggests that a 70% canopy removal would actually results in an increase in snow accumulation of only 50% of the increase expected in a complete clearcut.

Dunne and Leopold (1978) present extensive information that clearly demonstrates that snow melts rates from radiative sources (short and long wave radiation) do not decrease linearly with increased canopy cover. The decreases are very rapid from 0 to 30% cover and tend to taper off as canopy cover increases. As an example, in a balsam fir and lodgepole pine stand with 80% canopy removal the amount of solar radiation reaching the snowpack is only 40% of the amount measured in the clearcut. Thus a 20% retention would reduce solar radiation to the snowpack by much more than 20% and therefore this type of treatment could have a significant beneficial effect on reducing the peak flow impacts compared to a complete clearcut.

Snowmelt modeling efforts completed by Dunne and Leopold (1978) suggest that a 40% canopy retention will actually minimize the total amount of net radiation available for snowmelt during a sunny day (i.e. less than a clearcut and less than a complete forest). Consequently, this model suggests that snowmelt rates during a sunny day in the spring would be less in a cutblock that was 60% harvested than they would be in either a clearcut or an undisturbed mature forest. This is because such a treatment has significantly reduced the amount of solar radiation compared to a clearcut and reduced the amount of longwave radiation compared to an undisturbed mature forest. Although these numbers would vary between forest types, aspect and elevation, the models clearly suggest that even relatively low levels of partial retention (i.e. 20 to 30%) could have a significant beneficial impact on reducing the impacts to peak flows, compared to total clearcuts.

4. Blocks that are NSR should be dealt with aggressively so that the ECA can be lowered.

5. For upland areas (away from streams), small blocks should be amalgamated into larger blocks with 20% retention. This will reduce the length of active roads.

6. For higher elevation blocks (ESSF) retain understory (broken-up by skid trails). The understory must be tall enough that all of it’s live crown is above the maximum snowpack depth. A significant amount of “tall” understory can have a positive effect on the mitigation of peak flow increases if it is distributed throughout the cut-block. I recognize that by itself, this mitigative measure may only have a limited value. However, it could contribute to positive cumulative effects when implemented with other associated measure.

7. Use “frozen-in” winter roads with no ditch lines wherever possible. This will limit the negative effects of disturbing the natural drainage pattern.

8. In my opinion, the Moffat Creek watershed will be developing an “ECA” concern at the end of this development plan (albeit that this concern is a theoretical one). Although setting an absolute ECA threshold value is a difficult technical, political and economic endeavor, I believe that it would be prudent management to maintain the peak flow index in the moderate risk category. This assumes that items 1 to 7 above are included in the management regime of the Moffat Creek watershed.

The management of surface erosion should include:

1. Implement or fix erosion and sediment control practices on those stream crossings that were identified as a high erosion concern (5 crossings). All of these crossings are on small streams (class 4 or 5 width class) and fixing them is usually a relatively simple process (i.e. grass seed, drainage control or temporary sediment control).

2. During regular road maintenance activities, assess those crossings that were not included in our stream crossing survey. If there are any problems or concerns deal with them promptly and record the activities. The value of the “equivalent stream crossing density” can be lowered as the number of moderate and high concerns are lowered and the associated hazard lowered also.

3. Maintain effective Erosion and Sediment Control (ESC) plans for the Moffat watershed. This would include: a) Development of a plan with precise objectives and standards and clear operating procedures, b) clearly define the types of erosion and sediment control practices that need to be implemented, c) regular maintenance of any ESC structure that has been installed, d) regular field monitoring to evaluate the effectiveness of the plan.

The management of loss of riparian function should include:

1. The only way to reduce the riparian hazard is to continue working with the agricultural land owners so that appropriate vegetation is re-planted and channel sections stabilized where possible (site specific prescriptions are required).

APPENDIX 1 – Database of disturbed riparian areas

ID	Length (m)	Instability level	Source	Reach
Mof-01	1219.07	H	2	1
Mof-02	451.41	H	2	2
Mof-03	895.03	H	2	2
Mof-04	335.77	M	2	3
Mof-05	519.62	M	2	4
Mof-06	1203.2	M	2	4
Mof-07	12.03	M	2	4
Mof-09	508.92	VH	2	5
Mof-11	932.02	H	2	6
Mof-12	467.21	M	4	6
Mof-14	1642.76	M	4	11
Mof-15	1419.14	L	4	10
Mof-08	3229.98	H	2	5
Mof-08a	301.05	H	2	4
Mof-10	839.89	H	4	6
Mof-10a	534.36	H	4	5
Mof-13	287.71	L	4	7
Mof-13a	547.31	L	4	6

APPENDIX 2 – Database of large sediment sources

ID	Type	Cause	Deliverability	Degree of Revegetation	Activity Level
Mof-01	7	4	3	1	3
Mof-02	7	4	3	1	3
Mof-03	7	4	3	1	3
Mof-04	7	4	3	1	3
Mof-05	7	4	3	1	3
Mof-06	7	4	3	1	3
Mof-07	7	4	3	1	3
Mof-08	7	4	3	1	3
Mof-09	7	4	3	1	3
Mof-10	7	4	3	1	3
Mof-11	7	4	3	1	3
Mof-12	7	4	3	1	3
Mof-13	7	4	3	1	3
Mof-14	7	4	3	1	3
Mof-15	7	4	2	1	3
Mof-16	7	4	3	1	3
Mof-17	7	4	3	1	3
Mof-18	7	4	3	1	3
Mof-19	7	4	3	1	3
Mof-20	7	4	3	1	3
Mof-21	7	4	3	1	3
Mof-22	7	4	3	1	3
Mof-23	7	4	3	1	3
Mof-24	7	4	3	1	3
Mof-25	7	4	3	1	3
Mof-26	7	4	3	1	3
Mof-27	7	4	3	1	3
Mof-28	7	4	3	1	3
Mof-29	7	4	3	1	3
Mof-30	7	4	3	1	3
Mof-31	7	4	3	1	3
Mof-32	7	4	3	1	3
Mof-33	7	4	3	1	3
Mof-34	7	4	3	1	3
Mof-35	7	4	3	1	3
Mof-36	7	4	3	1	3
Mof-37	7	4	3	1	3
Mof-38	7	4	3	1	3

ID	Type	Cause	Deliverability	Degree of Revegetation	Activity Level
Mof-39	7	4	3	1	3
Mof-40	7	4	3	1	3
Mof-41	7	4	3	1	3
Mof-42	7	4	3	1	3
Mof-43	7	4	3	1	3

APPENDIX 3 – Database of stream crossing survey (surface erosion)

Moffat Stream Crossing Survey (SCQI) for surface erosion

Sub Basin	Cros-sing ID	UTM Easting	UTM Northing	Structure type	Size of Culvert	Crossing Erosion Score	WQCR	Stream width Class	Stream gradient Class
Moffat	MF10	630493	5779078	s.pt.		0.00	s.pt		0
Moffat	MF11	628656	5777940	5	500	0.85	High	5	1
Moffat	MF12	627643	5777737	1	bridge	0.00	s.pt	2	2
Moffat	MF13	633423	5775973	5	600	0.08	Low	3	2
Moffat	MF14	632341	5776011	5	600	0.08	Low	5	2
Moffat	MF15	632097	5776281	5	600	0.38	Low	4	1
Moffat	MF16	630522	5777021	5	400	0.02	None	beaver pond	1
Moffat	MF17	601428	5772096	s.pt.		0.00	s.pt		0
Moffat	MF18	601536	5773693	s.pt.		0.00	s.pt		0
Moffat	MF19	601948	5775051	5	800	0.21	Low	4	1
Moffat	MF2	632227	5779261	5	600	0.19	Low	5	1
Moffat	MF20	602509	5774672	5	400	0.02	None	4	1
Moffat	MF21	602806	5776404	5	600	0.02	None	5	1
Moffat	MF22	603337	5777525	s.pt.		0.00	s.pt		0
Moffat	MF23	604250	5778956	5	600	0.20	Low	5	1
Moffat	MF24	604652	5780211	s.pt.		0.00	s.pt		0
Moffat	MF25	603100	5780966	s.pt.		0.00	s.pt		0
Moffat	MF26	603487	5780407	s.pt.		0.00	s.pt		0
Moffat	MF27	604523	5780621	s.pt.		0.00	s.pt		0
Moffat	MF28	605230	5780472	1	NA	0.02	None	3	1
Moffat	MF29	602577	5781953	5	1200	0.08	Low	3	2
Moffat	MF3	632228	5779278	5	900	0.13	Low	5	1
Moffat	MF30	603028	5789465	5	600	0.34	Low		0
Moffat	MF31	608179	5797512	s.pt.		0.00	s.pt		0
Moffat	MF4	632166	5779287	5	1000	0.19	Low	4	2
Moffat	MF5	632158	5779290	5	600	0.85	High	4	2
Moffat	MF6	631934	5779350	5	1000	0.40	Low	4	2
Moffat	MF7	631743	5779316	5	1500	0.21	Low	3	2
Moffat	MF8	631627	5779358	5	600	0.21	Low	5	2
Moffat	MF9	631090	5779368	5	700	0.13	Low	5	2
Moffat	F01	626124	5784255	5	1200	0.20	Low	4	1
Moffat	F02	627080	5784144	5	600	0.52	Med	4	2
Moffat	F03	627472	5784148	5	600	0.64	Med	4	2
Moffat	F04	627804	5784217	5	500	0.85	High	4	2
Moffat	F05	627318	5786223	5	500	0.90	High	4	2
Moffat	F06	627403	5786235	5	1400	0.20	Low	3	2

Sub Basin	Cros-sing ID	UTM Easting	UTM Northing	Structure type	Size of Culvert	Crossing Erosion Score	WQCR	Stream width Class	Stream gradient Class
Moffat	F07	627845	5786080	5	600	0.48	Med	4	2
Moffat	F08	628381	5785005	5	800	0.90	High	4	4
Moffat	F09	628219	5784834	5	800	0.19	Low	5	2
Moffat	F10	628230	5784775	5	1200	0.18	Low	4	2
Moffat	F11	628741	5783001	2	NA	0.19	Low	3	3
Moffat	G01	617528	5779443	5	600x2, 800	0.55	Med	3	2
Moffat	G02	611752	5784067	5	500	0.22	Low	4	1
Moffat	G03	612287	5783046	5	500	0.22	Low	4	1
Moffat	G04	612671	5781833	5	800	0.31	Low	4	1
Moffat	G05	613280	5781901	5	600	0.22	Low	4	1
Moffat	G06	613443	5781304	5	1200	0.60	Med	4	1
Moffat	G07	613471	5780733	5	600	0.36	Low	4	2
Moffat	G08	615242	5779696	5	600	0.22	Low	4	2
Moffat	G09	616586	5779619	5	500	0.29	Low	4	2
Moffat	G10	617131	5779257	5	1000	0.47	Med	3	2
Moffat	G11	616746	5778696	2	NA	0.02	None	2	2
Moffat	G12	614008	5779017	5	900	0.54	Med	4	2

APPENDIX 4- Inventory of disturbed channel reaches

ID	Channel Width	Stream Type	One or 2 sided	Length of RL (km)	Land-use
MoffaRL-003	3	2	1	1.0031	1
MoffaRL-002	2	1	1	0.7155	1
MoffaRL-001	3	2	2	0.229	1
MoffaRL-004	3	2	2	0.8554	1
MoffaRL-005	2	1	2	3.9228	2(?)
MoffaRL-006	2	1	1	0.3029	1
MoffaRL-007	2	1	2	2.398	2
MoffaRL-008	2	1	1	1.0812	2
MoffaRL-009	2	1	1	1.1767	2
MoffaRL-010	2	1	2	0.4874	2
MoffaRL-011	2	1	1	0.165	2
MoffaRL-012	2	1	2	5.0729	2
MoffaRL-014	3	2	2	0.7245	2
MoffaRL-013	3	3	2	0.3999	2
MoffaRL-015	2	1	2	0.7708	1,2
MoffaRL-016	2	1	1	0.4614	2
MoffaRL-017	1	1	2	1.9956	2
MoffaRL-018	4	3	2	0.2114	1
MoffaRL-019	4	3	2	0.4477	1
MoffaRL-020	4	3	2	1.0988	1
MoffaRL-021	4	3	2	0.3785	1
MoffaRL-024	4	3	2	1.0607	1
MoffaRL-023	4	3	2	0.9094	1
MoffaRL-022	4	3	2	1.7264	1
MoffaRL-025	4	3	2	0.6497	1
MoffaRL-032	4	2	2	0.6121	1
MoffaRL-031	4	2	2	0.9761	1
MoffaRL-029	4	3	2	0.2024	1
MoffaRL-028	4	3	3	0.2118	1
MoffaRL-026	4	3	2	0.8742	1
MoffaRL-138	4	3	2	0.0789	1
MoffaRL-027	4	3	2	1.462	1
MoffaRL-030	3	3	2	0.2776	1
MoffaRL-033	2	3	2	0.6717	1
MoffaRL-034	4	2	2	0.5432	1
MoffaRL-044	4	3	2	0.8553	1
MoffaRL-035	4	3	2	0.853	1
MoffaRL-036	4	3	2	0.232	1
MoffaRL-037	4	3	2	0.465	1
MoffaRL-038	4	3	1	1.45	1

ID	Channel Width	Stream Type	One or 2 sided	Length of RL (km)	Land-use
MoffaRL-039	4	3	2	0.6251	1
MoffaRL-040	4	3	2	1.5805	1
MoffaRL-041	4	3	2	0.3864	1
MoffaRL-042	4	3	1	0.31	1
MoffaRL-043	4	3	2	0.423	1
MoffaRL-046	4	3	2	0.6775	1
MoffaRL-045	4	3	2	1.4053	1
MoffaRL-047	4	3	2	0.4261	1
MoffaRL-048	4	3	2	0.4745	1
MoffaRL-055	4	3	2	0.6369	1
MoffaRL-054	4	3	2	0.1912	1
MoffaRL-052	4	3	2	0.1401	1
MoffaRL-051	4	3	3	0.2787	1
MoffaRL-053	4	3	2	0.2583	1
MoffaRL-049	4	3	2	0.6028	1
MoffaRL-050	4	3	2	0.8543	1
MoffaRL-056	4	3	2	0.5999	1
MoffaRL-057	4	3	2	0.7849	1
MoffaRL-059	4	3	2	0.7873	1
MoffaRL-058	4	3	2	0.4933	1
MoffaRL-063	4	3	2	0.8685	1
MoffaRL-062	4	3	2	0.5423	1
MoffaRL-059	4	3	2	0.2141	1
MoffaRL-060	4	3	2	0.5543	1
MoffaRL-061	4	3	2	0.7739	1
MoffaRL-064	4	3	2	0.9585	1
MoffaRL-065	4	3	2	0.5077	1
MoffaRL-067	4	3	2	1.677	1
MoffaRL-066	4	2	2	0.7218	1
MoffaRL-069	4	3	2	0.7173	1
MoffaRL-068	4	3	2	0.666	1
MoffaRL-072	4	3	2	0.547	1
MoffaRL-074	4	3	2	0.4134	1
MoffaRL-071	4	3	2	0.2399	1
MoffaRL-073	4	3	2	0.2603	1
MoffaRL-076	4	3	2	1.523	1
MoffaRL-075	4	3	2	0.7205	1
MoffaRL-077	4	3	2	1.1348	1
MoffaRL-078	4	3	2	0.573	2
MoffaRL-080	4	3	2	0.5539	1
MoffaRL-079	4	3	2	0.266	1
MoffaRL-081	4	3	2	1.9813	2

ID	Channel Width	Stream Type	One or 2 sided	Length of RL (km)	Land-use
MoffaRL-082	4	3	2	0.3811	2
MoffaRL-083	4	3	2	0.3963	2
MoffaRL-084	4	3	2	0.1138	2
MoffaRL-085	4	3	2	0.2958	2
MoffaRL-088	4	3	2	0.1287	2
MoffaRL-087	4	3	2	0.2522	2
MoffaRL-086	4	3	2	0.306	2
MoffaRL-070	4	3	2	0.339	1
MoffaRL-089	4	3	2	0.3433	1
MoffaRL-090	4	3	2	0.3429	1
MoffaRL-091	4	3	2	0.8708	1
MoffaRL-092	3	2	2	2.2254	2
MoffaRL-093	4	3	2	0.4981	2
MoffaRL-094	4	3	2	0.5265	2
MoffaRL-095	4	3	2	0.3263	1
MoffaRL-096	4	3	2	0.6875	1
MoffaRL-097	4	3	2	0.6281	1
MoffaRL-098	4	3	2	0.3782	1
MoffaRL-099	4	3	2	0.4705	1
MoffaRL-100	4	3	2	0.6183	2
MoffaRL-101	4	3	2	0.4445	1
MoffaRL-102	4	3	2	0.1796	1
MoffaRL-103	4	3	2	0.1205	1
MoffaRL-104	4	3	2	0.3982	1
MoffaRL-105	4	3	2	0.808	1
MoffaRL-136	4	2	2	0.9676	2
MoffaRL-137	4	2	2	0.5605	1
MoffaRL-130	3	2	2	2.4185	2
MoffaRL-133	3	2	2	0.6603	2
MoffaRL-131	4	2	2	0.4259	2
MoffaRL-132	4	2	2	0.1379	2
MoffaRL-135	4	3	2	0.4831	2
MoffaRL-134	4	3	2	0.4146	1
MoffaRL-124	4	3	2	0.7612	1
MoffaRL-125	4	2	2	0.3788	1
MoffaRL-128	4	2	2	0.076	1
MoffaRL-127	4	3	2	0.138	2
MoffaRL-129	4	2	2	0.3393	1
MoffaRL-126	4	2	2	0.2398	2
MoffaRL-106	4	3	2	0.9668	1
MoffaRL-107	4	3	2	0.4032	1
MoffaRL-109	4	3	2	0.531	1

ID	Channel Width	Stream Type	One or 2 sided	Length of RL (km)	Land-use
MoffaRL-108	4	3	2	0.1835	2
MoffaRL-110	3	3	2	1.3729	2
MoffaRL-111	4	3	2	0.3303	1
MoffaRL-112	4	3	2	0.2733	1
MoffaRL-114	4	3	3	0.2234	1
MoffaRL-113	4	3	2	0.3252	2
MoffaRL-115	4	3	2	0.9203	2
MoffaRL-116	4	3	2	0.3673	1
MoffaRL-118	4	3	2	0.9765	2
MoffaRL-120	4	3	2	0.7735	2
MoffaRL-117	4	3	2	0.8124	2
MoffaRL-119	4	3	2	0.9182	2
MoffaRL-122	4	3	2	0.4824	2
MoffaRL-121	4	3	2	0.4811	2
MoffaRL-123	4	3	3	0.3741	2
MoffaRL-139	4	3	2	0.359	1
MoffaRL-140	4	3	1	0.4765	1
MoffaRL-141	4	3	2	1.3114	1
MoffaRL-142	4	3	2	0.2378	1
MoffaRL-143	4	3	2	0.717	1
MoffaRL-144	4	3	2	0.3282	1
MoffaRL-145	3	3	2	0.1038	1
MoffaRL-146	4	3	2	0.2195	1

Appendix 5 – Selected Photographs

Photograph # 1061: Rehabilitated small mass wasting event

Photograph #1075 Natural bank failures

Photograph #: 1070 Natural bank failures

Photograph #1091 Riparian removal in mid & lower reaches

Appendix 5 – Selected Photographs

Photograph #1494: De-activated old bridge

Photograph #211-3. Site F05, score = 0.9 (high)

Photograph #211-4. Site F08, score =0.9 (high)

Photograph #1492. Site MF28, score = 0.02 (none)