Watershed Risk Assessment

for

Harris Creek

Prepared for:

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1.0 INTRODUCTION

A hydrologic risk assessment has been completed on the Harris Creek watershed for the BC Timber Sales (BCTS) program, Okanagan – Columbia Business Area. Harris Creek is a designated fisheries sensitive watershed (FSW) draining an area of approximately 24,000 ha southeast of Lumby, BC[1] *[Overview map – Appendix A]*. The watershed is shared roughly 75/25 with Tolko Industries Inc. (Tolko) Forest development is planned by both parties to address in part recent mountain pine beetle (MPB) infestation.

Harris Creek becomes Bessette Creek at the confluence with a tributary sharing the name in the residual area *[Appendix A]*. The point of interest for the watershed is located at the crown/private land boundary downstream of the Nicklen Creek confluence. Six sub-basins have been delineated for discussion purposes upstream of this point – Nicklen, McAuley, Mosquito, Home, West Harris, and Upper Harris Creeks.

The purpose of the assessment is to address objectives set by government for fisheries sensitive watersheds as defined in the BCTS Forest Stewardship Plan (FSP)[2]. Specifically, BCTS is expected to:

i) Conserve the natural hydrological conditions, natural stream bed dynamics and integrity of stream channels in the Fisheries Sensitive Watershed,

ii) Conserve the quality, quantity and timing of water flows required by fish in the Fisheries Sensitive Watershed, and

iii) Prevent the cumulative hydrological effects of primary forest activities in the Fisheries Sensitive Watershed from resulting in a material adverse impact on the fish habitat in the watershed.

To achieve these objectives BCTS has specified basal area retention levels for Riparian Management Areas (RMA's) in FSW's and committed to the completion of hydrologic risk analyses were planned development is expected to be moderate or high risk with respect to resources at stake.

To assist in this regard the risk assessment will include the following components, as defined in the contract:

- Review of available background materials to identify any known watershed and fisheries related concerns.

[1] http://www.env.gov.bc.ca/wld/frpa/fsw/order/f-3-001%20to%20006%20-%20Ok-Sh%20LRMP.pdf
[2] BC Timber Sales, Okanagan-Columbia Business Area, Forest Stewardship Plan, July 2006.

- Assessment of:
    i) current watershed condition in the absence of mountain pine beetle and planned development, salvage or otherwise,
    ii) expected watershed condition with MPB and planned development, salvage or otherwise, and
    iii) expected watershed condition with planned development and loss of all remaining susceptible pine in the watershed over the next 3 – 5 years.
- Estimate of hydrologic recovery for two different scenarios:
    i) Scenario 1 – no further harvesting but the loss of all mature pine, and
    ii) Scenario 2 – implementation of the proposed harvesting plan plus the loss of the mature Lodgepole pine.
- Recommendations for proposed development or the implementation of other remedial measures to mitigate the effects of mountain pine beetle on fisheries resources.

2.0 BACKGROUND

The Harris Creek watershed has been reviewed numerous times over the last 15 years from water and fisheries related perspectives. Projects include Forest Renewal BC funded inventory and restoration activities, watershed assessments completed for restoration and forest development planning purposes, terrain stability mapping, and most recently fish passage culvert inspection work. Reports were kindly made available for review by Tolko Industries Ltd. as the previous major tenure holder in the watershed. Fisheries related information is also available from provincial databases[3].

Available fisheries information and prior report findings are summarized as follows:

- Harris and Bessette Creeks are known to support runs of coho, chinook, and sockeye salmon. Harris Creek is the second highest ranking fisheries watershed in the Upper Shuswap system as determined by the provincial WET model[4]. This rank is an important factor in the FSW designation.
- Both coho and chinook salmon have been sighted on the lower reaches of Harris Creek between Bessette and McAuley Creeks. It is likely that chinook use the Harris mainstem for spawning based on coarse substrate size and possibly rearing. Coho likely spawn in finer textured sections of

[3] http://www.fishwizard.com/default.htm
[4] http://www.env.gov.bc.ca/wld/documents/fsw/FSW%202006%20Information%20Paper%20v1.1.pdf

the mainstem and lower reaches of accessible tributary channels, and rear in the Bessette and Shuswap systems. There is a known cascade barrier on the Harris mainstem upstream of the West Harris confluence that may restrict upstream movement of anadromous species.

- Rainbow trout and various species of coarse fish inhabit most of the sub-basin mainstem channels and lakes at mid to upper elevation. Important rainbow spawning sites are noted in provincial databases around lakes in the Upper Harris and West Harris basins.
- Harris Creek has a history of placer mining and logging dating back to the late 1800's that included log drives on the mainstem channel and possibly the McAuley Creek tributary. Extensive old road and trail networks are present throughout the Harris residual and lower portions of the Nicklen, McAuley, Mosquito, West Harris, and Upper Harris basins. Placer mining claims were staked and worked to some extent along the entire Harris floodplain downstream of the Upper Harris basin confluence. Significant negative effects on riparian function, floodplain processes, channel stability, and fish and fish habitat would have resulted from these activities that were ongoing until approximately 1950.
- Fish passage culvert inspection work completed in Harris Creek[5] included fish presence/absence mapping where required for culvert inspection. Results have been included on the overview map *[Appendix A].* Not all streams were surveyed but where done presence/absence was confirmed.
- Culvert inspection revealed several sites where fish passage was either restricted or prevented by closed bottom structures (i.e. metal culverts). Many of the sites received scores lower than that required to justify replacement based on limited upstream habitat to be gained. Three sites scored high enough to justify replacement:
    - the Harris Mainline crossing on the Mosquito Lake outlet channel (known as site H6),
    - the uppermost Harris Mainline crossing on Mosquito Creek (known as site H8), and
    - the H100 non-status road crossing on Home Creek (known as site H12).

  The H100 structure was ineligible for replacement using Forest Investment Account (FIA) funds based on road status, but issues could have been addressed using FIA eligible permanent deactivation methods. One other maintenance related issue was noted at the Home Creek FSR crossing on a non-fish bearing portion of the Home Creek mainstem

[5] Snowy River Resources Ltd. 2007. Fish Passage Culvert Inspection – TSA22 and TFL49. Completed for BC Timber Sales and Tolko Industries Ltd.

channel (known as site H10). The culvert was crushed in that location resulting in flow over the road and down the ditchline. As of October 2009 no work had been done by either Tolko or BCTS at any of the culvert replacement or maintenance related priority sites.

- Terrain stability mapping (TSM) was first produced in Harris Creek by Dobson and Roed (1998) and later updated by Blyth[6] in 2002. The summary report provided in the latter describes the glacial history and important stability related issues. Key areas of concern involve glacio-lacustrine, glacio-fluvial and thick glacial till deposits in the main Harris valley and lower reaches of main tributary basins. Large failures in these material types and landforms have impacted on the Harris Creek system, partly the result of their proximity to the mainstem and larger tributaries. Glacio-lacustrine sediments were also noted at mid-elevation in the Home and Upper Harris basins. Aeolian, or wind deposited sediment is also noted in thin veneers on south and west aspects in particular. Aeolian and glacio-lacustrine materials are highly erodable and remain in suspension for long distances if introduced to the stream network (i.e. they are not good for fish).
- An Integrated Watershed Restoration Project was completed in Harris Creek in 1996[7]. The project included road inspection, Level 1 Watershed Assessment (IWAP), Channel Assessment, and Access Management Planning (AMP) components.
    - The Road Inspection covered portions of the permitted and non-status road network but not all and results are site-specific in nature. Several high priority sites were identified on both permitted and non-status roads but follow-up treatment is unclear. Permanent deactivation prescriptions were prepared in 1996[8] for approximately 29 km of road and trail in the area between Bessette Creek and Beetle Creek following landslide occurrence in the spring of 1996. Uncontrolled drainage on non-status roads in particular resulted in multiple landslide events culminating in a debris flow running out on the Harris Creek floodplain. It is not clear if prescriptions were implemented as no as-built reports are available.
    - Level 1 IWAP results indicated high potential surface erosion hazards in the watershed, residual and Mosquito basin largely the result of high road densities and the length of road close to water.

[6] Blyth Consulting, 2002. Terrain Stability Mapping (TSIL C) for the Harris Creek Watershed, completed for Riverside Forest Products Ltd., Lumby, BC.
[7] Dobson Engineering Ltd., 1996. Integrated Watershed Restoration Project for Harris Creek, completed for Riverside Forest Products Ltd., Lumby, BC.
[8] Dobson Engineering Ltd, 1996. Road Deactivation Prescriptions for the Nicklen Forest Service Road Areas – West of the Bessette Creek sub-basins, prepared for Riverside Forest Products Ltd. Lumby, BC.

Surface erosion hazards were moderate in the McAuley and Nicklen basins for the same reasons. Peak flow hazards were moderate in the Mosquito, Home, and Nicklen basins, and low elsewhere.

- The Channel Assessment noted several large landslide impacts on the Harris mainstem and chronic sediment production from ravelling slopes undercut during high flow periods. The channel network was determined to be stable otherwise with only minor increases in sediment load.
- The AMP outlined possible treatments to address problems identified in the road inspection and with roads and their effect on watershed condition, generally. Large portions of the non-status road network were identified for permanent deactivation with improvements on permitted roads where required. It is not clear what was done following the AMP except in the case of prescriptions prepared in the Nicklen FSR area .

- A Channel Restoration Project was completed for Bessette Creek between Nicklen Creek and Village of Lumby in 1997[9]. The report included an historic channel reconstruction and land-use report, Channel Assessment for Bessette Creek, and Watershed Assessment update with review of planned forest development.
  - The channel reconstruction and Channel Assessment components identified significant land-use related effects on Bessette Creek and its alluvial fan based on a comparison of historic and more recent aerial photography. High flow channels used to dissipate flood energy and associated sediment had been cut-off for flood protection reasons, riparian cover decreased, and overall channel length had been reduced 16% by confinement. The result was a shorter, steeper, and more sensitive channel to high flow and sediment load related disturbance. Recommendations were made for gravel excavation, bank protection using set-backs, re-activation of high flow channels, and improved riparian function. One large landslide into the channel from private land near the fan apex was identified as a major contributor to channel infilling and flooding related issues.
  - The Watershed Assessment update used current forest cover information and reviewed proposed and projected development through the use of a COMPLAN analysis, similar to total chance planning. Potential hazards were similar to those reported in 1996 – high peak flow and surface erosion rating for Mosquito and Nicklen, high riparian hazard in Mosquito and McAuley, moderate peak flow

[9] Dobson Engineering Ltd. 1997. Bessette Creek Channel Restoration Project, completed for Riverside Forest Products Ltd., Lumby, BC.

hazard in Home Creek and moderate surface erosion hazard in McAuley Creek. The riparian hazard for the watershed was moderate. Sensitive channels were discussed in the report with recommendations for good riparian management in fan and floodplain areas, and careful development over the long term to minimize potential effects on peak flow that would exacerbate sediment sources along the mainstem. Long term ECA's would remain less than 25% across the board according to the COMPLAN analysis. Development planned at the time was determined to be acceptable but only if the AMP and recommendations for channel restoration provided in the Bessette Creek restoration plan were implemented. It appears that development proceeded as planned without these requirements.

- More recent hydrologic assessment work has also been done to address MPB infestation in the Tolko portion of the Harris watershed but information is propriety and has not been made available for review.

3.0 METHODS

Ortho photos were used to map landslides, slumps and large rotational failures along the Harris mainstem. Alluvial fan and floodplain features were extracted from terrain stability mapping (TSM) files and generally added to using ortho photos and field checks to capture like features on smaller systems *[Appendix A]*. Fans and floodplains are important erosion and deposition areas where channel and riparian related changes can occur with increases in peak flow and sedimentation, or reductions in riparian function. The highest value fish habitat is often located in these areas also. The location and extent of fans and floodplains is considered approximate based on reconnaissance level field checking. Confirmation is required at the site level for block layout and/or road design purposes. Definitions and management considerations in fan and floodplain areas are provided in tabular form in Appendix B.

A review of the entire permitted road system (FSR and RP in the roads files) was completed for sediment source survey purposes along with approximately 30% of the non-status road and trail network. A complete review of the non-status network was considered important based on findings on the 30% reviewed but beyond the scope of the contract. Streams and riparian areas were reviewed strategically to assess stability and function, respectively.

A detailed ECA analysis was done to understand the potential effect of mountain pine beetle (MPB) infestation on susceptible stands and planned development

from an ECA perspective *[Appendix A]*. Methods were developed by Huggard[10] and refined for application in Harris Creek. The model accounts for dead standing pine, non-pine overstory, and understory related effects on ECA over time. Four scenarios have been modelled under two different MPB attack situations – moderate and heavy, with recovery over a 60 year period. Under the full attack situation all stands ≥50 years old with ≥40% overstory pine are attacked by MPB and all pines are killed. MPB mortality is assumed to have begun in Harris Creek one year ago and is expected to run its course over a five year period ending in 2014. Under the moderate MPB situation stands ≥50 years old with ≥40% overstory pine are potentially susceptible to MPB, but only 50% of such stands in the ESSF biogeoclimatic zone are killed. In other biogeoclimatic zones 65% of susceptible stands <100 years old and 80% of stands ≥100 years old are killed. Both runs are included for discussion purposes.

Scenarios include:

1. Un-salvaged - all susceptible pine is left to die with no salvage effort.
2. WTP 80+% Pl - all susceptible stands with 80% or more pine are clearcut salvaged with 10% retained in wildlife tree patches. The remaining susceptible pine is left to die with no additional salvage effort.
3. Proposed - stands proposed for development by BCTS and Tolko are clearcut logged. Remaining susceptible pine is left to die with no additional salvage effort.
4. Proposed +CC salvage – stands proposed for development by BCTS and Tolko are clearcut logged along with all remaining susceptible pine in the watershed.

Scenarios 1 and 3 were specifically requested by BCTS; scenario 2 is included as a potential best management practice (BMP) for a watershed with downstream resources at stake, and scenario 4 is the worst case from a short term ECA perspective.

The risk assessment component of the project follows partial risk analysis methods as defined in BC Ministry of Forests - Land Management Handbook 56[11]. Definitions for terms used in the risk assessment are as follows:

Risk assessment – involves the steps of preliminary assessment and risk estimation. It includes the systematic use of information to

[10] Huggard, D. 2008. Effects of salvage options for beetle-killed pine stands on ECA (December 2008 update). Unpublished report for BC Ministry of Environment, Kamloops.
[11] Land Management Handbook 56: Landslide Risk Case Studies in Forest Development Planning and Operations. BC Ministry of Forests, Research Branch, Victoria.

identify streamflow, sediment source, and riparian function related hazards and estimate the chance for, and severity of, injury or loss to individuals or populations, property, the environment, or other things of value (resources at stake).

Hazard – a source of potential harm, or a situation with a potential for causing harm, in terms of human injury, damage to property, the environment, and other things of value; or some combination of these. In watershed management increases in the frequency and magnitude of high flow events, sediment input to streams from roads and landslides, and reductions in riparian function are considered hazards.

Hazard rating – the measurement or expression of the likelihood of hazard occurrence, or probability of occurrence.

Consequence – the resource at stake (human well-being, property, the environment, or other things of value) and the change, loss, or damage to the resource(s) that may result from a landslide, road erosion event, high streamflow event, etc…

Risk – the chance of injury or loss as defined as a measure of the probability of hazard occurrence and the consequence of an adverse effect on the resource at stake.

4.0 ASSESSMENT

The Harris Creek watershed is described in the following sections in terms of natural characteristics and processes, current condition from a peak flow, sedimentation, and riparian function perspective, and conditions expected under the two mountain pine beetle and proposed development scenarios requested by BCTS. An evaluation of risk with respect to resources at stake is provided for current, MPB, and proposed development situations.

4.1 Watershed Characteristics

The Harris Creek watershed has a combination of plateau and mountainous characteristics based on its location relative to the Monashee Range. The upper third to half of each basin is low and rolling with extensive lake and wetland complexes. The middle reaches of all basins are steep and well incised leading down to fans built onto the Harris Creek floodplain. The lower reaches of all tributaries are cut into historic glacio-fluvial and/or glacio-lacustrine deposits that are identified in TSM files. The Harris floodplain is wide and extensive flanking the mainstem between Upper Harris and Nicklen Creeks. A large alluvial fan is present beyond the Nicklen confluence where then Bessette Creek loses

confinement en route to its confluence with Duteau Creek in the town of Lumby *[Appendix A]*.

Harris and Bessette Creeks are known to support runs of coho, chinook, and sockeye salmon from the Upper Shuswap system, as described above. Resident rainbow trout are found in all of the basin mainstem channels and headwater lakes in the Nicklen, Mosquito, West Harris, and Upper Harris basins. The salmon and their habitat are considered sensitive to increases in fine sediment load leading to increased turbidity and deposition among larger spawning substrate materials. Fine sediment accumulation in channels affects:

- the ability of fish to excavate spawning redds,
- egg survival rates, and
- invertebrate populations (i.e. food for fish).

Reductions in riparian function and increases in peak streamflow levels can also affect fish and fish habitat by destabilizing alluvial channels in particular, increasing stream temperatures, and decreasing organic material inputs such as leaf litter. Low flows are also an important consideration for fish access into spawning areas typically in the late summer and early fall. Rainbow trout are sensitive to similar disturbance types but considered less so based on abundance and distribution.

High flows most likely occur on Harris Creek during the spring snowmelt period with the highest flows generated by rain-on-snow events typically in the late spring. The snowline location at the time of peak flow on the mainstem is expected to be near 1420 m in elevation on average, or H50 in hypsometric terms. The snowline elevation is likely higher on solar aspects in the Mosquito and Home Creek basins and lower on more northerly aspects in the Nicklen, McAuley, West Harris, and Upper Harris basins.

Key resources at stake in the Harris Creek watershed and processes that affect them are as follows:

- Anadromous fish (salmon) and fish habitat throughout the Harris and Bessette Creek mainstem channels and on tributary fans – affected by:
    - fine sediment load and to a lesser degree coarse sediment load,
    - riparian function particularly in accessible fan and floodplain areas,
    - high flows that result in bank erosion and bed load transport, and
    - reductions in low flow.
- Resident fish habitat throughout accessible portions of the watershed – affected as above.

- Private property and both private and public infrastructure on the large Bessette Creek fan downstream of the Nicklen Creek confluence - affected by:
    - stream flows that result in sediment and debris transport onto the fan where accumulations can result in erosion and possible avulsion (i.e. change in channel course),
    - increases in sediment load that infill the channel increasing the likelihood of bank erosion and flooding, and
    - reductions in riparian function along active channels on the fan itself.

  Bessette Creek has been straightened and confined on the fan, but the fan is still considered active based on low bank heights near the apex and incomplete containment from a rip-rap/channelization perspective.
- Forest road infrastructure, namely culverts and bridges on systems with active floodplains and mobile sediment and debris - affected by:
    - increases in flow and sediment load, and
    - reductions in riparian function that lead to sediment production in upstream areas.

4.2 Current Condition

The Harris Creek watershed upstream of the Nicklen Creek confluence is in good condition at this time from a peak flow, low flow, and riparian function perspective, but only fair condition from a sedimentation perspective. Permitted and non-status roads, and associated landslides in some cases are active sources of sediment to the system which is affecting water quality and the integrity of stream channels. Road related sediment contributions are cumulative in nature and have a negative effect on fish and fish habitat, generally.

Hazards

Current peak flow hazard ratings are moderate in the Harris watershed and Mosquito Creek basin. Current equivalent clearcut area (ECA) levels above the snowline are considered low across the board *[Table 1]* but roads are affecting runoff in the Mosquito basin and Harris residual as a function of road density and drainage interception, diversion, and concentration, generally. Peak flow hazards are low in the Nicklen, McAuley, Home, West Harris, and Upper Harris basins based lower road densities, low rolling terrain at mid to upper elevation, and more lake and wetland complexes. Runoff is also diverted from upper McAuley Creek to Heart Creek, reducing peak streamflow levels on that system accordingly.

Table 1. Harris Creek Past Harvesting and ECA Summary

Unit	Area (ha)	Area logged (ha/%)	Area above the snowline (ha)	Area logged above the snowline (ha/%)	Current ECA above the snowline (%)
Nicklen	3,325	1,686/51	600	246/41	21
McAuley	3,012	700/23	1,787	411/23	23
Mosquito	2,627	1,330/51	1,272	666/52	23
West Harris	957	144/15	726	65/9	9
Home	960	524/55	650	256/39	25
Upper Harris	6,868	774/11	6201	618/10	15
Harris Watershed	24,640	6,883/28	12,320	2332/19	17

Current sedimentation hazard ratings are moderate for the watershed and both Mosquito and Nicklen basins, and low for the McAuley, Home, West Harris, and Upper Harris basins. The moderate hazard ratings are a function of:

- sediment input to channels from roads throughout the watershed, as described in detail in the road risk section *[Appendix C],*
- recent road related landslides into Harris Creek and main tributaries *[refer to landslide symbols on Overview Map – Appendix A]*,
- chronic undercutting and secondary erosion of large slumps and rotational failures in fine textured glacio-fluvial and glacio-lacustrine deposits along the Harris mainstem channel *[also shown as landslides – Appendix A]*, and
- uncontrolled cattle access to channels throughout the watershed.

Sediment input to McAuley Creek from one of the largest natural landslides recorded in the BC Southern Interior is negligible at this time. The event involved approximately 20 ha of steep hillslope in the mid-basin area that failed into the mainstem and continued as a debris flow for approximately 1 km. Deposits are very coarse in texture – sediment production is negligible and not expected to worsen over time *[Photo 1 – Appendix D].*

Sediment input to channels from road and road related sources is considered the most important forest management consideration for fish in the Harris Creek watershed at this time. This conclusion is based on a comprehensive review of permitted roads in the watershed but only a partial review of the non-status road network as shown on the road risk map *[Appendix C].* A complete review of the non-status network was considered beyond the terms of reference for the contract based on overall length and poor access. This type of activity is also eligible for Forest Investment Account (FIA) funding. Assessed road length by status and risk is summarized in Table 2. Forest Service Roads (FSR), roads under permit to Tolko Industries Ltd. (RP/CP), and non-status roads (NSR) are

included. Several short sections of private road are included in the NSR totals and described separately in the road risk section *[Appendix C].*

Table 2. Road Risk by Length and Status

Status	Risk and Road Length (km)				
	Very high	High	Moderate	Low	Not assessed
FSR	2.5	22.6	7.4	81.1	0.2
RP/CP	4.6	12.2	11.3	87.9	19.1
NSR	11.3	4.5	9.7	47.5	174

Specific areas of concern (high and very high risk) from a road related erosion, sedimentation and landslide perspective include:

- Any section of permitted or non-status road built through or draining down to glacio-fluvial and glacio-lacustrine terraces flanking the Harris Creek mainstem and the lower reaches of main tributaries. Small and large landslides into Harris Creek and tributaries have been caused by uncontrolled drainage and/or oversteepened or supported fill in these areas. Priority roads and road sections include:
    - Harris and Mosquito FSR's in and around the Mosquito basin/Harris residual area confluence.
    - Home Creek FSR around the Mosquito Creek crossing.
    - Nicklen FSR.
    - Dustin Road and Southwest Harris non-status *[Photo 2].*
    - Nicklen Road and both non-status and private spurs.
    - South, Southeast, and Southwest Harris; McAuley Northwest, and Denis non-status roads *[Photo 3].*
    - PRV2 on the north side of the residual.
    - Jeffery, South Jeffery and J100 roads *[Photos 4, 5].*
- Sections of permitted and non-status road built on fans or floodplains where washouts and diversions have occurred or are expected as a result of natural processes and insufficient structure design. Sections include:
    - McAuley and Nicklen FSR's.
    - Harris Flood 1 and 2 non-status.
    - Dustin and Dustin F roads *[Photo 6].*
    - Harris Southeast and Denis non-status *[Photo 7].*
- Sections on which uncontrolled drainage or diversions was observed with landslides, washouts, or erosion, generally. Sections include:

- Home Creek FSR at the Home Creek crossing where a blocked culvert has resulted in flow diversion to the Mosquito basin with subsequent tributary destabilization *[Photo 8].*
- Goat FSR at the Nicklen Creek crossing.
- Dustin Road *[Photo 9].*
- Upper Vidler Road.
- Mosquito South.
- McAuley Main.
- Brendan Road *[Photo 10].*
- Upper Amy *[Photo 11].*
- H100 and H100 non-status *[Photo 12].*

In the case of sediment input to channels from road erosion and road related slides, all of the issues can be addressed by implementing recommendations provided in the road risk tables. All work on non-status roads including completion of the road risk analysis is eligible for Forest Investment Account (FIA) funding. In the case of undercutting and secondary erosion of existing slumps and rotational failures in the residual, little can be done as Harris Creek is active on its floodplain naturally and dry ravelling on slide scars in these material types make re-vegetation difficult. Prevention of new forest development related failures of this type and magnitude should be the management priority.

Uncontrolled cattle access to channels, fish-bearing or otherwise, is also a source of fine sediment to the system. Channels and channel banks are trampled during the grazing season making sediment available for transport during freshet periods. In the case of small alluvial S6 and S4 channels in the Mosquito and Nicklen basins in particular, channels are required to reform each freshet through fine sediments turned up by cattle use. This disturbance and reformation pattern is ongoing, provides a measureable amount of fine sediment to the system annually, and is considered negative with respect to local and downstream fish and fish habitat. The range management problem is both widespread as it occurs throughout those portions of the watershed subject to range use, and concentrated in the case of sites that cattle frequent for water and/or shade related reasons *[Photo 13].* Controls on cattle access to water, both on crown and private land, should be an important consideration in Harris Creek for fisheries related reasons.

The riparian function hazard ratings for the watershed and all basins are low based on good retention in fan and floodplain areas generally. Where past harvesting has occurred along channels, riparian areas have either recovered in the case of the Harris Creek floodplain and past mining and logging related

disturbance, or in the case of more recent development the streams have been small and not reliant upon riparian vegetation for stability related reasons. Some increase in summer stream temperature and decrease in organic material input (i.e. leaf litter) has likely occurred as a result of past harvesting in the Nicklen, Mosquito, and Home Creek basins but its effect on mainstem fish and fish habitat has likely been negligible. Uncontrolled cattle access to channels is affecting riparian function particularly where early seral deciduous vegetation dominates. These communities have been largely created by past harvesting along small S6 and S4 channels in Vidler Creek and the Nicklen, Mosquito, and Home Creek basins but cattle use as described above may be preventing establishment of longer lived coniferous riparian vegetation.

Downstream of the Nicklen Creek confluence riparian function has been significantly impaired on private land for agriculture and flood protection reasons resulting in a high hazard situation. Natural fan processes have been restricted as a result making the lower system more sensitive to flow and sedimentation related disturbance. While it is unlikely that natural processes will be restored across the larger fan area *[Appendix A]*, riparian function related improvements could be realized along the main channel by establishing set-backs on private land to allow some lateral channel movement and sediment storage, and planting native riparian vegetation. This is an important consideration given high fish values on the Bessette Creek and Upper Shuswap River systems.

Risk

There is currently a high risk of negative effects on both anadromous and resident fish and fish habitat in the Harris Creek watershed as a result of sediment generation and delivery from roads and road related slump, landslide, and larger rotational failure events, and cattle access to channels. This rating is a function of the moderate sedimentation hazard for the watershed and high consequence being the effect of increased sedimentation on known high value fish spawning habitat both within and downstream of the Harris Creek watershed. The high sedimentation hazard can be reduced and maintained at lower levels by:

- implementing recommendations provided in the road risk section, which will largely address road drainage diversion issues also,
- reducing cattle access to channels, and
- conducting future forest development in a way that:
    - prevents any related slumps and large rotational failures in glacio-fluvial and glacio-lacustrine deposits in the main Harris Creek valley and lower reaches of the tributary basins,

- minimizes development related effects on peak flows that can increase floodplain activity and erosion of unstable toe slopes in the residual, and
- retains and protects mature riparian vegetation in mapped fan and floodplain areas.

There is currently a high risk of negative effects on public and private land and infrastructure as a result of elevated sediment loads on the Harris Creek mainstem and both restrictions on natural fan processes and reductions in riparian function on private land downstream of the Nicklen Creek confluence. This rating is a function of moderate peak flow and sedimentation hazards in the watershed, a high riparian function hazard on private land downstream of Nicklen Creek, and moderate to high consequence rating. The lower system is more sensitive to high flow and sedimentation related disturbance as a result of agricultural and flood protection related activities in this area. The peak flow and sedimentation hazards can be mitigated as described above and the riparian function hazard downstream of Nicklen Creek could be reduced by making others aware of the situation and opportunity for some improvement through the establishment of setbacks along active portions of the channel and establishment of mature native riparian vegetation in these areas. Some improvements have been made by the Village of Lumby and Fisheries and Oceans Canada (DFO) in this regard but more could be done to benefit fish in this area.

Risk with respect to failure of existing permitted and non-status road drainage infrastructure, damage to road prism related investments, and effect on other resource values range from moderate to very high at select sites as outlined in the road risk section. Most issues involve:

- structures on fan or floodplain features where damage is expected with lateral channel movement, use of high flow channels, and accumulations of sediment and debris at structure inlets, or
- under sizing with respect to flows and mobile sediment and debris, generally.

Issues can all be addressed by implementing recommendations provided in the road risk section. Options include relocating roads and crossings out of fan and floodplain areas, replacing existing structures with those more capable of passing expected flows with entrained sediment and debris, armouring to prevent erosion and diversion in the event of failure, and improving water management generally.

4.3 Expected Condition - Mountain Pine Beetle and Planned Development Scenarios

Lodgepole pine in the Harris Creek watershed is being affected by mountain pine beetle. Mortality levels have been low so far but ongoing attack is expected by BCTS and Tolko staff. To understand the potential for attack and likelihood of mortality, stand susceptibility was modelled using stand age, species composition, and biogeoclimatic zone considerations. Results indicate pine leading stands occupy approximately 17% of the watershed *[Appendix A]*. Of the total pine leading stands 68% are considered highly susceptible to some level of attack and mortality, 5% are considered moderately susceptible, and 27% have a low susceptibility. Approximately 60% of the moderate and highly susceptible stands are located below the snowline whereas 100% of the low susceptibility stands are found above the snowline. Low susceptibility stands are found typically in the Engelmann Spruce – Sub-alpine Fir Biogeoclimatic zone. Some mortality is expected in all areas affected by MPB and it is important to note that juvenile pine stands have not been included in the model based on limited susceptibility information.

The result of MPB infestation in Harris Creek will be a reduction in forest cover over time as dead pine become defoliated and eventually fall and deteriorate on the forest floor. Reductions will be offset by any non-pine overstory in the stand or understory that is released by the demise of pine. Regeneration within dead pine stands can also occur helping to offset the effects over time. Reductions in forest cover will result in increases in snow accumulation and snow melt rates in openings, making more water available for runoff earlier, and potentially increasing the frequency and magnitude of high flow events (i.e. peak flows) in the watershed and affected basins, particularly where reductions occur above the snow line. Water yield can also increase over the short to medium term as water use by trees is reduced as the stand is replaced. The opposite situation can also occur with reduced water yield over the medium to long term if large areas affected by pine regenerate at the same time creating a single dominant seral stage situation. In the latter case, large areas of young vigorous regeneration can be expected to uptake or use more water than that used by the older pre-MPB stand resulting in lower groundwater levels and less water available for runoff. Low flows can be affected by increased water use during the growing season which is an important consideration for fish.

Riparian areas can be affected by MPB if pine are present but the effect on channels is expected to be largely beneficial on channels larger than 1.5 m bankfull width provided accumulations of woody debris do not create hazardous situations with respect to jams, avulsions in fan or floodplain areas, and resources at stake. Riparian stands are usually mixed with pine being less abundant than other more moisture tolerant species.

Salvage of affected or potentially affected stands using clearcut or selective methods essentially expedites the reduction in forest cover making more water available for runoff in the short term but can also expedite the recovery process if sites are planted shortly after harvest. Salvage also requires the construction of new and use of existing forest roads. Salvage in riparian areas is not considered appropriate on streams larger than 1.5 m wide for reasons provided above and salvage in adjacent areas can result in wind related damage to management and reserve zones.

Un-salvaged scenario

Under the un-salvaged scenario MPB effects are allowed to progress through the Harris Creek watershed unchecked by salvage activity after December 31, 2009.

Hazards

Under the un-salvaged scenario riparian function within and downstream of the Harris Creek watershed should not be significantly affected. Hazard ratings will remain low for the watershed and basins, and high along that portion of Bessette Creek flowing through private land downstream of the Nicklen Creek confluence. Pine that is killed in riparian areas can contribute large woody debris to channels which is seen as a natural process; episodic in nature in fire and insect dominated stands. Non-pine species are common in riparian stands, particularly those in fan and floodplain areas.

The peak flow hazard for the watershed will remain in the moderate hazard category as a result of road drainage issues outlined above. Equivalent clearcut area (ECA) levels for the watershed above the snowline will remain low (<25%) for both moderate and full MPB attack situations under the un-salvaged scenario and are not the driver behind the peak flow hazard rating *[Figure 1]*.

In the basins the peak flow hazard in Mosquito Creek will also remain moderate based on the roads contribution. Very limited MPB effects on ECA will be realized in Mosquito Creek. In the Nicklen, McAuley, and West Harris basins ECA levels above the snowline will increase to moderate under the un-salvaged scenario (25-50% range)*[Figures 3, 4, 5]* resulting in a moderate peak flow hazard in the West Harris basin but low hazards in the Nicklen and McAuley basins. In the case of Nicklen Creek MPB effects on runoff and streamflow are expected to be well buffered by Nicklen Lake and other waterbodies on the main channel below the snowline. In the case of McAuley Creek effects are buffered by the licensed diversion to Heart Creek and massive debris flow deposit in the main valley *[Photo 1]* that acts as a storage mechanism for runoff, similar to a large floodplain or series of wetland and small lake complexes. West Harris Creek has

small lake and wetland complexes at upper elevation but MPB affected stands are downstream of this point and therefore expected to affect runoff and peak flow levels accordingly. Peak flow hazard ratings will remain low in the Home Creek and Upper Harris basins based on limited MPB susceptibility *[Figures 6, 7].*

From a sedimentation perspective only those sites affected by MPB related increases in runoff and streamflow both above and below the snowline can be expected to generate more sediment as a result of increased erosion or increased likelihood of structure failure and washout. The lower reaches of the West Harris basin and residual area between Nicklen and West Harris Creeks fit this description. There are numerous road sites and sections, permitted and non-status, in this area that are generating sediment as a result of drainage diversions, and failed or undersized drainage structures *[refer to road risk section – Appendix C]*. The result will be an increase in the sedimentation hazard rating in the West Harris basin to moderate to account for expected diversions and resulting scour at the Harris Southwest non-status road crossing on the fan, and possible structure blockage and erosion at the permitted Dustin Road crossing above. An increase in erosion and sedimentation is also expected in the affected portion of the residual, particularly that accessed by the McAuley FSR and spurs, but the effect will not be significant enough at the watershed level to justify an increase in the hazard rating. This is a concern for management of problem sites in large residual areas that are typically reported on at the watershed level only. Effective use of road risk information in this context *[Appendix C]* can address the issues in this area that are expected to have negative effects on fish.

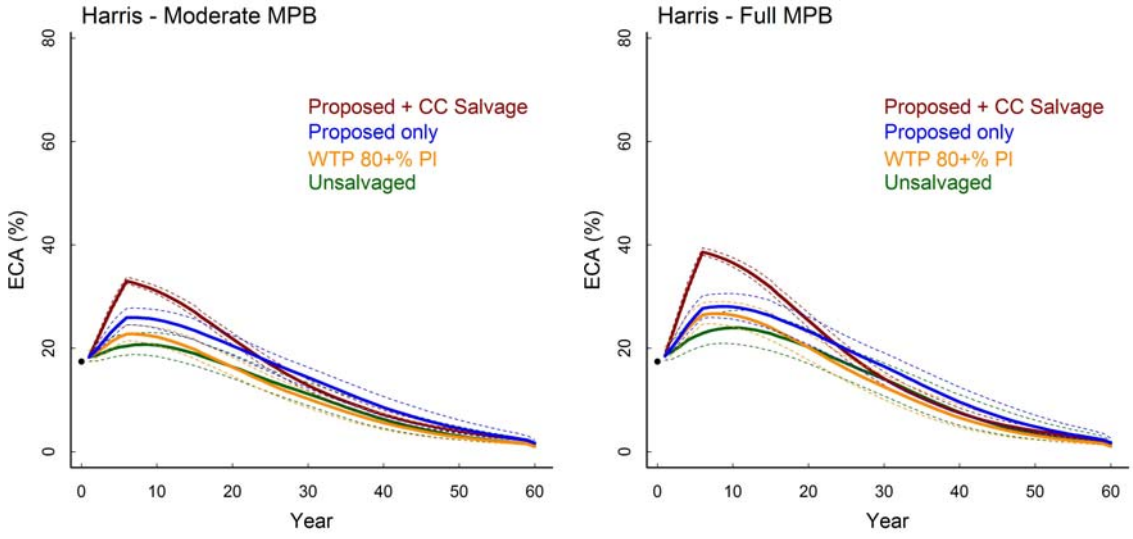

Figure 1. Equivalent clearcut areas for the Harris Creek watershed above the snowline under moderate and full attack situations for four scenarios – un-salvaged, WTP 80+%PI, Proposed only, and Proposed + clearcut (CC) salvage.

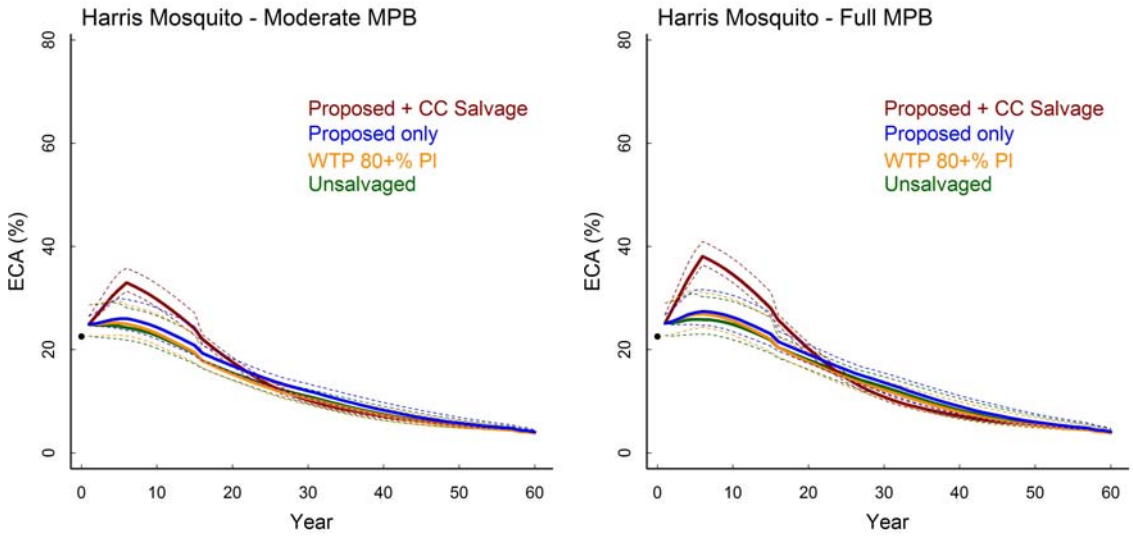

Figure 2. Equivalent clearcut areas for the Mosquito Creek basin above the snowline.

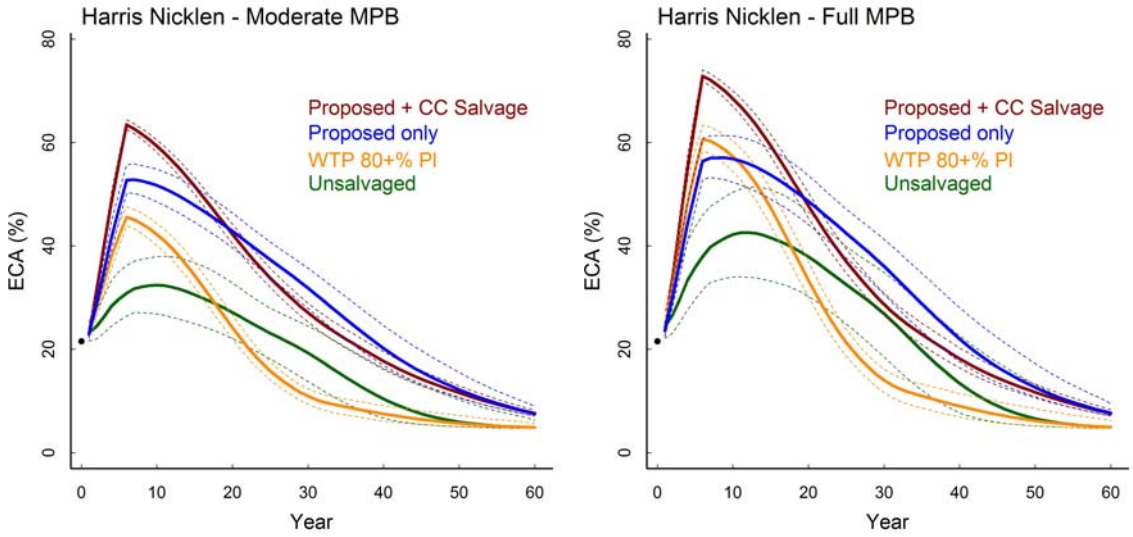

Figure 3. Equivalent clearcut areas for the Nicklen Creek basin above the snowline.

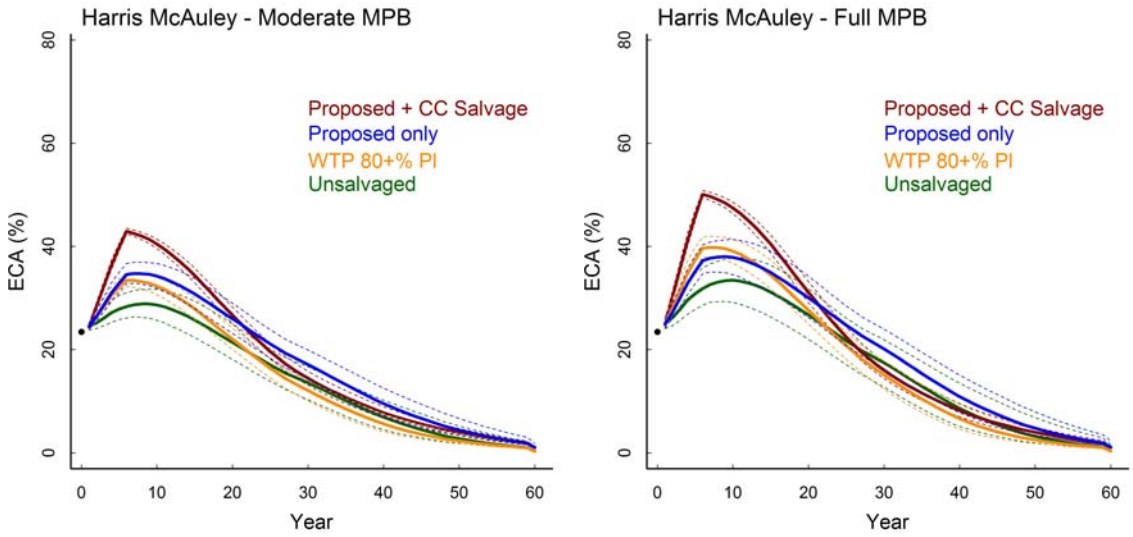

Figure 4. Equivalent clearcut areas for the McAuley Creek basin above the snowline.

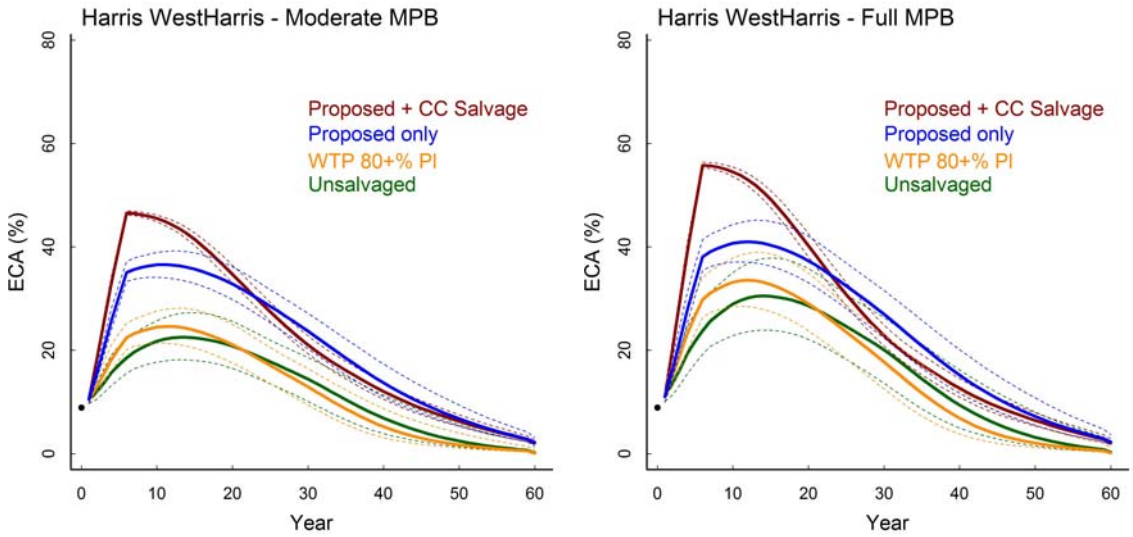

Figure 5. Equivalent clearcut areas for the West Harris Creek basin above the snowline.

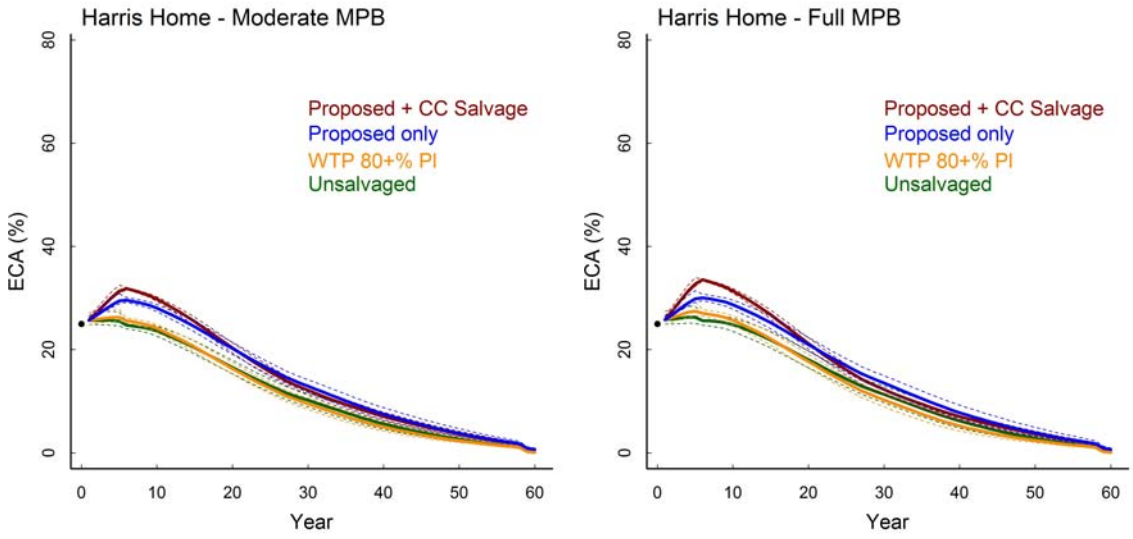

Figure 6. Equivalent clearcut areas for the Home Creek basin above the snowline.

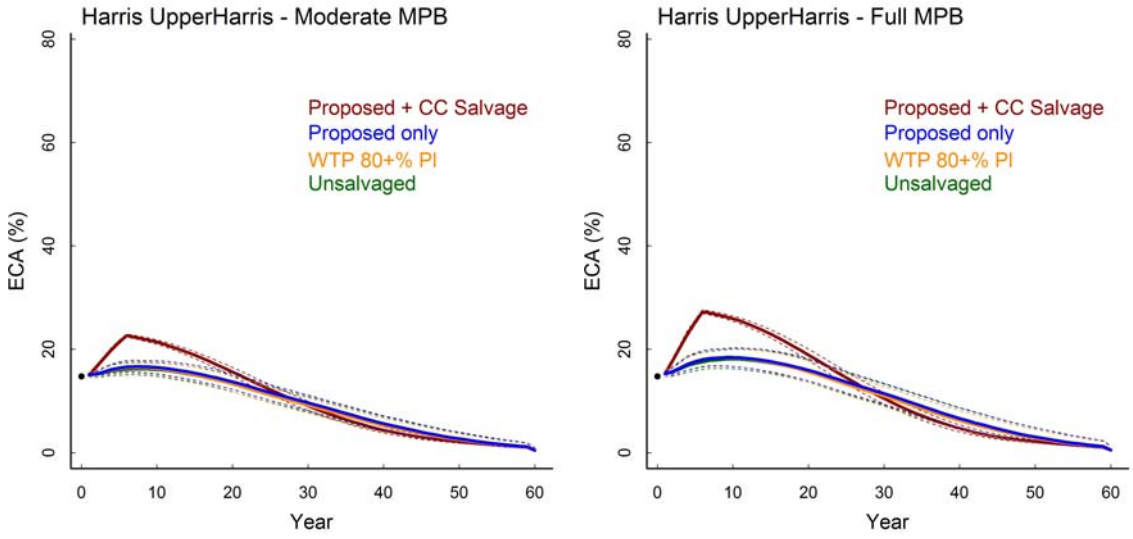

Figure 7. Equivalent clearcut areas for the Upper Harris Creek basin above the snowline.

Risk

The risk of negative effects on fish and fish habitat at the watershed level is high and not expected to change with MPB under the un-salvaged scenario. The risk of negative effects on fish in the West Harris basin and affected portion of the residual area is expected to increase to moderate based on increasing sedimentation and peak flow hazards in these areas. Sedimentation hazards can be mitigated by implementing recommendations in the road risk section but MPB effects on runoff and streamflow cannot. The best management practice in this situation is to ensure that road and road drainage infrastructure is capable of

passing expected flows with entrained sediment and debris, and that failure of existing structures does not result in major diversions of flow.

The risk of negative effects on public and private land and infrastructure downstream of the Nicklen Creek confluence is high and should not be affected by MPB under the un-salvaged scenario.

The risk of damage to permitted and non-status road infrastructure and associated resources can be expected to increase with MPB under the un-salvaged scenario where increases in runoff are expected. The West Harris basin and south side of the residual between Nicklen and West Harris Creeks will be most affected in this regard. Risk levels are site specific as outlined in the road risk section and can be addressed by implementing recommendations provided.

Proposed Development Plan Scenario

Under the proposed development scenario areas shown as proposed blocks on the overview map *[Apppendix A]* are clearcut with no retention; wildlife tree patch (WTP) or otherwise. This is considered a worst-case scenario from an ECA perspective as a minimum of 10% of the proposed blocks will be retained in WTP's.

Under the proposed scenario the key consideration is incremental effect(s) on water quality and quantity, as they relate to fish and fish habitat, which may result from primary forest activities. Other resource values also warrant some attention from a due diligence perspective including public and private land and infrastructure downstream of the Harris Creek watershed, and forest road infrastructure throughout the watershed.

Hazards

A total area of 1,200 ha or 5% of the watershed is proposed for development by BCTS and Tolko at this time; 700 ha of which is located above the snowline. Peak ECA levels for the watershed above the snowline are expected to be between 25 and 28% depending on the severity of MPB attack *[Figure 1].* The incremental increase in ECA with proposed development over the un-salvaged scenario is approximately 4.0%, considered to be within the margin of error for the analysis. For this reason, no incremental effect on peak flow hazard at the watershed level is expected with development as planned.

At the basin level, the effect of proposed development on ECA and peak flows is expected to be negligible in the Nicklen, Mosquito, Home, Upper Harris, and McAuley Creek basins. Effects are expected to be well buffered by lakes and wetlands in the case of Nicklen Creek and the diversion and debris flow deposit

in McAuley Creek. The amount of development planned is low in the other basins.

In West Harris Creek there will be a measurable increase in ECA with proposed development over the un-salvaged scenario but it will remain in the moderate range (25-50%). However, the peak flow hazard for the basin is expected to increase to high as a result of planned development in conjunction with basin aspect, configuration, and lack of lake or wetland areas downstream of planned blocks above the snowline. Small northerly aspect basins such as West Harris Creek are more sensitive to development related increases in peak flows as a result of their "flashy" nature. A similar situation is expected in the residual area to the west where several large blocks accessed by the McAuley FSR (K64F and K6A9) are planned in the headwaters of tributary channels. These potential peak flow hazards can be mitigated by reducing the amount of development planned above the snowline in both cases, particularly in low MPB susceptibility areas *[Appendix A].*

From a sedimentation perspective sites affected by MPB and planned development related increases in streamflow and/or increased road construction and use required for access reasons can be expected to generate and deliver more sediment to streams. Based on a review of planned development and the road risk map likely areas where an increase in road risk and sediment generation can be expected is as follows:

- McAuley FSR and spurs including Dustin, Dustin F, Brendan, Hannah, Mia, Amy, Amy West, and Southeast Harris non-status.
- Goat FSR around the Nicklen Creek crossing.
- Nicklen and Beetle FSR's and non-status spurs – some not assessed.
- South and Southwest Harris non-status.
- Jeffery and South Jeffery.

The additional input of sediment to streams is not expected to affect the moderate sedimentation hazard for the watershed, but is expected to increase the sedimentation hazard from moderate to high in the West Harris basin and residual between Nicklen and West Harris Creeks. This represents a potential incremental increase in sedimentation hazard over the un-salvaged scenario. The potential increase can be mitigated by reducing the amount of development planned above the snowline in the West Harris basin and residual area between McAuley and West Harris Creeks, particularly in low MPB susceptibility areas, and addressing downstream road related issues prior to or in conjunction with planned development *[Appendix C].*

The riparian function hazard for the watershed and basins should not be affected by planned development. Most of the blocks planned by BCTS and Tolko are located in mid to upper slope areas where streams are generally not fish bearing or small with limited riparian requirements from a stability perspective. Only one stream reviewed in the BCTS operating area - block K5SK - was determined to be large S6 in size (>1.5 m bankfull width) along which mature riparian vegetation is required for stability reasons. Block K6B6 also overlaps a portion of the mapped Harris Creek floodplain below the Nicklen FSR. Floodplain extent will need to be determined in this area with protection of mature timber on the active portion for short and long term stability and process related reasons. Two blocks in the Tolko operating area - LV1080 and LV1081 – are located in close proximity to the fish-bearing portion of Nicklen Creek along which mature riparian vegetation is also required for stability and fish habitat related reasons. Mapped fan and floodplain features *[Appendix A]* are good indicators of areas where retention of mature riparian vegetation is required for stability and process related reasons. Post harvest wind related damage should be an important consideration for any retention planned in riparian areas.

Risk

The risk of negative effects on fish and fish habitat at the watershed level is high but is not expected to be affected by planned development. For the West Harris basin, residual area between Nicklen and West Harris Creeks, and channels downstream the risk is currently moderate but expected to increase to high with planned development above the snowline. This is a potential incremental increase is risk based on expected increases in the peak flow and sedimentation hazards as a result of proposed development. Both peak flow and sedimentation hazards can be mitigated by reducing the amount of development planned above the snowline, particularly in low MPB susceptibility areas, and addressing downstream road related issues prior to or in conjunction with planned development. Planned development related effects on fish and fish habitat in the remaining basins are expected to be negligible.

The risk of negative effects on public and private land and infrastructure downstream of the Nicklen Creek confluence is high and should not be affected by planned development.

The risk of damage to permitted and non-status road infrastructure and effect on other resource values can be expected to increase with planned development where associated increases in runoff and sedimentation are expected. Specific roads and road sections of concern include:

- McAuley FSR and spurs including Dustin, Dustin F, Brendan, Hannah, Mia, Amy, Amy West, and Southeast Harris non-status.

- Goat FSR around the Nicklen Creek crossing.
- Nicklen and Beetle FSR's and non-status spurs – some not assessed.
- South and Southwest Harris non-status.
- Jeffery and South Jeffery.

5.0 RECOMMENDATIONS

The following recommendations are provided to address BCTS FSP and general stewardship obligations in the Harris Creek watershed.

5.1 Stewardship

- Complete the road risk analysis on non-status roads in the Harris Creek watershed using Forest Investment Account funds, then prepare prescriptions and undertake works on priority roads as soon as possible with a focus on those potentially affected by MPB and/or involve fish passage. The purpose of all FIA funded work in this case would be to reduce sediment production from non-status roads in the Harris Creek watershed, and ultimately the quality and quantity of fish habitat over the medium to long term.
- Notify the Ministry of Forests and Range and Tolko Industries Ltd. with regard to road risk related issues on FSR and otherwise permitted roads under their care in the Harris Creek watershed, negative effect on fish and fish habitat, and constraining effect that some are having on BCTS forest development activities.
- Make the Ministry of Forests and Range aware of range related contributions of sediment to fish bearing waters in the Harris Creek watershed specifically:
    - uncontrolled cattle access to channels,
    - old possibly abandoned corrals situated on streams, and
    - cattle related damage to small alluvial systems that renders them un-classifiable after use requiring reformation during subsequent freshet periods with measurable input of sediment to fish bearing and non-fish bearing channels.
- Notify Tolko Industries Ltd. of the requirement for mature timber for channel and fan stability, and fish habitat reasons along Nicklen Creek in the vicinity of proposed blocks LV1080 and LV1081.
- Make the Village of Lumby and Fisheries and Oceans Canada aware of past land-use related effects on the Bessette Creek fan and associated fish habitat between Nicklen Creek and the confluence with Duteau Creek, and

opportunities to improve conditions by establishing set-back reserves and re-vegetating riparian areas.

- Make the Village of Lumby and Regional District of the North Okanagan aware of the high risk of channel erosion and flooding related effects on public and private land and infrastructure on the Bessette Creek fan between Nicklen Creek and Duteau Creek, largely the result of past land-use related effects on the channel in this area, and opportunity to reduce potential effects on resources at stake by improving riparian function, restoring natural fan processes where possible, and improving bank protection generally.

5.2 Forest Management

- Review and implement treatments recommended in the road risk section *[Appendix C]* for FSR's under BCTS care on a priority bases to reduce actual and potential sediment production from roads and mitigate both current sedimentation and peak flow hazards and expected increases in sedimentation hazard and risk in areas affected by MPB and planned development.
- Retain and protect mature timber for channel stability and process related reasons along the large S6 channel in block K5SK, and wherever planned or future development encroaches on fan and floodplain areas. Fan and floodplain descriptions and management considerations are provided in Appendix B. Post harvest windthrow should be an important consideration for retention in K5SK and on fans and floodplains, generally.
- Determine the extent of the Harris Creek floodplain along the lower boundary of block K6B6 and retain and protect mature timber within and adjacent to the active portion for stability and process related reasons.
- Mitigate potential incremental increases in peak flow and sedimentation hazards associated with planned development in the West Harris basin and residual area between McAuley and West Harris Creeks by reducing the amount of development planned above the snowline, particularly in low MPB susceptibility areas, and addressing downstream road related issues prior to or in conjunction with planned development.
- Review Terrain Stability Mapping (TSM) information available for Harris Creek and in particular soil erodability information contained therein that identifies glacio-fluvial, glacio-lacustrine, and aeolian deposits that are highly susceptible to erosion and/or failure when affected by uncontrolled drainage in particular. Utilize this information in

conjunction with stability related information (typically Terrain Class IV and V polygons) to minimize the likelihood of major sediment inputs from erosion, slumps and slides in these soil/terrain types when conducting forest management activities in the watershed. Soil erodability is rated low through very high in TSM shapefiles under column "*sfcero_pot"* (surface soil erosion potential).

6.0 CLOSURE

This report dated March 2010 has been prepared exclusively for BC Timber Sales Okanagan-Columbia Business Area. M.J. Milne & Associates Ltd. accepts no responsibility for use of this document for purposes other than the management of forest and water related resources on behalf of BCTS in the Harris Creek watershed.

This concludes the hydrologic risk assessment of the Harris Creek watershed and proposed MPB salvage plans. We trust that the information contained herein is complete and consistent with the scope of work assigned to M.J. Milne & Associates Ltd.

Original is signed and sealed

Michael J. Milne M.E.S.
Watershed Hydrologist
ABCFP Limited Licensee #0004

Harris Creek - Hydrologic Risk Assessment Overview Map

Existing opening
Alluvial fan
Private land
Floodplain

Pine susceptibility to MPB attack and related mortality

High
Moderate
Low

Development planned by BCTS and Tolko

Terrain stability

Class IV
Class V

Streams

Confirmed fish bearing
Confirmed not fish bearing
No information

20 m contour

Expected snowline location at the time of peak flow (H50 - 1420 m)
Forest tenure boundary
Landslide

MJM 02/10

Harris residual
Nicklen
Mosquito
Home
McAuley
West Harris
Upper Harris

Bessette Creek
Nicklen Creek
Beatle Creek
Virdler Creek
Mosquito Creek
McAuley Creek
West Harris Creek
Upper Harris Creek
Home Creek
Nicklen Lake
Mosquito Lake

Tolko
BCTS

K6B6
K627
8672
K625
K6SG
K5SH
K5SK
8624
8625
8275
8627
8615
K5T7
K5T8
8616
K5T5
8271
8730
8224
8635
8636
8622
8620
8677
8678
8690
K68Y
K5SW
K5SV
K64F
K6A9
K6A8
8692
8707
8693
K6AC
8723
K673
K5SZ
K5T9
K5ZF
K5ZG

N
W
E
S

3 0 3 6 Kilometers

Alluvial Fan

Polygon Type	Description	Management considerations
Alluvial Fan	Conical-shaped landscape feature formed by the deposition of sand, gravel, cobbles, boulders and organic debris when confined streams enter a larger valley. Found most frequently in lower slope locations but can occur wherever small streams join larger channels, or streams flow into lakes or onto low gradient floodplain or terrace areas. Deposition on fans can be strictly alluvial (flowing water related), a combination of alluvial and debris flow related, or strictly debris flow related. Alluvial fans can have active and relic (inactive or historic) areas, with active areas normally incised into and smaller in extent than relic areas. Relic fans or portions of fans are normally stable, built during earlier periods when the watershed had either higher streamflows and/or sediment transport levels, or in the case of lake or marine deposition during higher stage periods (i.e. higher water levels). Numerous old, abandoned, or high flow (distributary) channels can be present in active fan areas that provide valuable fish habitat during high flow periods. It is important to note that fish may access these channels from their confluence with the larger valley bottom stream or water body. The active portion(s) of alluvial fans are sites of constant interplay between supply of water and sediment. Aggradation occurs if sediment load increases, gradually in the case of alluvial or fluvial action, rapidly in the case of debris flow deposition (either naturally or due to land-use activity). Degradation or scour occurs if sediment load is reduced. Aggradation is the primary cause of channel re-alignment or avulsion on fans. Both standing and downed trees and understory vegetation on fans and in fan channels play an important role in fan stability and the dissipation of energy; both flow and sediment related. Forest development on alluvial fans and within large woody debris contribution areas for fans can reduce channel bank and fan stability, restrict fish access, and increase both short and long-term erosion. Alluvial fans can be the most sensitive depositional feature on the landscape and if de-stabilized can take one full tree crop rotation (50 to 250 years) to recover depending on fan size, stream power, and sediment load.	**Goal:** Maintain short and long-term fan and fan channel stability and fish access to off-channel habitat areas. **Management:** The presence and extent of active fan and large woody debris contribution areas should be confirmed in the field and mapped prior to any road or cutblock layout. Little or no road and trail construction should occur within active fan areas. Road crossings on fan channels should be placed above or as close to the fan apex as possible (uppermost point where the tributary channel enters the larger valley). Where roads and trails are required on fans overland construction methods are recommended with careful route selection to minimize effects on fan drainage and fish access to off-channel habitat areas. Climbing and descending grades on fans should be avoided at all times. Crossings on active and high flow channels should be designed to contain flow and minimize erosion in the event of failure or overtopping of the road surface. Maintenance of un-logged stand characteristics should be the primary objective in active fan areas and within large woody debris contribution areas. Retention rates should range from 70% retention to full retention with a preference given to large trees. Where harvesting is considered, single tree selection, group selection, or small patch cuts are best suited to meet riparian stand structure requirements. Windthrow in large woody debris contribution and active fan areas should be an important consideration in any harvesting plans that are prepared within or near to these features.

Floodplain

Polygon Type	Description	Management considerations
Floodplain	Defined as the area adjacent to stream channels that is either inundated or saturated during high flow periods. Floodplains are normally bounded by a distinct break in slope and obvious transition in vegetation type. Floodplain deposits are alluvial (transported and deposited by flowing water) in nature and erodable if riparian vegetation is not present and/or functional. Floodplains typically contain many side channels, old channels, and other depressions that provide valuable fish habitat during high flow periods. Road construction in floodplain areas can restrict or prevent fish access to these habitat features. A stream channel can change course on its floodplain several times within a harvest rotation via active bank erosion and channel avulsion. Bank erosion and avulsion processes can be accelerated by forest harvesting that removes vegetation required for bank and floodplain stability. Standing and downed trees and understory vegetation on the floodplain play a critical role in reducing flood flow velocity, and reducing potential erosion and downstream sedimentation. Mature timber within a minimum of one tree length from the floodplain margin (referred to as the large woody debris contribution area) also plays a role in floodplain stability and erosion control. Floodplains are highly sensitive to disturbance and if de-stabilized, recovery may take up to one full tree crop rotation (50 to 250 years) depending on stream power, proximity to major sediment sources, and sediment load.	**Goal:** Maintain short and long term channel and floodplain stability, and fish access to off-channel habitat areas. **Management:** The extent of active floodplain and large woody debris contribution areas should be confirmed in the field and mapped prior to any road or cutblock layout. Little or no road and trail construction should occur within floodplain areas. Where roads and trails are required overland construction methods should be used with careful route selection to minimize effects on floodplain drainage and fish access to off-channel habitat features. Crossings on active channels should be designed to pass all flow with entrained sediment and debris, or fail in a safe manner such that sediment production and effects on natural drainage patterns are minimized. Fish are an important consideration in this regard. Maintenance of un-logged stand characteristics should be the primary objective on floodplains and within large woody debris contribution areas. Retention rates should range from 70% retention to full retention with a preference given to large trees. Where harvesting is considered, single tree selection, group selection, or small patch cuts are best suited to meet riparian stand structure requirements. Windthrow in large woody debris contribution areas and on the floodplain should be an important consideration in any harvesting plans that are prepared within or near to these features.

FSR Road Risk Table - Harris Creek

Basin	Road name	Length (m)	Status	Comments	Hazard	Resource at stake	Probability of hazard occurrence	Effect on resource at stake	Risk	Recommendation
Harris residual	MCAULEY MAIN	686	FSR	Road and crossing on active floodplain, no flood relief, diversion of large high flow channel in ditch, history of washouts.	Road washout, sediment input to fish stream, loss of access.	Fish habitat, road infrastructure, public safety, access.	H	H	VH	Relocate crossing and deactivate or provide flood relief, armour road prism and approaches on floodplain.
Mosquito	HOME MAIN	926	FSR	Undersized structure, mobile debris, unstable fill, landslide into Mosquito Creek.	Landslide, road washout.	Water quality, fish habitat, road infrastructure.	H	H	VH	Stabilize road prism, improve water management, install span structure.
Nicklen	GOAT MAIN	912	FSR	Steep downhill approaches, significant input of fine sediment to fish stream. Chronic.	Road erosion, sediment input to fish bearing waters.	Water quality, fish habitat.	H	H	VH	Relocate and deactivate existing or surface with competent materials and maintain.
Harris residual	UPPER VIDLER	718	FSR	Drainage diversion and concentration onto steep slope, slump into Vidler Creek.	Landslides into stream, sediment input to fish bearing waters.	Water quality, fish habitat.	H	M	H	Restore and maintain natural drainage on approaches.
Harris residual	MOSQUITO MAIN	786	FSR	Potential for concentrated flows down onto Class IV and V terrain adjacent to Harris Creek.	Drainage concentration on steep slopes, landslides into mainstem.	Water quality, fish habitat	M	H	H	Review and maintain regularly to prevent any drainage diversion.
Harris residual	NICKLEN MAIN	2256	FSR	Floodplain crossing, good span but no flood relief on approaches.	Road of road prism, sediment input to fish stream.	downstream fish, road infrastructure, public safety,	H	M	H	Relocate crossing and deactivate existing or provide flood relief structures and armour prism on floodplain.
Harris residual	HARRIS MAIN	913	FSR	Long ditch runs, potential to concentrate runoff onto Class IV and V terrain connected to fish streams.	Drainage concentration onto steep slopes, landslides into fish streams.	Water quality, fish habitat.	M	H	H	Install additional culverts to restore natural drainage pattern and maintain regularly.
Mosquito	HARRIS MAIN	3510	FSR	Upper high risk section. Uncontrolled drainage, supported fill, landslides into Mosquito Creek.	Landslides into fish stream	Water quality, fish habitat.	H	M	H	Stabilize road prism, improve water management and sediment control.
Mosquito	HOME MAIN	322	FSR	Blocked culvert causing diversion into Mosquito basin with significant scour in recipient channel.	Channel erosion, road washout, sediment input to fish stream.	Water quality, fish habitat, road infrastructure.	H	M	H	Replace structure on Home Creek to restore natural drainage.
Harris residual	MCAULEY MAIN	2724	FSR	Recent upgrade, insufficient culverts, road erosion, culverts failing.	Road erosion, sediment input to tributaries	Water quality, downstream fish habitat.	H	M	H	Improve water management and maintain, or deactivate.
Harris residual	BEETLE MAIN	9672	FSR	Diversions above Class IV terrain, not maintained, flow increased in some draws.	Erosion, landslides onto Harris floodplain or into tributaries.	Water quality, fish habitat.	M	H	H	Improve water management and maintain or deactivate.
Mosquito	HARRIS MAIN	1726	FSR	Lower high risk section. Long ditch runs, potential to concentrate runoff onto Class IV and V terrain connected to fish streams.	Drainage concentration onto steep slopes, landslides into fish streams.	Water quality, fish habitat.	M	H	H	Install additional culverts to restore natural drainage pattern and maintain regularly.
Mosquito	N 1031.15 (HARRIS CREEK BR22.5	692	FSR	Waterbars failing, water on road, sediment input to tributary.	Erosion, sediment input to streams.	Water quality, fish habitat.	H	L	M	Improve water management or deactivate.

FSR Road Risk Table - Harris Creek

Basin	Road name	Length (m)	Status	Comments	Hazard	Resource at stake	Probability of hazard occurrence	Effect on resource at stake	Risk	Recommendation
Harris residual	HARRIS MAIN	623	FSR	Surface erosion on approaches in large draw with input to downstream fish habitat.	Surface erosion, impaired water quality.	Water quality, fish habitat	H	L	M	Improve water management and sediment controls on approaches.
Harris residual	HARRIS MAIN	2120	FSR	Dry but low culvert frequency, diversions to low spots above large bank failures into Harris Creek. Suspicious.	Drainage concentration onto Class IV and V slopes, possible landslides.	Water quality, fish habitat	L	H	M	Improve culvert frequency to ensure all draws are piped. Review and maintain frequently.
Mosquito	MOSQUITO MAIN	2645	FSR	Potential for drainage diversion above steep slopes. Low risk if maintained.	Drainage diversion, slumps or slides into streams.	Water quality, fish habitat.	L	H	M	Review and maintain regularly.
Mosquito	HARRIS MAIN	822	FSR	Water on road, erosion, sediment input to Mosquito Creek.	Erosion, sediment input to fish bearing waters.	Water quality, fish habitat.	H	L	M	Improve water management.
Harris residual	BEETLE MAIN	189	FSR	Culvert on large S6 with mobile sediment and debris.	Blockage, erosion of crossing.	Water quality, road infrastructure.	H	L	M	Maintain regularly or replace with suitable open bottom structure.
Harris residual	WYPER MAIN	306	FSR	Culvert on large S6 with mobile sediment and debris.	Eventual blockage with erosion of crossing.	Water quality, downstream fish habitat.	M	L	M	Review and maintain regularly or replace with suitable open bottom.

Harris Non-status Road Risk

Basin	Road name	Length (m)	Status	Comments	Hazard	Resource at stake	Probability of hazard occurrence	Effect on resource at stake	Risk	Recommendation
Harris residual	HARRIS SOUTHEAST NS	1760.506	NS	Two major fan crossings, one diversion, several landslides into Harris Creek.	Diversions, road scour, landslides into mainstem.	Water quality, fish habitat	H	H	VH	Deactivate non-status road.
Harris residual	SOUTH HARRIS NS	4670.051	NS	NSR on unstable terrace. Multiple slides into Harris Creek , fan crossings, erosion, more to come.	Landslides into mainstem, road erosion.	Water quality, fish habitat.	H	H	VH	Deactivate non-status road system - numerous spurs not assessed.
Nicklen	Nick PRV	3702.994	NS	Old roads on private land, poor water management, multiple slides and erosion into Nicklen and Harris Creeks. Some sections non-status.	Landslides, road erosion.	Water quality, fish habitat.	H	H	VH	Deactivate non-status portions, make landowners aware of other issues.
Harris residual	SOUTHWEST HARRIS NS	1120.924	NS	Floodplain and terrace road, will affect Harris, diversion from tributary onto road causing slides.	Landslides into tributary, diversion on Harris floodplain, road erosion.	Water quality, fish habitat.	H	H	VH	Deactivate non-status road system.
Harris residual	SOUTHWEST HARRIS NS	1495.261	NS	Diversions above Class IV terrain, erosion.	Landslides into tributary and sediment input to streams.	Water quality, fish habitat.	M	H	H	Deactivate non-status road.
Harris residual	UPPER AMY	558.123	NS	Culvert failed, flow through back-up, insufficient size, diversion down road likely.	Diversion, road erosion, sediment input to streams.	Water quality, downstream fish habitat.	H	M	H	Upgrade and maintain or deactivate.
Harris residual	HARRIS FLOOD 1	807.313	NS	Floodplain channel, diversion onto road likely, will result in concentrated flows and scour.	Road on active floodplain, will concentrate water and erosion with diversion.	Fish habitat, water quality	H	M	H	Deactivate by restoring natural high flow channels through road to prevent diversion.
Harris residual	HARRIS FLOOD 2	197.438	NS	Floodplain channel, diversion onto road likely, will result in concentrated flows and scour.	Erosion and scour on floodplain.	Fish habitat, water quality.	H	M	H	Deactivate by restoring high flow channels through old road prism.
Harris Residual	AMY	144.710	NS	Large fill, small culvert, and small backup. Will fail and erode fill.	Road erosion, sediment input to tributary.	Water quality, downstream fish habitat.	H	M	H	Upgrade and maintain or deactivate properly.
McAuley	DENIS NS	388.089	NS	Uncontrolled drainage on terrace, road approaches on floodplain.	Slumps onto floodplain, erosion of approaches.	Water quality, fish habitat.	H	M	H	Deactivate the non-status road, removal all fill from floodplain.
McAuley	MCAULEY NORTHWEST	546.536	NS	Diverted S6 down to terrace, landslide onto floodplain.	Landslides on McAuley floodplain	Water quality, fish habitat.	H	M	H	Deactivate non-status road system. Numerous other NS spurs not assessed.
Harris residual	PRV 2	345.933	NS	Old trail on private land, diversion down to headscarp of large failure into Harris Creek. May be old NSR.	Drainage concentration on terrace, large failures into Harris Creek.	Water quality, fish habitat.	M	H	H	Make landowner aware of issue, recommend deactivation. Work may be FIA fundable.
Upper Harris	H100 NS	187.812	NS	Barrier to fish passage from Snowy River report. Washed out crossing, still eroding.	Road erosion, sediment input to stream.	Water quality, downstream fish habitat.	H	M	H	Deactivate properly, armour, and close to all vehicles.
Nicklen	WEST NICKLEN NS	1089.037	NS	Water on road, erosion.	Erosion, sediment input to streams.	Water quality, downstream fish habitat.	M	M	M	Deactivate non-status road.
Nicklen	WEST NICKLEN NS	118.040	NS	Crossing blown out for unknown reason, minor sediment input.	Road erosion, sediment input to tributary.	Water quality, downstream fish habitat.	M	L	M	Armour crossing and investigate cause.
Nicklen	NICKLEN NS	2100.797	NS	Temp deactivation poorly done. Waterbars failing, on or near floodplain.	Road erosion, sediment input to streams.	Water quality, downstream fish habitat.	M	M	M	Improve deactivation.
Harris residual	MIA	227.187	NS	Culvert not backed up in draw, limited flow but will fail over time.	Road erosion, sediment input to tributary	Water quality, downstream fish habitat.	M	L	M	Deactivate.
Harris residual	AMY WEST	606.906	NS	Waterbarred, culverts still in place, will fail and erode over time.	Road erosion, sediment input to tributary	Water quality, downstream fish habitat.	M	L	M	Deactivate
Harris Residual	AMY	2012.848	NS	Temporary deactivation, culverts still in place, failing.	Road erosion, sediment input to tributaries	Water quality, downstream fish habitat.	M	M	M	Upgrade and maintain or deactivate properly.

Harris Non-status Road Risk

Basin	Road name	Length (m)	Status	Comments	Hazard	Resource at stake	Probability of hazard occurrence	Effect on resource at stake	Risk	Recommendation
Harris residual	NORTH HARRIS NS	752.816	NS	Steep supported fill in draws above FSR.	Slumps or slides onto FSR below.	FSR	L	M	M	Pullback fill in draws to stabilize road prism, recreational and range access would be lost.
Mosquito	VIDLER EAST NS	1162.911	NS	Drainage concentrated on running surface, erosion down to FSR. Stressing FSR infrastructure.	Surface erosion, sediment input to streams.	Water quality, fish habitat.	H	L	M	Deactivate.
Home	JEFFERY NS	1270.949	NS	Failing waterbars, erosion, sediment input to streams.	Erosion, sediment input to streams.	Water quality, downstream fish habitat.	M	M	M	Deactivate properly.
Harris residual	MID BEETLE NS	200.484	NS	Culvert on large S6 not backed up, will erode prism.	Road erosion, sediment input to stream.	Water quality, downstream fish habitat.	M	L	M	Back up culvert and armour or deactivate.

Tolko Road Risk Table - Harris Creek

Basin	Road name	Length (m)	Status	Comments	Hazard	Resource at stake	Probability of hazard occurrence	Effect on resource at stake	Risk	Recommendation
Harris residual	JEFFERY	102.269	RP	Undersized crossing on fan, sediment input from approaches.	Erosion, road washout, sediment input to fish-bearing waters.	Water quality, fish habitat, road infrastructure.	H	H	VH	Close and relocate or upgrade to span with revised approaches.
Harris residual	J100	651.261	RP	Diversion down to unstable slopes above Harris Creek.	Erosion, landslides into mainstem channel.	Water quality, fish habitat.	H	H	VH	Improve water management or deactivate properly.
Harris Residual	SOUTH JEFFERY	2313.855	RP	Built on terrace above Class IV and V terrain, drainage concentration, landslides into mainstem.	Landslides into Harris Creek	Water quality, fish habitat.	H	H	VH	Close and relocate with deactivation of all spurs, or improve water management and stability.
West Harris	DUSTIN	1530.827	RP	Failing cutslopes and drainage infrastructure, concentration onto steep slopes likely, one slump already.	Landslide into West Harris Creek, possible debris flow or debris flood to fan.	Water quality, fish habitat, downstream road infrastructure.	H	H	VH	Improve and maintain drainage infrastructure or deactivate.
Mosquito	SOUTH MOSQUITO	1779.971	CP	Failing waterbars, diversions above Class IV and V terrain.	Landslides into Mosquito Creek	Water quality, fish habitat.	M	H	H	Improve water management or deactivate properly.
McAuley	DENIS	318.739	RP	Small diversion on terrace caused slide onto McAuley floodplain. Uncontrolled drainage.	Drainage diversion on terrace, slides onto floodplain.	Water quality, fish habitat.	H	M	H	Improve water management and maintain or deactivate.
Harris residual	DUSTIN F	335.304	RP	Main crossing failing, will erode prism or divert on fan.	Road erosion, diversion on fan.	Water quality, fish habitat.	H	M	H	Deactivate
Mosquito	BEAR	168.315	RP	Crossing stressed by increase in flow from Home Creek diversion above and sediment accumulation.	Road washout, sediment input to fish stream.	Water quality, fish habitat, road infrastructure.	H	M	H	Restore diversion above and replace crossing as required.
Upper Harris	H-100	2196.777	RP	Failing waterbars, uncontrolled drainage above steep slopes, one landslide known, trails below.	Erosion, landslides into large Harris tributary.	Water quality, fish habitat.	M	H	H	Improve water management or deactivate properly.
West Harris	DUSTIN	510.007	RP	Temporary, undersized crossing channel with mobile sediment and debris. Designed to fail with minimal effect on water quality according to Terratech.	Washout, sediment input to fish stream.	Water quality, fish habitat, road infrastructure.	H	M	H	Deactivate as per plan or replace with larger span for longer term use.
Harris residual	DUSTIN	3911.360	RP	Gentle over steep area, diversions occurring or likely in future. One landslide into Harris Creek from culvert discharge onto non-status road below.	Drainage diversion, landslides into West Harris and Harris Creeks.	Water quality, fish habitat.	M	H	H	Maintain infrastructure or deactivate.
Harris residual	BRENDAN	148.928	RP	Culvert on large S6 with mobile debris, will fail and erode prism.	Road erosion, sediment input to tributary.	Water quality, downstream fish habitat.	M	M	H	Replace with span capable of passing expected materials or deactivate.
Nicklen	NICKLEN	2874.204	RP	Poor water management, water on road, erosion, diversion above steep slopes.	Road erosion, possible slides onto Harris floodplain.	Water quality, fish habitat.	M	H	H	Improve water management and maintain or deactivate.
Upper Harris	RYAN SOUTH	1777.197	CP	Failing waterbars, water on road, sediment input to tributary.	Road erosion, sediment input to streams.	Water quality, downstream fish habitat.	M	M	M	Improve water management or deactivate properly.
Upper Harris	H-300	301.983	DEL	Good metal span but active channel with mobile debris.	Eventual blockage with erosion of approaches.	Water quality, fish habitat.	M	M	M	Maintain or deactivate.
Upper Harris	H-300	1165.341	DEL	Good code road but not maintained, long term erosion hazard.	Erosion, sediment input to tributary.	Water quality, downstream fish habitat.	L	M	M	Maintain or deactivate.

Tolko Road Risk Table - Harris Creek

Basin	Road name	Length (m)	Status	Comments	Hazard	Resource at stake	Probability of hazard occurrence	Effect on resource at stake	Risk	Recommendation
McAuley	MARY	1571.315	RP	Limited runoff but culverts not backed up above steep slope coupled to McAuley floodplain.	Drainage diversion above steep slopes, road erosion.	Water quality, fish habitat.	M	L	M	Maintain or deactivate.
Mosquito	UPPER MOSQUITO WEST	219.667	RP	Diversion down running surface, erosion, sediment input to Mosquito Creek.	Erosion, sediment input to fish bearing waters.	Water quality, fish habitat.	H	L	M	Improve water management or deactivate.
Harris residual	JEFFERY	671.622	RP	Failing waterbars, water on road, sediment input to streams	Erosion, sediment input to streams.	Water quality, downstream fish habitat	M	M	M	Deactivate properly.
Mosquito	MAX	171.181	RP	Surface erosion, sediment input to tributary.	Erosion, sediment input to fish bearing waters.	Water quality, fish habitat.	H	L	M	Improve water management and sediment controls.
Mosquito	UPPER MOSQUITO NORTH	506.042	RP	Water on road, erosion, sediment input to Mosquito Creek.	Sediment input to fish bearing waters.	Water quality, fish habitat.	H	L	M	Improve water management or deactivate.
Mosquito	UPPER MOSQUITO EAST	1953.481	RP	Uncontrolled drainage, erosion, sediment input to Mosquito Creek.	Erosion, sediment input to streams.	Water quality, fish habitat.	H	L	M	Improve water management or deactivate.
Mosquito	SOUTHEAST MOSQUITO	1160.615	RP	Erosion on grades, close to Mosquito Creek.	Sediment input to fish stream	Water quality, fish habitat.	M	M	M	Improve water management or deactivate properly.
Upper Harris	NORTH JEFFERY	726.506	RP	Waterbars failing, erosion, sediment input to streams.	Erosion, sediment input to streams.	Water quality, downstream fish habitat.	M	M	M	Deactivate properly.
Home	H-100	721.077	RP	Drainage diversion, erosion down to crossing, sediment input to stream.	Erosion, sediment input to stream.	Water quality, downstream fish habitat.	H	L	M	Improve water management or deactivate.
Upper Harris	UPPER HARRIS	113.407	RP	Old log stringer bridge on floodplain, abutments failing.	Erosion around abutments, sediment input to resident fish habitat.	Water quality, fish habitat, road infrastructure, access.	M	L	M	Repair and maintain or deactivate.
Upper Harris	UPPER HARRIS	116.630	RP	Log bridge	Eventual collapse	Access, public safety	H	L	M	Maintain or deactivate.
Upper Harris	UPPER HARRIS	140.548	RP	Log bridge, sediment input from approaches.	Eventual collapse.	Access, public safety, water quality	H	L	M	Maintain or deactivate.

Harris Creek - Road Risk Map

Road status

- FSR
- RP/CP
- NSR

Road risk

- Very high
- High
- Moderate
- Low
- Not assessed

Private land

Alluvial fan

Floodplain

Pine susceptibility to MPB attack and related mortality

High | Moderate | Low

Development planned by BCTS and Tolko

Terrain stability

Class IV | Class V

Streams

- Confirmed fish bearing
- Confirmed not fish bearing
- No information
- Forest tenure boundary

20 m contour

Landslide

MJM 02/10

Harris residual

Nicklen

Mosquito

Home

McAuley

West Harris

Upper Harris

Nicklen Lake

Mosquito Lake

Home Creek

Mosquito Creek

Vidler Creek

McAuley Creek

West Harris Creek

Upper Harris Creek

Bessette Creek

Nicklen Creek

Beetle Creek

3 0 3 6 Kilometers

Photo 1. Large natural landslide and debris flow deposit in McAuley basin. Sediment input to McAuley Creek may have been significant at the time of occurrence but ongoing sediment production is negligible.

Photo 2. Recent landslide off of Harris Southwest non-status road from culvert discharge on Dustin Road above.

Photo 3. One of several landslides into Harris Creek or tributaries from non-status roads built in or on glacio-fluvial and glacio-lacustrine terraces in the residual area. In this case South Harris non-status road. Drainage infrastructure is failing resulting in diversions into unconditioned areas connected to channels. In other areas oversteepened or supported fill is failing resulting in landslides into channels and onto the Harris Creek floodplain.

Photo 4. Erosion in glacio-fluvial terrace materials below culverts on Jeffery and South Jeffery Roads. Drainage is diverted and concentrated on these sites from roads leading down to or built on the terrace.

Photo 5. Section of the Jeffery and South Jeffery roads showing fine textured glacio-fluvial deposits, erosion, and headscarp of slide at left. Maintenance of infrastructure is very difficult in this material type without significant armour or bioengineering application. Alternate locations are preferred with restoration of natural drainage on and above and re-contouring.

Photo 6. Scoured fan channel and infilled culvert on Dustin F road. The structure is backed up with a water bar but not armoured. The road prism will washout when the structure fails and flow may escape down the road to the southwest. Downstream of the crossing the stream has diverted down the Harris Southwest non-status road resulting in significant scour and sediment input to Harris Creek. Situation typical of road crossings on fan.

Photo 7. Failed Denis non-status road crossing on McAuley Creek floodplain. Approaches are built from alluvial material, are restricting floodplain processes, and will continue to erode over time with input to the channel.

Photo 8. Blocked culvert at Home FSR crossing on Home Creek. Flow is diverted down the ditch from this site and into the Mosquito basin where increased discharge is scouring channels, increasing sedimentation levels, and stressing downstream road infrastructure.

Photo 9. Recent slump off of upper switchback on Dustin Road above West Harris Creek. Cutslopes and drainage infrastructure are failing in this area resulting in drainage diversion onto Class IV terrain.

Photo 10. Brendan Road crossing on large S6 channel in residual with mobile sediment and debris. Culverts on channels like this are prone to failure as a result of sediment and debris accumulations at the inlet. Oversized culverts or open bottom structures are more appropriate in these cases.

Photo 11. Failed culvert at Upper Amy non-status road crossing on tributary in residual. Flow is moving through waterbar but diversion down the road is likely with ongoing erosion and both range and recreational use.

Photo 12. Washed out H100 non-status road crossing on Upper Harris tributary. The site is a source of sediment to fish bearing waters, a barrier to fish passage, and eligible for deactivation using FIA funds.

Photo 13. Old or abandoned corral situated on Vidler Creek upstream of resident and anadromous fish and fish habitat. Evidence of recent cattle access to the channel.