

Upper Adams Watershed Risk Analysis

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1.0 INTRODUCTION

At the request of Mr. Toby Jeffreys of Gilbert Smith Forest Products Ltd. (Barriere), Forsite Consultants Ltd. (Forsite) was retained to carry out an overview risk analysis for the Upper Adams River Watershed Area. This watershed is located in the Clearwater Forest District, and is bounded by the Finn Creek, Carman Creek, Cedar Creek, bear Creek and Storm Creek watersheds. The area is a residual watershed unit, and as such has no POI. The study area is located north of Tumtum Lake, on the west side of the Adams River – as shown in the overview map in Figure 1 below.

The objective of this project is to complete a risk assessment for each road segment in the study area, in an attempt to quantify current risks and to identify areas of high risk which would impact future forest development. Risk in the context of this project pertains to landslides resulting from forest or other resource development, surface erosion and sediment delivery to streams as a result of landslides or erosion events

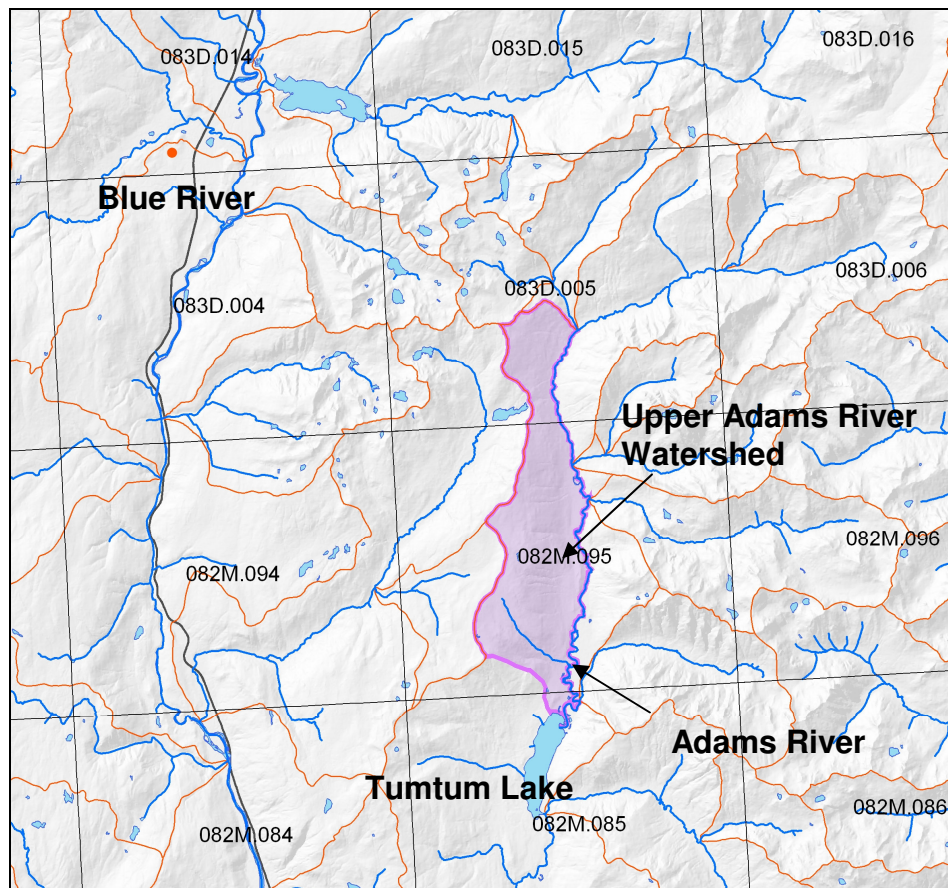


Figure 1 – Location Key Map of Study Area

1.1 PHYSIOGRAPHY

The study area is located in the Columbia Mountains physiographic region. The topography is steep, ranging between 680m to 1900m at the upper elevations of the watershed. Bedrock in the area is mapped as

Proterozoic to Palaeozoic undivided metamorphic rock of the Shuswap Assemblage, to Upper Proterozoic coarse clastic sedimentary rocks of the horse creek and mica Creek Successions. Field observations revealed metamorphic bedrock, primarily gneiss in the southern portion of the watershed - this bedrock is generally not highly permeable. In the northern portion of the watershed, a more fractured and permeable meta-sedimentary bedrock material was observed.

Surficial materials in the study area are primarily sandy till deposits and glaciofluvial materials. The U-shaped valley exhibits the typical characteristics of glaciation, with deposits of till and colluvium on the valley sides, and accumulations of till and silty-sand fluvial materials on the flat valley bottom.

1.2 CLIMATE AND HYDROLOGY

The study area is located in the Columbia Mountains Hydrologic Zone 13. The watershed is mapped as being primarily within the ICH vk1 biogeoclimatic zone variant with some ICH wk1 in the southern portion of the study area adjacent to Tumtum Lake, and with higher elevations (undeveloped) in the ESSF wc2 variant.

The Upper Adams River Watershed is a 'residual area' covering an area of approximately 5800 ha. The Adams River is classed as S1 in the study area, with tributary streams classed as S5 or S6, with the mouths of streams mapped as S3 adjacent to the Adams River.

Soils were generally found to be well to rapidly draining.

1.3 NATURAL SLOPE INSTABILITY

Due to the steep topography, generally rapidly draining soils and sandy surficial materials, a number of the creeks in this area were found to have significant recent debris flow/flood events. Sites are described in detail below. None of these events appeared to be linked directly to the forest development – most of which has taken place in the lower elevations of the watershed. Development on steeper upper slopes is much more recent. Air photo analysis shows that debris flow events pre-date development on the upper slopes.

There are a number of snow avalanche paths that descend from a ridge on the west side of the watershed, that extend down to the valley bottom. These are natural events that periodically deposit significant snow, coarse woody debris and sediment into the Adams River and it's immediate tributaries. Forest harvesting in areas adjacent to and downslope of these natural avalanche paths may have resulted in an increase in the amount of material delivered to the Adams River.

3.0 METHODOLOGY

This study was completed in 4 phases. The first phase involved a review of approximately 1:20000 scale air photos of the study area (photos are stereo coverage, flown in 1997) Initial potential assessment sites were identified, as well as a general overview of geomorphological processes and landforms. The air photo review part of this study identified both naturally occurring sediment sources and potential areas of instability as well as those attributable to forest development. For the purposes of the risk assessment only those sediment sources or potential areas of instability related to forestry or other land use development were assessed as these are the only sites where restoration work will eventually be proposed. However, the existence of natural sediment sources within a particular drainage was considered when assessing the risk to a stream from forest

development related sediment sources or landslide hazards.

The second phase involved a review of base mapping to identify large or obvious sediment sources as well as identification of road sections located on terrain mapped as potentially unstable or unstable. The base map contained the following information:

- Black / White Orthophoto (approximate year: 2001)
- Elevation Contours and “slopes over 60%” layer.
- Hydrology – Streams with classification, lakes, wetlands
- Terrain Stability mapping - including terrain stability hazard class (TSHC), Soil erosion potential class, and soil drainage classification.
- Roads layer
- Cutblocks and logging history
- Bedrock Geology

The ortho photo, cutblock and road overlays are more recent than the airphotos (Orthophoto 2001, block and road mapping 2006), and helped to identify more potential assessment sites, particularly in areas of new development. In this phase, terrain mapping and elevation contours were used to produce and refine estimates of hazard and runout potential. Stream classification was used to determine locations of consequence elements.

Long profiles of the Adams River, and of major streams which either support debris flows or may otherwise deliver sediment downstream to fish bearing reaches in the area were developed concurrently to gain an understanding of stream channel geometry and identify stream reaches where sediment sources would have the largest impact in terms of downstream transport. These long profiles are attached in Appendix A.

Following this office-based review, a draft map and spreadsheet report of the potential assessment site was submitted to Mr. Toby Jeffries of Gilbert Smith Forest Products Ltd., and a telephone discussion with Mr. Jeffries was conducted to confirm assessment sites and to identify additional potential sites. Refinements to the sites were made accordingly to prioritize field sites for inspection.

Third, a field review was conducted of identified sites and road sections. During the ground truthing a number of the sites identified in the overview assessment were dropped and additional new sites were added. It was found that in this particular area many of the existing landslides/debris flows or sediment sources were too small to be recognizable on air photos.

Fourth, the airphoto analysis, mapping information and field investigation results were combined to produce a final risk analysis for point sites and road sections within the study area (see section 3.1 below for risk analysis procedure). The results of the analysis are presented in tabular format in tables 1,2 and 3 below, and are mapped on Figure 2 (attached).

3.1 RISK ASSESSMENT PROCEDURE

This project involved the completion of a partial risk analysis (MOF 2004). Partial risk analysis involves determining the likelihood of occurrence of a landslide or erosion event and that event being a hazard to and directly or indirectly reaching or otherwise affecting a specific value at risk. Partial risk analysis is not a measure of the expected degree of damage to a specific value. For example where we have identified a landslide hazard from a particular road section we have estimated the potential runout and magnitude of such a slide. If it is likely that that slide may runout to a stream with known fish habitat we have not determined the

degree of damage that such a landslide would have on the fish habitat, only that the slide may impact it. And deliver a certain amount of sediment and debris.

In some cases to make informed decisions, it may be necessary to also consider the value or cost of values at risk. Specific or total risk analysis involves partial risk analysis, together with estimates of the degree of harm or loss to a given value or set of values if the landslide or erosional event does occur. For the purposes of this risk assessment (prioritizing sites for FIA funded deactivation or environmental maintenance) a partial risk analysis was determined to be suitable.

4.0 GENERAL OBSERVATIONS

No significant landslide events were observed in the area during this study that were a result of road construction or forest harvesting. Older harvesting was limited to the valley bottom, and easily accessible timber on relatively gentle slopes. The main access road (the Finn-Tum Mainline) is located primarily on moderate to gentle side slopes. The lower road system, where located in close proximity to the Adams River and fish-bearing portions of its tributaries, has the highest hazard of sediment delivery.

Newer timber development has accessed timber on steeper slopes in two areas: (1) In the southern portion of the watershed the 1350 road and associated spurs access a number of blocks (162-4,5,6 and 7). This road system is generally located on a large convex face. Soils are generally well drained sandy tills and colluvial materials over gneissic bedrock. Because of the well drained nature of the soils, generally only minor drainage accumulation was observed on the road system. The road system does not intersect any major streams, except the upper portion of the 1350 road – which has been recontoured. There is therefore very little connectivity between sediment production on the road system and any fish bearing streams.

(2) In the northern and central portion of the watershed, timber is accessed by the 1050 road system. This road system accesses timber on the uniform face unit situated above the Adams River. A number of streams drain this face. Because of the uniform slopes on this face, there is little opportunity for drainage accumulation, and drainage along the road system was found to be generally well dispersed. Soil materials again were found to be well drained sandy tills and colluvial materials. Sediment production along this road system was found to be low, with connectivity of sediment sources to fish bearing reaches of streams and the main stem being generally moderate to low, except in areas immediately adjacent to the main stream channels.

The primary hazard in these upper slope road systems is the potential for roads to intercept and divert surface and shallow subsurface flows, especially during freshet or extreme precipitation events, resulting in instability downslope in a ‘gentle over steep’ type of failure mechanism.

Silty sand road surface materials coupled with wet soil conditions at the toe of the slope along the southern portion of the face unit, (along the Finn-Tum mainline) is leading to significant sediment production on the road surface, resulting in aggradation in culverts and ditchlines, and direct sediment delivery to fish streams immediately downslope of the road.

There is considerable snow avalanche activity along the 1050 road – harvesting of blocks, notably block 33-5, may be facilitating avalanche runout and debris delivery to the Adams River. The extent of this effect however is not known and an avalanche assessment is beyond scope of this project. It is highly unlikely that the road system has any appreciable affect on sediment delivery to streams by avalanche activity.

5.0 RISK ANALYSIS

Airphoto and field investigations have revealed three different processes which result in risk to consequence elements (primarily delivery of sediment to fish bearing streams in the watershed). These are (1) risk of road related landslides (2) Sediment delivery to streams via road surface runoff, and (3) risk related to natural debris flow events.

5.1. PARTIAL RISK OF FUTURE ROAD-RELATED LANDSLIDES

No sites were identified in the study area where recent road-related landslides had occurred. Generally this can be attributed to well drained soil conditions, and generally the lack of a significant road system on steep and unstable slopes. The proportion of roads on steep, unstable or potentially unstable slopes is low. Most of the development in the area has taken place on lower slopes, with harvest and road building on the upper, steeper slopes in the watershed being much more recent.

Terrain mapping information, analysis of slopes and stream gradients, and field observations were used to obtain a subjective rating of the hazard of future potential for road-related landslides (likelihood of events). Sites with potential hazard are identified in **Table 1**. The elements at risk were identified (primarily fish habitat concerns) as well as the subjective probability that such an event would impact these elements.

5.2 PARTIAL RISK OF ROAD SURFACE SEDIMENT DELIVERY TO STREAMS

Sites with either potential or existing sediment production problems not related to landslides or catastrophic road prism failures are identified in **Table 2**. These are sites where eroding sand to silt size materials on the road surfaces are being delivered directly to streams – mainly at culvert locations. This is resulting in small, but nevertheless steady input of fine sediment to fish bearing reaches or directly connected non-fish bearing tributaries. These sites are primarily located on the Finn-Tum mainline, where the road is adjacent to fish streams and the Adams River, generally with high connectivity. Sites where sediment production was observed but connectivity to the stream network was negligible or very low were omitted from the risk assessment.

The hazard described in Table 2 is assumed to be High (i.e. equal to $P(H) = 1$) as the sediment delivery / processes were observed as ongoing. I should be noted that no consequence values have been assigned, and that a high rating in table 2 does not have the same implications as a high rating in table 1.

5.3 PARTIAL RISK OF DEBRIS FLOWS.

The steep gradient creeks on the face unit are prone to natural debris flows/floods, and as such will periodically deliver large pulses of sediment to downslope fish bearing reaches of these tributaries and to the Adams River.

These are generally high magnitude, low frequency events with significant sediment delivery, and hence significant impact. In the Upper Adams Watershed, it was found that the road systems are not having a significant impact on the frequency of these events – no direct linkage was observed between the road system, and events which may have triggered large-scale events such as debris flows. Forest harvesting on the upper slopes in the watershed areas of these debris-flow supporting creeks may have an impact on the magnitude and frequency of debris flows events as a result of changes in hydrologic effects – i.e. timing of snowmelt and/or precipitation event runoff. The development on the lower slopes appears to have very little to negligible influence on the debris flow hazard – these events are generally large and any materials entrained (e.g. the road

prism) will likely be small in magnitude compared to natural debris production.

Sites with an existing natural debris flow hazard are identified in **Table 3**. The subjective potential for future debris flow events was determined from field observation, analysis of stream profiles (Appendix A), airphoto analysis and terrain mapping information. The probability of debris flow events impacting fish habitat is almost invariably equal to 1 (*i.e.* is assumed a debris flow will deliver sediment to a fish bearing reach).

Mitigation of risk in debris flow prone channels is limited to ensuring that road systems on upper slopes are not diverting and concentrating drainage into draw sidewalls, resulting in processes which would initiate landslides which may trigger debris flows. This can be achieved by thorough deactivation of the road systems.

TABLE 1 - RISK ASSESSMENT – SITES WITH ROAD RELATED LANDSLIDE POTENTIAL

Site Location		Site Characteristics	Hazard Description		Elements at risk and probability of spatial effect		Partial Risk P(HA) ^{3,4}	Mitigation Strategies
Road	Site Number		Type	Likelihood P(H) ¹	Elements at risk	P(SIH) ²		
1350 Road	1	The 1350 road system is located on a uniform face, with no apparent significant drainage features, except the streams mapped (S5 to the south and an S6 (Stream 1) to the north. Soils in this system are generally well drained, and the roads were conducting only minor surface runoff at the time of the field investigation. The hazard on this section of road is the potential for road surface runoff during spring freshet or during an extreme precipitation event along the road segment upslope of stream 1 (see figure 2) resulting in a sidewall failure which may contribute to a debris flow.	Surficial slide as a result of drainage concentration along section of 1350 road. Sediment delivery to Stream 1 and possible subsequent debris flow in Stream 1	High ⁴	S3 reach of stream downslope, Adams River (S1)	High	Very High	<ul style="list-style-type: none"> Deactivate 1350 road on this section to ensure drainage dispersion. – install frequent cross drains (min 40m spacing) on approach to draw.
1350 Road System	2	The 1350 road system is located on a uniform face, Soils in this system are generally well drained, some minor concentration of flows is taking place.	Surficial slide as a result of drainage concentration along section of 1350 road.	Moderate ⁵	S3 reach of stream downslope, Adams River (S1)	Moderate	Moderate	<ul style="list-style-type: none"> Deactivate 1350 road system to ensure drainage dispersion. – install frequent cross drains (min 40m spacing)
Finn-Tum Mainline	7	Two draws converge here in a wet area. At 7A (Figure 2) the stream is mapped as S3, at 7B, there is an S6 stream. This becomes an S2 class stream immediately downslope. The two streams converge at dual 600mm CMPs which are losing functioning and infilling with sediment. Continued infilling could lead to a washout of the road, and entrainment of significant road surface and road prism material. There is currently minor but steady sediment input into culvert outlet from road system. Because of an infilled and small diameter culvert, fish passage to the high side of road as mapped is very unlikely.	Failure of culvert and washout of road prism. <50m ³	High	Loss of Road prism <50m ³ sediment delivery to S1 (Adams)	High	Very High	<ul style="list-style-type: none"> Replace culvert with one 1000mm culvert Improve / clean ditchline
Finn-Tum Mainline	9	There is a natural debris flow/flood channel at an unmapped stream at Site 9. The area upslope is uniform and planar, with significant seepage emanating all along the road cut to the south. Both the stream flow and seepage are channelled along a ditch on the high side of the road for about 50m to the south to a 1200mm CMP. An S2 class stream is located about 50m downslope of the culvert. This ditchline is perched above the level of the road. There is a berm in place deflecting flow into the ditch line. However, a large flow event could be channelled over the road, entraining a significant amount of road fill material, resulting in a road prism failure / washout. A profile was constructed of the approximate debris flow channel location, and is included in Appendix B.	Flow could overtop berm / ditch, run down road and potentially erode ~30m of road prism.	High	Loss of Road prism <50m ³ , deposition into S2 stream below.	High	Very High	<ul style="list-style-type: none"> Deepen ditchline to 1200mm culvert crossing. Use excavated material to build up berm on high side of road. Grass seed ditchline and berm.
Finn-Tum Mainline	10	A 600mm CMP at this location is too short, with both the inlet and the outlet being infilled by raveling road prism materials, and the culvert could become plugged. A plugged culvert could lead to a washout, inputting significant sediment to the stream system as a road washout. Stream gradients downstream are gentle. There is an S1 class stream (back channel of the Adams River) located ~85m downslope.	Plugged culvert resulting in road washout.	Moderate	Loss of Road prism <50m ³ , deposition into S1 stream below.	High	High	<ul style="list-style-type: none"> Replace culvert, armour culvert inlet. Grass seed ditchline (sediment control)
Finn-Tum Mainline	11	Short 600mm CMP, with both the inlet and the outlet being infilled by raveling road prism materials, and the culvert could become plugged. A plugged culvert could lead to a washout, inputting significant sediment to the stream system as a road washout. Stream gradients downstream are gentle. There is an S1 class stream (back channel of the Adams River) located ~75m downslope.	Plugged culvert could lead to road washout.	Moderate	Loss of Road prism <50m ³ , deposition into S1 stream below.	High	High	<ul style="list-style-type: none"> Replace culvert, armour culvert inlet. Grass seed ditchline (sediment control)

¹ P(H) Probability of occurrence of a specific hazardous landslide

² P(SIH) The probability that there will be a spatial effect, given that a specific hazardous landslide occurs.

³ P(HA) Probability of occurrence of a specific hazardous landslide and the probability of it reaching or otherwise affecting the site occupied by a specific element

⁴ A high likelihood means that a landslide is probable unless the site conditions are significantly better than assumed.

⁵ A moderate likelihood means that a landslide is not likely but possible unless the site conditions are significantly better than assumed.

TABLE 1 - RISK ASSESSMENT – SITES WITH ROAD RELATED LANDSLIDE POTENTIAL

Site Location		Site Characteristics	Hazard Description		Elements at risk and probability of spatial effect		Partial Risk P(HA) ^{3,4}	Mitigation Strategies
Road	Site Number		Type	Likelihood P(H) ¹	Elements at risk	P(SIH) ²		
Finn-Tum Mainline	14	Large draw with a badly damaged and mangled 600 CMP. Road surface runoff is entering the inlet and outlet from both north and south directions, carrying a significant amount of silty-sand material. Road surface runoff is scouring the outlet and eating away at the road prism. Road prism is primarily sandy material and easily erodible. The inlet is also infilling with sandy material, and will likely be plugged. Slopes below are rocky, channel is poorly defined. Much of the sediment is likely to settle out just downslope, but silt fraction likely to enter S3 and subsequently S1.	Failure of culvert subsequent washout of road prism.	High	Loss of Road prism Sediment Delivery to S3 / S1	Moderate	High	<ul style="list-style-type: none"> Replace Culvert with 600mm minimum. In-slope road on approaches, or install shallow cross-ditches to divert road surface water along ditchline. Grass seed ditchlines (sediment control)
1050 Road	18	Terrain Class IV area. No well defined stream channel. 800 CMP – minor road surface runoff entering draw. Ponding water on the road surface. Avalanche path crosses road at this site – there is moderate hazard of blockage of the stream with debris. Connectivity to the Stream system below is low – there is no defined channel.	Blocked culvert may lead to road washout, small to moderate slide / fillslope failure.	Moderate	Minor sediment delivery to S1 downstream	Low	Low	<ul style="list-style-type: none"> Monitor, clean as required with regular road maintenance. Install failsafe cross ditch with seasonal deactivation
1050 Road	19	Crushed and twisted cross drain culvert in place. No mapped stream. Sandy till / glaciofluvial materials with clasts of rounded boulder/cobble size. There is no well defined channel here, and a considerable distance over open ground to the Adams River.	Failure of culvert subsequent washout of road prism.	Moderate	<50m ³ sediment Delivery to S1 (Adams River)	Low	Low	<ul style="list-style-type: none"> Replace with 600mm culvert
1050 Road	20	S6 crossing in terrain class V. No debris flow activity was noted in the channel downstream of this point, possible snow avalanche debris observed at inlet. Inlet may become clogged with avalanche debris, leading to subsequent washout.		Low	Sediment delivery to S1 Reach	Moderate	Low	<ul style="list-style-type: none"> Monitor, clean as required with regular road maintenance.
1050 Road	21	This site is situated in the upper steep portion of an S5 drainage system, on slopes well over 60%. The area is classed as TSHC IV. There is a small cable block downslope of the road. There is an 1800mm CMP in place. Snow avalanches impact the road in this channel. There is a risk of the culvert becoming clogged with avalanche debris, however as the culvert is of significant diameter, the hazard of a catastrophic washout is low.	Culvert plugged with snow / avalanche debris, sudden outflow resulting in sediment mobilisation	Low	Sediment delivery to S2 / Adams (S1)	Moderate	Low	<ul style="list-style-type: none"> Monitor, clean as required with regular road maintenance.
1050.15 Road	22	The 1050.15 road system is the access to block 162-3, an older block mapped as sufficiently restocked. The block is located on There is a low hazard that the road system will lead to accumulation and diversion of surface and shallow subsurface flows, contributing to the instability in the draw of Stream 3.	Surficial slide on draw sidewalls due to drainage accumulation /on the road system Subsequent debris flow in stream channel.	Low	Sediment Delivery to S5, and subsequently S3,S2,S1	Low	Low	<ul style="list-style-type: none"> Deactivate 1050.15 Road system to ensure drainage dispersion.

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Site Location		Site Characteristics	Hazard Description		Elements at risk and probability of spatial effect		Partial Risk P(HA) ^{3,4}	Mitigation Strategies
Road	Site Number	Surficial Materials and Slope Morphology	Type	Likelihood P(H) ¹	Elements at risk	P(SIH) ²		
1050 Road	23	<p>The 1050 road and Blocks 162-3 and 162-3A are situated in the upper steep portion of an S5 drainage system, on slopes well over 60%. The area is classed as TSHC V. The stream crossing has been deactivated. The road through this section is on well drained sandy soils. There is a hazard of drainage accumulation onto the draw sidewalls on the approach to the crossing of Stream 3. This could result in a slide on the draw sidewall, with a subsequent debris flow initiation in Stream 3 that would impact the Fish bearing reaches downstream.</p> <p>Although cutblock hydrology may be contributing to the hazard, there is no evidence of the road contributing directly to past debris flows. No signs of debris flows were observed at this site, the events crossing the road downslope likely initiate in the channel downslope of the cutblock, probably below the confluence with the S5 stream entering at about the 1020 contour.</p> <p>Ribbons in the field indicate a deactivation prescription has been prepared. Other mitigation options are limited.</p> <p>A profile of Stream 3 is included in Appendix B – road crossing location is indicated.</p>	<p>Surficial slide on draw sidewalls due to drainage accumulation /on the road.</p> <p>Subsequent debris flow in stream channel.</p>	Moderate	Sediment Delivery to S5, and subsequently S3,S2,S1	Moderate	Moderate	<ul style="list-style-type: none"> Deactivate 1050 Road to ensure drainage dispersion – install frequent cross drains (min 40m spacing) on approach to draw.

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TABLE 2 - RISK ASSESSMENT – SITES WITH ROAD SURFACE RUNOFF ENTERING STREAMS

Site Location		Site Characteristics	Hazard Description		Elements at risk and probability of spatial effect		Partial Risk P(HA) ^{3,4}	Mitigation Strategies
Road	Site Number		Type	Likelihood P(H) ¹	Elements at risk	P(SIH) ²		
Finn-Tum Mainline	5	The section of The Finn-Tum Mainline between Stream 1 and Stream 2 is located downslope of an existing cutblock. There are considerable surface flows / seepage along this section. Ditches and culverts are aggrading, and there is considerable road surface runoff. Sediment is being delivered to a number of fish streams, however slopes below the road are gentle, somewhat limiting transport of sediment.	Road surface / ditchline sediment production and delivery to stream system.	High	Sediment delivery to 4 fish streams along this section (see map Figure 2).	High	Very High	<ul style="list-style-type: none"> • Maintain Culverts • Grass seed ditchline • Maintain grader berm at fish streams to minimise road runoff into crossings
Finn-Tum Mainline	12	600 CMP - Inlet being infilled by ravelling road prism materials. Minor sediment production on road running off into outlet.	Road surface / ditchline sediment production and delivery to stream system.	High	Sediment delivery to S1 downstream	Low	Moderate	<ul style="list-style-type: none"> • Clean culvert inlet and armour • Grass seed ditchline • Maintain grader berm to minimise road runoff into crossing
Finn-Tum Mainline	13	Minor road surface runoff entering outlet of 600 CMP culvert	Road surface / ditchline sediment production and delivery to stream system.	High	Minor sediment delivery to S1 downstream	Low	Moderate	<ul style="list-style-type: none"> • Maintain grader berm at fish streams to minimise road runoff into crossings
Finn-Tum Mainline	15	S6 Stream crossing, 800mm CMP. Platy metamorphic, fractured well drained bedrock, blanket of silty-sand soils. Some minor sediment production on the road section entering stream	Road surface / ditchline sediment production and delivery to stream system.	High	Sediment delivery to S3/S1	Low	High	<ul style="list-style-type: none"> • Maintain grader berm at fish streams to minimise road runoff into crossings • Install settlement basin at inlet of 600mm CMP stream crossing on lower road crossing (downstream of site 15)
Finn-Tum Mainline	16/17	Blocky angular bedrock with colluvial soils, silty-sand material in road surfacing. Minor sediment input into stream. Dual 800mm CMPs take flow at 16. There is a flat area / sump at 17 at which most fine sediment settles out. Fine material from road surface being introduced into outlet at 16. Stream gradients downslope become more gentle	Road surface / ditchline sediment production and delivery to stream system.	High	Sediment delivery to S1 downstream	Moderate	Moderate	<ul style="list-style-type: none"> • Clean culvert inlets • Grass seed ditchline • Maintain grader berm to minimise road runoff into crossing

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TABLE 3 - RISK ASSESSMENT – NATURAL DEBRIS FLOW CHANNELS

Site Location		Site Characteristics	Hazard Description		Elements at risk and probability of spatial effect		Partial Risk P(HA) ^{3,4}	Mitigation Strategies
Road	Site Number	Surficial Materials and Slope Morphology	Type	Likelihood P(H) ¹	Elements at risk	P(SIH) ²		
Finn-Tum Mainline	3	<p>A Scoured debris flow channel, appears likely to have a history of road washouts. 500 CMP in place with shallow burial and a large shallow sump.</p> <p>Sandy till / glaciofluvial materials with clasts of rounded gneissic rock. Slopes below are moderate, with no mapped stream. Evidence below the road of significant debris movement, possible debris flow or flood.</p> <p>There is existing development upslope, including a road system. (Block 162-5), however there is no evidence upslope of significant diversions due to road system. These roads are mostly ditchless, constructed on rapidly draining rocky soils with sandy matrix. In addition, the flow path is evident on 1997 airphotos, and pre-dates development upslope.</p> <p>There is a possibility that hydrologic change due to harvest activities may increase frequency of large debris-transporting events.</p>	Natural Debris Flow	Moderate	Sediment delivery to S1	High	High	<ul style="list-style-type: none"> Deactivation of 1350 road system upslope as per recommendations in Table 1
Finn-Tum Mainline	4	<p>Large, deeply incised natural debris flow channel. There is a 500 CMP in place. There is evidence at and downslope of the road of significant debris movement, possible debris flow or floods, with large, recent, debris deposits downslope of road – the channel has been scoured clean. Materials are sandy till / glaciofluvial materials with clasts of rounded gneissic rock. Stream is mapped as S3 for a considerable distance upslope of the crossing, but fish passage is not likely 50m downstream of the road. The channel is mapped as TSHC IV.</p> <p>Road / development likely has negligible influence on debris flow activity; site 1 is the switchback upslope. The upper road crossing in channel upslope has been fully deactivated and recontoured, and there does not appear to be any diversion or concentration of flows at that site.</p> <p>It is possible that hydrologic change due to harvest activities (Block 162-5) may increase frequency of large debris-transporting events, although most of the development is not in the immediate watershed of the draw, and the block has been sufficiently restocked.</p> <p>A profile of this stream is included in Appendix B.</p>	Natural Debris Flow	Moderate	Sediment delivery to S1	High	High	<ul style="list-style-type: none"> Deactivation of 1350 road system upslope as per recommendations in Table 1
Finn-Tum Mainline	6	<p>This site is located at the height of land on a debris flow fan. There is no evidence of recent debris flow activity, and there is only minimal sediment input to stream system with no development upslope. Materials are sandy till / glaciofluvial materials with clasts of rounded gneissic rock. The gullies upslope are classes as TSHC V. There is a 1200CMP located here with a perched outlet, which impedes fish passage. The mapped course of the stream channel is incorrect, and the actual stream channel has been indicated in Figure 2.</p> <p>There is a negligible hazard resulting from the stream crossing, but there is a natural debris flow hazard. A profile of this stream is included in Appendix B.</p>	Natural Debris Flow	Low	Sediment delivery to S3 / S1	High	Moderate	<ul style="list-style-type: none"> Debris flow hazard should be considered in a Terrain Stability Assessment with any future development upslope.

¹ P(H) Probability of occurrence of a specific hazardous landslide

² P(SIH) The probability that there will be a spatial effect, given that a specific hazardous landslide occurs.

³ P(HA) Probability of occurrence of a specific hazardous landslide and the probability of it reaching or otherwise affecting the site occupied by a specific element

⁴ A high likelihood means that a landslide is probable unless the site conditions are significantly better than assumed.

⁵ A moderate likelihood means that a landslide is not likely but possible unless the site conditions are significantly better than assumed.

TABLE 3 - RISK ASSESSMENT – NATURAL DEBRIS FLOW CHANNELS

Site Location		Site Characteristics	Hazard Description		Elements at risk and probability of spatial effect		Partial Risk P(HA) ^{3,4}	Mitigation Strategies
Road	Site Number	Surficial Materials and Slope Morphology	Type	Likelihood P(H) ¹	Elements at risk	P(SIH) ²		
Finn-Tum Mainline	8	<p>Natural debris flow channel, with a history of road washouts. Sandy till / glaciofluvial materials with clasts of rounded boulder/cobble size. Terrain class V upslope. The stream is classed as S3, but the 500 CMP has a perched outlet (0.2m) likely to impede fish passage past this point. Connectivity to Adams River (S1) is high.</p> <p>A good grader berm and favourable road geometry minimise the amount of road surface runoff entering the stream system at this site.</p> <p>There is existing development upslope(Block 162-3), including a road system. The road system does not appear to be contributing to the existing natural hazard. (See site 23) There is a possibility that hydrologic change due to harvest activities upslope may increase frequency of large debris-transporting events.</p> <p>A profile of the stream is located in Appendix B for reference.</p>	Natural Debris Flow	Moderate	Sediment delivery to S1	High	High	Deactivation of 1050 road system upslope as per recommendations in Table 1

¹ P(H) Probability of occurrence of a specific hazardous landslide

² P(SIH) The probability that there will be a spatial effect, given that a specific hazardous landslide occurs.

³ P(HA) Probability of occurrence of a specific hazardous landslide and the probability of it reaching or otherwise affecting the site occupied by a specific element

⁴ A high likelihood means that a landslide is probable unless the site conditions are significantly better than assumed.

⁵ A moderate likelihood means that a landslide is not likely but possible unless the site conditions are significantly better than assumed.

6.0 CONCLUSION

Generally, no large debris mobilising events that can be directly attributed to forest development were identified in this study. The study identifies potential risks due to road-related landslides and on-going as well as potential sediment production. The incidences of naturally occurring debris flow areas was noted as well.

Risks from road related landslides in this area area all related to hazards posed by drainage interception, accumulation and diversion. These hazards can generally be mitigated by (i) care with drainage concentration issues i.e. prevention of concentration of flows on road systems and (ii) care with culvert function i.e. ensuring culverts remain functional to prevent blockage and catastrophic failure.

Risks posed by ongoing sedimentation involve low volumes of material compared to the risks of landslides and debris flows. Nonetheless, these effects are ongoing and cumulative, and the total impact on the stream system of chronic sedimentation may be of a much more significant magnitude if taken collectively. Most of the sites with ongoing sedimentation concerns are located on lower slopes, directly adjacent to (direct connectivity with) fish bearing streams. The risks identified resulting to sediment production hazards can generally be mitigated with simple methods, such as grass seeding and regular road maintenance.

The risks due to natural debris flows involve much higher inputs of sediment, likely several orders of magnitude higher than the other risks mentioned above, however the return periods of these events is much lower. Generally mitigation of debris flow risk in this area involves minimising triggering events such as road related landslides.

Future development:

Assessment of risks associated with future development in the study area is beyond the scope of this study, however some general observations are offered. The nature of the hazards identified in the body of this report should be considered when planning future development.

For example, given the nature of the debris flow hazards in the gully complex on the steep upper slopes of the watershed, future development should consider the potential for increased likelihood of debris flows in these areas. Of particular concern is the area between Stream 2 and Stream 3 (Figure 2), the area which could potentially be accessed by extension of the 1050 road system. Future development planned in the upper portions of the watershed located adjacent to the gully complex between Stream 1 and Stream 2 (Terrain Class V) should likely be avoided. In the lower portion of the development area, any new development along the Fin-Tum mainline and adjacent lower slopes should consider the potential high likelihood of chronic sediment production adjacent to the fish bearing streams. Current development (blocks and roads) in the lower development area intercept and divert significant groundwater, it is likely that future development will experience similar sedimentation related issues as described in this report for the existing sites.

Future development in this watershed should, where appropriate, be subject to a project-specific detailed risk analysis (Terrain Stability Assessment) which considers the impacts of harvest and road construction on the debris flow hazard, road-related landslide risk and sedimentation concerns.

7.0 CLOSURE

This risk analysis has been carried out in accordance with generally accepted engineering and geoscientific practice for the area. Conclusions and recommendations presented herein are based on air photo interpretation and visual site inspections of selected areas in each watershed. Due to the nature of this assessment procedure it is possible that some sites may have been missed that were not identifiable on air photos or located along the roads that we assessed in the field. Further, assessments of soils and slope stability are based on interpretation of surface features and limited sub-surface investigation; actual ground conditions may vary from those inferred.

We trust that this report satisfies your present requirements. Should you have any questions or comments, please contact our office at your convenience.

Sincerely,

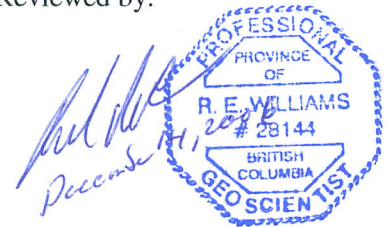
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(Author unknown) Upper Adams River Watershed IWAP Level 1 Analysis, April 23, 1997. Excerpt Provided by Gilbert Smith.

Appendix A – Assessment Site Locations

Appendix A - Locations of Assessment Sties
Datum :UTM Zone 11, WGS 84

Site	Partial Risk	Easting	Northing
1	Very High	354812	5754501
2	Moderate	354365	5754743
3	High	355447	5755012
4	High	355432	5755254
5	Very High	355603	5755960
6	Moderate	355591	5756706
7	Very High	355700	5756837
8	High	356008	5758453
9	Very High	356143	5759489
10	High	356227	5760685
11	High	356230	5760751
12	Moderate	356239	5760905
13	Moderate	356262	5760980
14	High	355548	5764898
15	Moderate	355881	5766161
16	High	356063	5766787
17	High	355927	5766842
18	Low	355322	5762500
19	Low	355425	5761987
20	Low	355101	5760505
21	Low	354923	5759908
22	Low	354803	5759008
23	Moderate	354600	5758691

