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FINAL REPORT

**WATERSHED ASSESSMENT:
SITKUM, BOURKE, AND
CLAYTON CREEKS**

Prepared for:

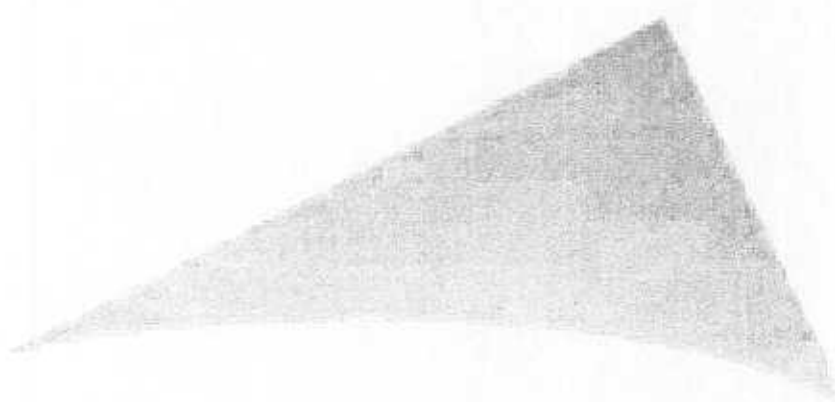
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Project 039-04.02

November 2000



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Environmental Consultants Ltd.



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February 15, 2002

Reference: 039-04.02

Ms. Kathy Howard, R.P.F.
Slocan Forest Products Ltd.
Slocan Division
Slocan, B.C.
V0G 2C0

Dear Ms. Howard:

Re: Watershed Assessment: Sitkum, Bourke, and Clayton Creeks: Final Report

Summit Environmental Consultants Ltd. is pleased to provide you with one hard copy and a CD-Rom containing a digital copy of a final report on the above-noted project. This report has been updated from the draft report to reflect the issues discussed at the November 16, 2000 meeting of the Watershed Advisory Committee. The minutes for the meeting are appended to the report.

Please call if you have any questions regarding the report.

Yours truly,

Summit Environmental Consultants Ltd.

Brian T. Guy, Ph.D., P.Geo., P.H.
Senior Geoscientist

Enclosures: One bound copy of Final Report
 CD-Rom with digital copy of Final Report

February 14, 2002

MAR 21 2002

Reference: 039-04.02

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Slocan Forest Products Ltd.
Slocan Division
Slocan, B.C.
V0G 2C0

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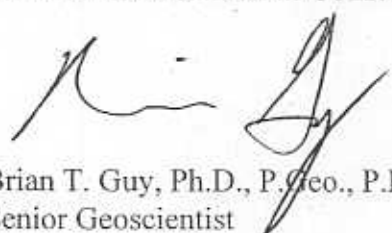
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1.0 INTRODUCTION

1.1 PROJECT BACKGROUND AND OBJECTIVES

This report presents the results of a field and office investigation undertaken at the request of Slocan Forest Products Ltd. - Slocan Division (Slocan) to update a watershed assessment presented in May 2000 for the Sitkum, Bourke, and Clayton Creek watersheds (Summit Environmental Consultants Ltd., 2000a). The May 2000 report was a compilation and integration of several previous studies that had been completed within the study area (Figure 1.1) over the previous several years, including a detailed channel assessment completed in May 1997.

The present study was designed to review channel and sediment supply conditions within the three study area watersheds according to the modern Watershed Assessment Procedure (WAP) guidebook (MoF/MELP, 1999); and to address several specific recommendations presented in the May 2000 report (which included the recommendations of a Watershed Advisory Committee meeting held on May 11, 2000). Accordingly, the specific objectives of the study were:

1. review the channel conditions of Sitkum Creek, Bourke Creek, and Clayton Creek, specifically channel disturbance, stability, and sensitivity to future disturbance;
2. map the erosion and sediment delivery potential of roads within the study area;
3. assess the stability of existing landslides within the study area;
4. to assess the present condition of landslides and recommend restoration efforts;
5. provide both general and specific advice for forest management in the study area;
6. investigate the channel of Sitkum Creek within macro-reaches C, D, and E, and prepare appropriate restoration prescriptions if residual sediment from slides is found within the channel in this area;
7. assess the effectiveness of the measures recently implemented to reduce the flood risk on the Sitkum Creek fan;
8. re-inspect the channel of Sitkum Creek on the fan, and if necessary provide additional recommendations for further reduction in flood risk;

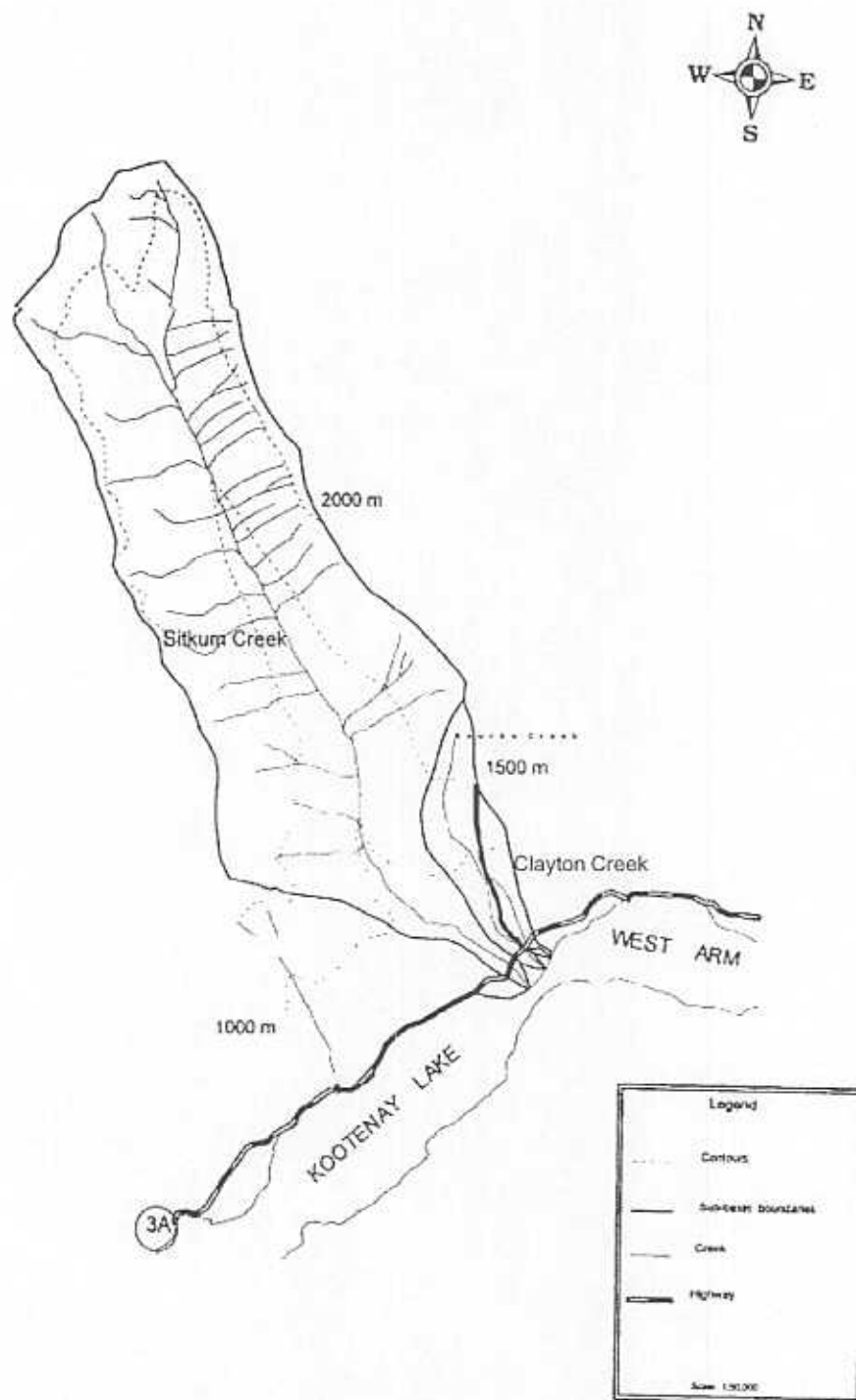


Figure 1.1 Locations of Sitkum, Bourke, and Clayton Creek watersheds.

9. assess the drainage conditions on road sections near six switchbacks within the first 5 km of Sitkum Creek FSR, in order to determine risks to Bourke Creek, and prepare rehabilitation prescriptions if necessary;
10. inspect the Bourke slide and the channel of Bourke Creek within and downslope of the slide zone, evaluate rehabilitation measures implemented to date, and prepare additional rehabilitation prescriptions if necessary;
11. assess the status of drainage improvements implemented for the West Sitkum Face FSR;
12. investigate a series of skid trails within an area of historic logging near the junction of the Sitkum Creek FSR and an old road to a historic fire on the ridge between Sitkum and Kokanee Creeks; and,
13. investigate an unnamed gully downslope of proposed block 17-3; and,
14. add terrain symbols to the watershed assessment map.

The field and office program completed in summer 2000 satisfied each of these study objectives. A subsequent meeting of the Watershed Advisory Committee was held on November 16, 2000 to review the draft findings of the study. The minutes of that meeting are included in Appendix D of this report.

1.2 PREVIOUS RELEVANT STUDIES

Previous studies undertaken in the study area summarized in Summit (2000a) include the following:

- a hazard assessment of the Sitkum Creek alluvial fan (NHCL and TCL, 1990);
- a Level I Interior Watershed Assessment (Summit, 1997a);
- a detailed channel assessment (Summit, 1997b);
- a riparian classification study (Wild Stone Resources Ltd., 1994);
- a terrain stability assessment and mapping project (Banting Engineering Ltd., 1996); and
- a fish inventory (Kokanee Forests Consulting, 1997);

Additional relevant studies completed since that time include:

- a hydrological assessment of proposed block 17-3 (Summit, 2000c); and,
- a review of potential seepage issues associated with proposed block 17-1 (Summit, 2000d).

The present report integrates all relevant previous information with the findings of the summer 2000 office and field program, and presents recommendations for future forest management as well as restoration opportunities.

1.3 STUDY AREA DESCRIPTION

The study area consists of three separate Community Watersheds: Sitkum Creek, Bourke Creek, and Clayton Creek (Map 1). Each of these creeks flow into the West Arm of Kootenay Lake after crossing the Sitkum Creek fan, which houses most of the settlement within the study area. Previous reports have combined Bourke Creek and Clayton Creek into a single watershed as it was believed that Clayton Creek was a tributary of Bourke Creek. However, during the field investigation for the present report, Clayton Creek was confirmed to be an independent stream. The study area is located approximately 15 km northeast of Nelson, B.C. along highway 3A. With a total area of 30.61 km², the study area ranges in elevation from 528 m at the lake, to 2359 m in the headwaters of Sitkum Creek. Three biogeoclimatic zones exist within the study area: Interior Cedar Hemlock (ICH), Englemann Spruce-Subalpine Fir (ESSF), and Alpine Tundra (AT). The watershed has been subject to historical mining and forest development, and has residential development on its depositional fan (Plate 2). The majority of private land is located in the lower elevations of each watershed, with the exception of a private claim surrounding an old mine in the headwaters of Sitkum Creek. Slocan Forest Products Ltd. (SFP) holds forest tenure on Crown Land in the study area. Each watershed has a community water intake located upstream of the powerline crossing (Map 1), as well as several private water intakes within the lower elevations (Table 1.1).

The geology of the study area is described in Summit (2000a) as Cretaceous granitic rocks overlain with basal till and colluvium. Terrain mapping (TSIL B) (Banting Engineering Ltd., 1996) identifies extensive areas of erodible terrain with high sediment delivery potential to the stream network (Map

1). In addition, a significant portion of the watershed is identified as potentially unstable (Class IV and V) terrain. The upper elevations consist of steep to moderately-steep bedrock outcrops and a sandy colluvial veneer. Blankets of glacial till with a sandy matrix are found in most polygons below 1800 m combined with a sandy colluvial veneer. Below approximately 750 m elevation a kame terrace of sandy glaciofluvial material runs along the Kootenay Lake valley and within the study area. The alluvial fan of Sitkum Creek was deposited soon after deglaciation (Summit, 1997b) and much of this material was derived from stream erosion through the kame terrace. The fan is approximately 0.44 km² in size and results from deposits from each of the three study area streams. The fan slopes between 8 and 12% and is considered to have a high flood hazard, as it has experienced many avulsions (NHCL and TCL, 1990). There are debris flow levees near the apex of the fan that currently confine the channel during high flows. Efforts to reinforce the channel have been undertaken in avulsion-prone areas, as the consequences of a flood event are high due to residential development and water supply and transportation infrastructure.

Fisheries information is derived from a riparian classification (Wild Stone Resources Ltd., 1994) and a fish habitat assessment (KFC, 1997), which found Rainbow Trout, Kokanee, Mountain whitefish, and Bull Trout near the mouth and in macro-reach A of Sitkum Creek. In addition Westslope Cutthroat Trout were found near the reach break of macro-reaches G and H. It is assumed for our purposes that Bourke and Clayton Creeks are fish-bearing up to a gradient of 20% (Map 1).

Mean daily temperatures at the nearest climate station in Nelson (1955019872, elevation 604 m) vary from 17°C in summer to 0°C in winter, and precipitation levels reach a maximum from November to January (Environment Canada, 1993). Thirty-two percent of the annual average of 670 mm precipitation falls as snow. It is expected that conditions in the lower elevations of the study area are similar to these values, but that the total annual precipitation and the proportion falling as snow increase with elevation within the study area. The highest flows of the year in the study area creeks occur in May and June, as a result of snowmelt.

Table 1.1 presents updated water licence information for the study area. The table differs slightly from a similar table presented in Summit (2000a) in that licence Z112251 on Sitkum Creek has been added, and licence 4003689 has been removed.

Table 1.1 Water licences for Sitkum Creek study area (updated to August 2000)

Intake	Licence #	Use	Licensee	Intake Source
Q4	Z111263	Domestic	Gary Glockner	Sitkum Creek
GG	F018612	domestic & irrigation	Mary Wetzel	" "
	C070909	Irrigation	Elizabeth Wallach	" "
	C062543	waterworks local authority	Sitkum Cr. Improvement Dist.	" "
K4	C065141	Domestic	Sitkum Cr. Improvement Dist.	" "
G4	C046000	Domestic	Nick Bowolin	" "
R4	Z111540	Domestic	Mathais Ander	" "
H3	F012169	domestic & irrigation	William Harrison	" "
	F012170	domestic	William Harrison	" "
N4	C107712	domestic	James Ross	" "
VV	F012169	domestic & irrigation	William Harrison	" "
V3	C047488	domestic & irrigation	Silvia Heinrich	" "
N3	C036422	domestic	Silvia Heinrich	" "
	F016306	domestic	Silvia Heinrich	" "
H	Z112251	domestic & irrigation	James Razzell	" "
31	4003689	irrigation	James Razzell	Unnamed spring
X4	C058568	waterworks local authority	Bourke Cr. Improvement Distr.	Bourke Creek
W4	C057764	waterworks local authority	Bourke Cr. Improvement Distr.	" "
	C057765	waterworks local authority	Bourke Cr. Improvement Distr.	" "
	C057766	waterworks local authority	Bourke Cr. Improvement Distr.	" "
	C057767	waterworks local authority	Bourke Cr. Improvement Distr.	" "
	C057768	waterworks local authority	Bourke Cr. Improvement Distr.	" "
	C057769	waterworks local authority	Bourke Cr. Improvement Distr.	" "
	C057770	waterworks local authority	Bourke Cr. Improvement Distr.	" "
	C057771	waterworks & irrigation local authority	Bourke Cr. Improvement Distr.	" "
	C057772	irrigation local authority	Bourke Cr. Improvement Distr.	" "
	C057773	waterworks local authority	Bourke Cr. Improvement Distr.	" "
	C057779	waterworks local authority	Bourke Cr. Improvement Distr.	" "
	C057780	waterworks local authority	Bourke Cr. Improvement Distr.	" "
	C057781	waterworks local authority	Bourke Cr. Improvement Distr.	" "
	C057782	waterworks local authority	Bourke Cr. Improvement Distr.	" "
	C057783	waterworks local authority	Bourke Cr. Improvement Distr.	" "
	C057784	waterworks & irrigation local authority	Bourke Cr. Improvement Distr.	" "
	C057774	waterworks local authority	Bourke Cr. Improvement Distr.	" "
	C057775	waterworks & irrigation local authority	Bourke Cr. Improvement Distr.	" "

Table 1.1 Water Licences for Sitkum Creek Study Area (updated to August 2000) continued:

Intake	Licence #	Use	Licensee	Intake Source
W4	C057776	waterworks & irrigation local authority	Bourke Cr. Improvement Distr.	Bourke Creek
	C057777	waterworks local authority	Bourke Cr. Improvement Distr.	" "
	C057778	waterworks local authority	Bourke Cr. Improvement Distr.	" "
	C057785	waterworks local authority	Bourke Cr. Improvement Distr.	" "
	C057786	waterworks local authority	Bourke Cr. Improvement Distr.	" "
	C057787	waterworks local authority	Bourke Cr. Improvement Distr.	" "
	C057788	waterworks local authority	Bourke Cr. Improvement Distr.	" "
	C057789	waterworks local authority	Bourke Cr. Improvement Distr.	" "
	C057790	waterworks local authority	Bourke Cr. Improvement Distr.	" "
	C057791	waterworks local authority	Bourke Cr. Improvement Distr.	" "
	C057792	waterworks local authority	Bourke Cr. Improvement Distr.	" "
	C057793	waterworks local authority	Bourke Cr. Improvement Distr.	" "
	C057794	waterworks local authority	Bourke Cr. Improvement Distr.	" "
	C057795	waterworks local authority	Bourke Cr. Improvement Distr.	" "
	C057796	waterworks local authority	Bourke Cr. Improvement Distr.	" "
	C057797	waterworks & irrigation local authority	Bourke Cr. Improvement Distr.	" "
	C057798	waterworks local authority	Bourke Cr. Improvement Distr.	" "
	C057799	waterworks local authority	Bourke Cr. Improvement Distr.	" "
	C057800	waterworks local authority	Bourke Cr. Improvement Distr.	" "
	C057801	waterworks local authority	Bourke Cr. Improvement Distr.	" "
	C057802	waterworks local authority	Bourke Cr. Improvement Distr.	" "
	C057803	waterworks local authority	Bourke Cr. Improvement Distr.	" "
	C058770	waterworks local authority	Bourke Cr. Improvement Distr.	" "
	C069517	waterworks local authority	Bourke Cr. Improvement Distr.	" "
	C069518	waterworks local authority	Bourke Cr. Improvement Distr.	" "
	C060619	waterworks local authority	Bourke Cr. Improvement Distr.	" "
Q4	C063753	domestic	Jose Buznego	Lindy Creek
V4	C062668	waterworks local authority	Clayton Cr. Improvement Distr.	Clayton Creek

Note: This table is based on information provided by the Kootenay Lake Forest District, and BC Ministry of Environment, Lands, and Parks, Nelson, B.C. August 2000.

2.0 STUDY METHODS

To satisfy the objectives outlined in Section 1.1 a study program including office and field components was implemented. Office analyses involved:

- a review of existing reports and information;
- airphoto interpretation of watershed and channel conditions;

- determination of the extent of recent restoration efforts; and
- a review of the current forest development plan.

The concept of “red flag” ECA values was adopted from the May 2000 report (Summit, 2000a). Red flag ECAs are based on “channel response potential” and the consequences of channel change, as defined in Section 8.0. Figure 2.1 shows a conceptual interpretation of the relationship between ECA and channel impacts for various values of channel response potential.

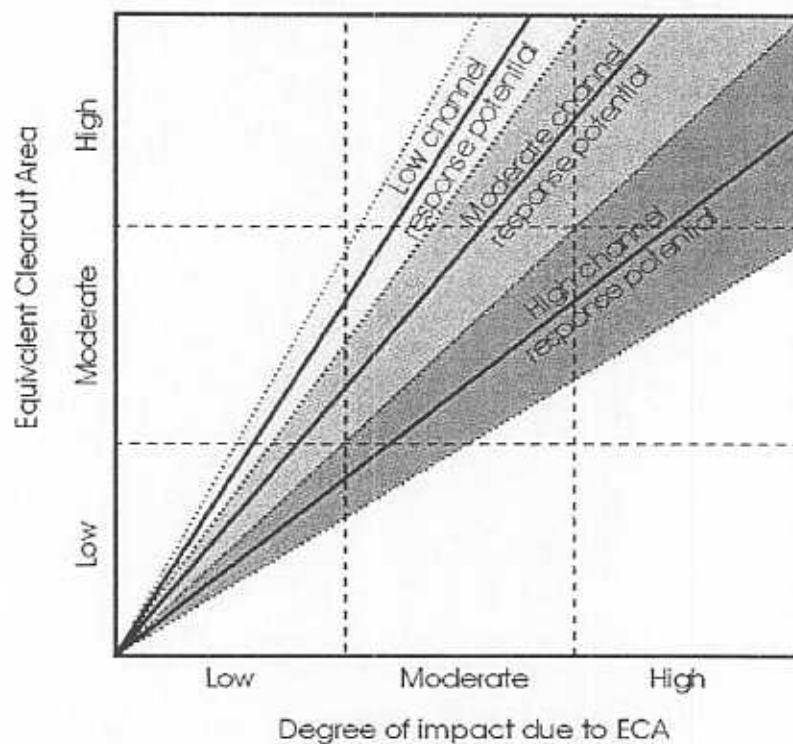


Figure 2.1 Conceptual representation of the relationship between ECA and channel changes for various levels of channel response potential.

A field assessment was completed during a three-day period (August 2-4, 2000). Additional field work was completed on August 18, 2000. The entire study area was first inspected from the air (via helicopter) during which notes on channel conditions, roads, and sediment sources were made. The helicopter facilitated inspection of the valley sides, in particular near proposed block CP 17-3, which borders a steep gully with a history of debris torrents.

Areas accessible by truck were then inspected during the remainder of the field program. This included an assessment of the Sitkum/Alpine FSR, the Old Sitkum Road, and the skid trails built during historical logging. Channel inspections were done in macro-reaches B, H, and I of Sitkum Creek, reaches 3, 4, 5, and 6 of Bourke Creek, and reaches 2, 3, and 4 in Clayton Creek. The headscarp, transport zone, and toe of the Bourke Slide (B2) was investigated and the location of Bourke and Clayton Creeks on the alluvial fan were confirmed.

Roads were assessed in terms of their potential to generate and deliver sediment to the stream network, and additional restoration opportunities were identified. Road sediment erosion potential was classified as low, moderate, or high according to the amount of sediment derived from the road surface, ditchline, cutslopes, and fillslopes. Sediment delivery potential was also classified as low, moderate, or high, and is defined as the potential for sediment to be delivered to the stream network. Sediment hazard was determined through combination of these two factors as shown in Table 2.1 below.

Table 2.1 Determination of Sediment Hazard from Sediment Erosion Potential and Sediment Delivery Potential

		Sediment Delivery Potential		
Sediment Erosion Potential		LOW	MODERATE	HIGH
	LOW	Low	Low	Low
	MODERATE	Low	Moderate	Moderate
	HIGH	Low	Moderate	High

This field-based method of rating sediment hazard differs from that used in the 1997 IWAP, in which the road network was overlain with a Surface Erosion Hazard map (Banting Engineering Ltd., 1996), and accounts for differences in the reported "Length of Road as a Sediment Source" (Table 3.1) between the present report and the May 2000 report (Summit, 2000a).

Channel reaches were assessed for disturbance, stability, and sensitivity using methods consistent with the modern WAP guidebook (MOF/MELP, 1999). Definitions for these and other technical terms utilized in this report are provided in Section 8.0, and are consistent with those used in Summit (2000a). However, it is noteworthy that some of the terminology used in Summit (2000a) and in the present report differs slightly from the terminology used in Summit (1997b). For example, the term "hydrologic hazard" is no longer used – it has been replaced with the more specific term "channel response potential". Readers unsure of the meaning of any technical terms appearing in the report should refer to Section 8.0.

3.0 WATERSHED CONDITIONS

3.1 WATERSHED REPORT CARD

Table 3.1 (the *Watershed Report Card*) presents a summary of characteristics of each watershed. ECAs determined for end-1999 are provided in Table 3.2, separated into Crown and private land, and into areas $>H_{60}$ and $<H_{60}$. The H_{60} line is the elevation above which lies 60% of the watershed area. Peak flows are considered to be more sensitive to forest harvesting at elevations near or exceeding H_{60} , a concept which has been recently verified in the Kootenay Lake Forest District (Gluns, 2000). The H_{60} elevations for the Sitkum, Bourke, and Clayton Creek watersheds are 1,600 m, 1020 m, and 710 m, respectively. Note that Table 3.2 also reports the ECA additions associated with the current forest development plan (proposed CP 17). This component of the table is addressed in Section 5.0 of the report.

Table 3.1 Watershed Report Card for the study area

	<i>Watershed</i>	Sitkum Creek	Bourke Creek	Clayton Creek
	Total Watershed Area (km ²)	28.26	1.44	0.65
1	Percentage of Watershed Harvested (%)	3.3	16.7	22.1
2	Equivalent Clearcut Area (ECA)	end-1999	end-1999	end-1999
	Overall ECA (above and below H ₆₀) (ha)	24.7	5.1	2.1
	Overall ECA (above and below H ₆₀) (%)	0.9	3.5	3.3
3	Total Road Density (km/km ²)	0.7	2.0	1.6
4	Length of Road as a Sediment Source (km) ^A	1.7	0.2	0.0
5	Total Number of Anthropogenic Landslides	13	2	0
6	Length of Road on Potentially Unstable Slopes (km) ^B	6.5	0.3	0.0
7	Number of Stream Crossings	12	3	4
8	Length of Stream Logged to the Streambank (km)	0.0	0.8	0.4
9	Length of Stream with High Channel Sensitivity (km) ^C	0.9	0.0	0.1
	Length of Stream with High Channel Sensitivity (%) ^F	7.2	0.0	11.1

A. Derived from a combination of high sediment production and high sediment delivery potential.

B. Derived from Terrain Stability Map (Banting Engineering Ltd., 1996).

C. Stream length with "High" channel sensitivity (see the glossary for definition of sensitivity).

Table 3.2 Existing (end-1999) and future (with CP 17) ECAs in the study area.

Sitkum Creek:				
	Total	Crown Land	Private Land	Crown Land above H ₆₀ line
Area (ha)	2826.0	2813.5	12.5	1695.6
ECA (ha)	24.7	22.2	3.5	15.0
ECA (%)	0.9	0.8	28.0	0.9
Recommended "red flag" ECA (ha)	565.2	562.7	2.5	339.1
Recommended "red flag" ECA (%)	20	20	20	20
Area available for harvest (ha)	540.5	540.5	-1.0	324.1
Proposed CP 17 addition (ha)	45.2	45.2	0.0	7.2
ECA with CP 17 (ha)	69.9	67.4	3.5	22.2
ECA with CP 17 (%)	2.5	2.4	28.0	1.3

Bourke Creek:				
	Total	Crown Land	Private Land	Crown Land above H ₆₀ line
Area (ha)	144	117.9	26.1	86.4
ECA (ha)	5.1	3.5	1.6	2.8
ECA (%)	3.5	3.0	6.1	3.2
Recommended "red flag" ECA (ha)	36.0	29.5	6.5	21.6
Recommended "red flag" ECA (%)	25	25	25	25
Area available for harvest (ha)	30.9	26.0	4.9	18.8
Proposed CP 17 addition (ha)	10.1	10.1	0.0	2.2
ECA with CP 17 (ha)	15.2	13.6	1.6	5.0
ECA with CP 17 (%)	10.6	11.5	6.1	5.8

Table 3.2 Existing (end-1999) and future (with CP 17) ECAs in the study area: continued.

Clayton Creek:				
	Total	Crown Land	Private Land	Crown Land above H ₆₀ line
Area (ha)	64.5	30.0	34.5	30.0
ECA (ha)	2.1	0.9	1.2	0.9
ECA (%)	3.3	3.0	3.5	3.0
Recommended "red flag" ECA (ha)	16.1	7.5	8.6	7.5
Recommended "red flag" ECA (%)	25	25	25	25
Area available for harvest (ha)	14.0	6.6	7.4	6.6
Proposed CP 17 addition (ha)	0.0	0.0	0.0	0.0
ECA with CP 17 (ha)	2.1	0.9	1.2	0.9
ECA with CP 17 (%)	3.3	3.0	3.5	3.0

Notes: Opening 11 (90% recovered) is assumed to coincide with Crown land/private land boundary

Overall end-1999 ECAs for the Sitkum, Bourke, and Clayton Creek watersheds are 0.9%, 3.5%, and 3.3% respectively. Proposed harvesting (CP 17) affects only the Sitkum and Bourke watersheds, and will increase the ECA to 2.5% and 10.6% respectively. In both cases, the post-harvesting ECAs are well below the "red flag" ECA values.

3.2 WATERSHED TERRAIN SENSITIVITY

The field investigation in August 2000 revealed several factors that indicate that portions of the valley slopes within the Sitkum Creek watershed are somewhat sensitive to disturbance. Two recent debris flows were noted (S15 and S16 – see Map 1), along with multiple avalanche tracks in the upper portion of the watershed, along the eastern slopes (Plates 1 and 13). In addition, a gully on the western slope (S2) showed evidence of historic debris torrent activity. The relatively high number of landslides along the Old Sitkum Creek Road (Table 3.1, Map 1) also highlights the slope sensitivity. The initiation zones of S15 and S16 were investigated during the helicopter flight. Although the evidence was very subtle, the likely initiating factor in both cases was minor blowdown in the immediate vicinity of the headscarp.

Steep terrain within the watershed has a high potential to deliver sediment and debris to the channel network, as evidenced by the amount of woody debris in the mainstem of Sitkum Creek derived from avalanche activity (Plate 5). A relatively high percentage of the terrain within the watershed has been identified as potentially unstable by Banting Engineering Ltd. (1996). Blocks and roads in these areas have experienced stability problems in the past, and proposed development must consider these factors in their layout and design. Specific recommendations for future development are given in Section 5.3.

Roads across valley-bottom glacio-fluvial sediments in the middle portions of the Sitkum Creek watershed have experienced stability problems (Plates 10, 11, and 12). A seepage zone located along the Sitkum Creek FSR near the crossing of Sitkum Creek has a 250 m stretch of slumping cutslope (Plate 12). This area was identified as a stability concern, especially with the proposed blocks 17-75 and 17-1 immediately upslope. This issue is discussed further in a terrain stability report (Woods, 2000) and in Section 5.3, as well as in a separate letter report (Summit, 2000d).

3.3 ROADS AND SEDIMENT SOURCES

3.3.1 Roads

There are four roads within the study area:

1. The Sitkum Creek (Alpine) FSR (hereafter referred to as the Sitkum Creek FSR) leaves Highway 3 east of the Sitkum Creek bridge, and travels up into the Sitkum Creek watershed for about 15 km to the headwaters. There is one crossing of the creek, at 8.3 km. Downgrade of about km 5, segments of the road are located within the Bourke Creek watershed.
2. The Old Sitkum Creek Road is a 2.8 km section of old road along Sitkum Creek, between about km 3 and km 8 on the Sitkum FSR.
3. An old road leaves the Sitkum Creek FSR at km 5.4 to access an old high elevation burn on the divide between Sitkum and Kokanee Creeks.
4. Short sections of the West Sitkum Face FSR cross into the Sitkum Creek watershed.

As outlined in Section 2.0, roads were assessed initially by helicopter, then inspected on the ground. Assessments of the potential for road segments to produce and deliver sediment to the stream network were made by rating each segment as low, moderate, or high. These factors were then combined to produce a Sediment Hazard rating. Detailed notes on road condition are presented in Appendix A.

Sitkum Creek FSR

The entire length of the Sitkum Creek FSR was driven and assessed for sediment hazard. Details of the survey are presented in table format in Appendix A. A 10-km stretch (1 km to 11 km) was seasonally deactivated in 1999. However, the road will require upgrading prior to harvesting of the proposed blocks. The assessment highlighted several locations that require drainage and road surface improvements to prevent any further slide initiation, and to improve access to the upper watershed:

- from 2.85 km to 3.70 km the ditches are filling with sand and the road surface is rutting;
- from 7.75 km to 7.90 km the road is eroded and rocky and 4x4 passage is difficult;
- between 5.6 km and 7.9 km the road has several areas affected by surface erosion;
- from 8.05 km to 8.30 km a seepage zone along the cutslope is causing slumping into the ditch and onto the road, which at this point is located within a few metres of the valley flat adjacent to Sitkum Creek (Plate 12);
- from 8.3 km to 8.8 km non-cohesive sands in the cutslope are slumping and filling the ditches due to a less-pronounced seepage zone, and culverts are in danger of plugging – this area includes slide S12 (Plates 10 and 11);
- at 8.75 km the road surface has failed (slide S13), leaving a 2-3 m high headscarp in the fillslope (Plate 11);
- at 9.35 km the cutslope has failed resulting in difficult 4x4 passage;
- from 9.40 km to 10.60 km the ditches are shallow and plugging from a raveling cutslope;
- at 10.2 km the road is eroded by a stream crossing and 4x4 passage is difficult;

- from 10.6 km to 11.05 km the road surface is rutted from surface flow diverted out of a plugged ditch;
- at 11.5 km a debris flow (S15) has crossed the road, and although 4x4 passage has been partially restored, it is still difficult (Plate 13);
- at 12.1 km the road surface is severely rutted from diverted stream flow onto the road surface (Plate 14); and
- at 13.1 km a second debris flow (S16) has crossed the road, and although 4x4 passage has been partially restored, it remains difficult.

Recommended measures to address these problems are provided in Section 4.0.

Road conditions near six switchbacks (labelled SB-1, 2, 3, 4, 4A, and 5 on Map 1) were investigated in order to address risks to Bourke Creek. The results are summarized here:

- at SB-1, which is located on private land, there are no back-up cross ditches for the culverts;
- at SB-2 the cross-ditches are shallow and allow some water to run down the road surface;
- at SB-3 and SB-4 the drainage structures are well-placed and functioning;
- at SB-4A the cutslope is ravelling and filling the ditch below; and
- at SB-5, a cross-ditch below the corner is filling with sand and appears to convey a relatively large flow.

Recommended rehabilitation measures are provided in Section 4.0, and additional details are provided in Appendix A.

Old Sitkum Creek Road

The Old Sitkum Creek Road was permanently deactivated in 1999 with full pullback and seeding (Plate 15). The road remains closed and access is limited to foot traffic. The entire road length was traversed during the field investigation. The deactivated road crosses the headscarps of several of the slides along this road (Map 1). Each slide was assessed in terms of stability and deactivation success. The road pullback is generally good, and grass and clover has become established on 30-

40% of the exposed surface. A few specific locations would benefit from additional restoration activity. There is no access for machinery to the road, so any action undertaken must be by hand. In distances from the lower junction with the Sitkum Creek FSR, sites of concern are:

- at 0.31 km a gully is marked for a cross ditch, but none has been installed;
- at 0.57 km, slide S3 has minor headscarp instability and oversteepened fill material;
- between 1.28 km and 1.31 km the original road surface has vegetation establishing along the middle and sides, but not in the wheel tracks due to compaction;
- at 1.77 km, slide S8 has minor headscarp instability and oversteepened fill material, and requires additional pullback; and
- seed has established along only a portion of the full pullback sections.

Recommended actions are provided in Section 4.0.

Old Road to Burn

The old road to the ridge-top burn has been previously deactivated. Inspection of the entire road from the air confirmed that the road represents a low hazard sediment source. This was confirmed on foot along the lowest 300 m of the road.

West Sitkum Face FSR

Short lengths of the West Sitkum Face FSR were reviewed in the field on August 18, 2000 (Map 1), and confirmed to represent a low sediment hazard.

3.3.2 Sediment Sources

Sediment sources investigated included landslides, debris flows, and a network of old skid trails located in historic logging near the junction of the Sitkum Creek FSR and the old road to the burn.

Landslides and Debris Flows

Landslides identified in the May 2000 report were inspected by helicopter and foot. Two recent debris flows (S15 and S16) were identified from the air in August 2000. However both were determined to have resulted from natural factors, and are not included in the landslide count (Table 3.1). Natural avalanche tracks are similarly not included. There are presently 13 anthropogenic landslides within the Sitkum Creek watershed, of which 9 originate from the Old Sitkum Creek Road, and two within the Bourke Creek watershed. Each was assessed for size, stability, success of restoration measures, and further restoration potential. Two slides have high instability and have damaged the road surface: S12 and S13. Four slides are moderately stable and have had some restoration work: B2, S3, S8, and S9. The remaining nine slides show low or low-moderate activity and are vegetating well. The recent pullback of the Old Sitkum Road will further improve the stability of the slides located along it. Details are presented in Appendix A.

One of the largest slides, B2, occurred on April 24, 1999, initiating at switchback SB-4 on the Sitkum Ck FSR, and traveled into and subsequently down Bourke Creek (Map 1, Plates 17, 18, and 19). Mr. Doug Nicol of the Nelson Forest Region described the slide in a letter report to Mr. Ken Haynes of the Kootenay Lake Forest District (Nicol, 1999). While the slide began as a debris slide at elevation 1110 m, it became confined by the gully walls and became a debris flow. The material entered Bourke Creek at elevation 950 m, then continued down the creek to elevation 810 m. The transported slide volume was estimated at 3,000 m³, while the transported road fill volume was only about 200 m³. Nicol (1999) indicated that the slide track would likely continue to provide sediment to Bourke Creek for several years, even after revegetation, and suggested that alternative water sources be investigated for consumptive use.

The field investigation of slide B2 included an assessment of the slide headscarp, runout zone, and toe. The sediment and debris lobe at the slide toe is stable, and will not likely ever be moved by hydrologic processes, although it will likely continue to produce sand-sized and finer sediment to the channel for several years. The flow splits into many small distributaries through the sediment lobe, and one branch running around to the right bank is transporting decayed organic sediments from within the lobe, and a smelly rusty coating lines the channel (Plate 20). This has reportedly caused

annoyance to the water users (Dave Toews, pers. comm, 2000). Channeling the flow into a single branch through the lobe may eliminate the transport of this material downstream.

The seeding is taking well, with approximately 50-60% of the slide area vegetated (Plates 17 and 18). However some additional seed would be beneficial, especially at the lowest end of the runout zone where no seed has established. Recommendations for work are discussed further in Section 4.0.

Slides B1 and B2 are linked to the road switchbacks immediately upslope of each slide. Slide B1 initiated on an open slope of 55% that was receiving water from the road surface. The headscarp 35 m downslope of the road highlights the relatively high sensitivity of the surrounding slopes to changes in drainage pattern.

Skid trails

A foot traverse of about 300 m of this trail network, upslope of the Sitkum Creek FSR, indicated there are no stability issues associated with these old trails, as vegetation is becoming well established over the surfaces (Plate 16), and there are no significant drainage issues remaining.

3.4 CHANNEL CONDITIONS AND SENSITIVITY ANALYSIS

This section reports the present channel conditions for Bourke Creek, Clayton Creek, and Sitkum Creek. The text incorporates information from Summit (1997b), Summit (2000b), and observations made during site visits and a helicopter flight in August 2000.

3.4.1 Bourke Creek

With the exception of slide B2, which has impacted Reach 5 of Bourke Creek, and contributed sediment through to downstream reaches, the condition of Bourke Creek is similar to its condition as reported in Summit (1997b) and Summit (2000a). The channel is stable throughout its reaches and is generally step-pool in morphology. It has a low sensitivity as it is confined within a steep gully

and armoured with colluvial boulders and bedrock. The steep gradient of the channel indicates it has the ability to transport debris flows down to the depositional fan. Slide B2 is one such event that traveled 350 m down the gully and deposited a debris lobe where the gully widens slightly. Management of the watershed should recognize the debris flow potential of the channel.

Slide B2 has severely impacted reach 5 and slightly impacted reaches 4 and 3 by increasing the amount of fine sediment on the banks. High transport rates and bedrock chutes in reaches 3 and 4 have maintained a low level of disturbance, even though a large amount of fine sediment moved through these reaches as a result of the slide. Reach 5 appears drastically different than it did prior to the slide, as the riparian zone was ripped out during the slide (Plates 18 and 19, compared with photographs 7 and 8 from Summit, 1997b). Gully sides consist of exposed soil that has generally seeded well but is ravelling and lacking a surface cover in some areas. The debris flow had the potential to change the morphology of the reach, however due to its low sensitivity, the channel morphology has remained a bouldery steep-cascade, similar to its pre-slide condition. Where the debris flow lobe settled out, about 50 m above the reach 4/5 boundary, the channel splits as it flows through the sediment lobe and the dense stable jam formed by large woody debris (LWD).

The channel sensitivity assessment (Map 1) and designation of a "High" watershed routing efficiency leads to the designation of a "Moderate" channel response potential for Bourke Creek.

3.4.2 Clayton Creek

Clayton Creek is a stable stream channel confined within a small gully and armoured with mossy colluvial lag boulders. The channel is generally step-pool with frequent LWD steps and bedrock exposures. The channel condition is well described in Summit (1997b) and Summit (2000b) and has changed little from these descriptions. Previous mapping of the channel pattern however has been incorrect, and the actual drainage path was traced in the field. The creek is not a tributary to Bourke Creek as previously mapped, and instead becomes ditched upon reaching the fan, and runs through several residential properties before entering the lake (Map 1).

The sensitivity assessment (Map 1) and designation of a "High" watershed routing efficiency leads to the designation of a "Moderate" channel response potential for Clayton Creek. The overall channel response potential for the Clayton watershed is therefore "Moderate".

3.4.3 Sitkum Creek

Sitkum Creek has previously been differentiated into nine macro-reaches, which have been adopted for the present study:

- the downstream-most macro-reaches (A and B) include the Sitkum Creek fan and have relatively erodible banks and an aggrading bed (Plate 2);
- the mid-lower macro-reaches (C to E) are highly canyonized and have extensive lengths of predominantly non-alluvial bed and banks (Plate 3);
- the mid-upper macro-reaches (F to H) have predominantly alluvial bed and banks, but large colluvial material is provided to the channel via direct hillslope coupling (Plate 4);
- the upper macro-reach (I) has extensive lengths of predominantly non-alluvial bed and banks, with the channel armoured by colluvial boulders and cobbles (Plate 5).

Each reach of Sitkum Creek was inspected during the helicopter flight, followed by a detailed ground inspection of reaches B, H, and I. The channel assessment (CAP) reported in Summit, 1997b provides an accurate description of the processes that affect the fan of Sitkum Creek. Both macro-reaches on the fan (A and B) have been anthropogenically modified (channelization, placement of bank protection and removal of riparian forest). These reaches A and B are aggraded (as would be expected in a depositional zone), and the banks consist of relatively sensitive easily-eroded clast-supported fluvial deposits. Protective works completed since 1997 have eliminated some of the stability issues identified in Summit (1997b). In particular, protection of the community intake and its access road have been improved. There is less LWD in the channel than reported in Summit (1997b), although overall channel morphology has not changed. Two sites would benefit from additional protective work, which is not considered to be critical:

1. a boulder bar (3 m long by 2 m wide by 0.75 m deep – total about 4 m³) is located just upstream of the Highway 3A crossing, and the degree of aggradation may prevent high flow from safely passing under the bridge;
2. the water intake at 160 m above the Hwy 3A crossing is protected with a low (about 1 m high) berm, which is lower than nearby banks, and it is subject to overbank flows;

At two other sites, natural bank erosion was notable:

1. at 200 m upstream of the Hwy 3A crossing the right bank is weak and eroding;
2. at 330 m upstream of the Hwy 3A crossing the right bank is eroding at a bend and is vulnerable at high flows.

Recommendations for protective action are described in Section 4.1.

Macro-reaches C through H have been described in Summit (1997b) and summarized in Summit (2000a). Macro-reach I was not inspected in the field work completed for the 1997 report due to snow-cover. Macro-reach I has both an east and a west channel that join at the reach break with macro-reach H. The eastern tributary has been highly impacted by avalanching. The channel is heavily loaded with functioning LWD derived from a large avalanche track from the west (Plate 5). This effect is natural and the channel does not show severe signs of disturbance such as multiple channels or sediment storage. The western tributary is not as heavily loaded with debris as the eastern tributary. However a sediment wedge behind LWD was noted in the lower portion of this section (Plate 6). It is unclear if it is a weir built for water use at the nearby mine or if it is naturally derived. Nevertheless, the accumulation of sediment has the potential to move downstream should the LWD decay and break up. Deposition of the coarse sediment would likely occur in macro-reaches H to F with minor effects. Fine sediment may continue down to the intake, however dissipation would prevent any large amounts from reaching the intake at a single time. There are no recommendations to alter the present situation.

Only 210 m of macro-reaches C, D, and E were inspected during the field work completed for Summit (1997b). Accordingly, the entire reach lengths were inspected from the air in August 2000. As a result of this inspection, the descriptions given in Summit (1997b) have been verified, although there are some additional notable comments concerning these reaches. Remaining disturbance from the slides derived from the Old Sitkum Creek Road is only slightly detectable in the form of minor channel widening at a few locations. Local and cumulative downstream impacts at the time of the slides were probably larger, but transport rates are evidently high enough to remove most of the sediment moving into these reaches (either from upstream or from the valley sides). A suspected debris jam within macro-reach D was not found. A steep debris torrent channel (S2 - Map 1) has affected macro-reach F in the past, although it has not tormented for at least 20 years. A historic headscarp is visible at about 1400 m elevation. Development within the vicinity of this channel should account for the debris torrent risk.

The characteristics of macro-reaches F and G have not significantly changed since the 1997 report.

Sitkum Creek has been designated overall with a "High" channel response potential, due to the "High" sensitivity of the lower two macro-reaches, and a "High" watershed routing efficiency.

4.0 WATERSHED RESTORATION ACTIVITIES

4.1 SITKUM CREEK ALLUVIAL FAN

Since the 1997 report, the access road to the community intake has been improved, and the intake has been better protected. None of the other recommendations provided by NHCL and TCL (1990) or Summit (1997b) have been implemented. Because minor adjustments to the channel have occurred on the alluvial fan since 1997, most of the Summit (1997b) recommendations are no longer valid. However, as a result of the August 2000 inspection, minor improvements could be made at two locations to reduce flood risk:

1. a boulder bar is located just upstream of the Highway 3A crossing, and the degree of aggradation may prevent high flows from safely passing under the bridge. Excavation of approximately 4 m³ of boulders in this vicinity will at least temporarily increase the cross-sectional area under the bridge sufficiently; and,
2. the berm protecting the water intake 160 m above the Hwy 3A crossing should be raised by about 1 m.

This work is not urgent, but should probably be done within two years, with the necessary permits and approvals in place.

4.2 SITKUM CREEK (ALPINE) FSR

About 10 km of the Sitkum Creek FSR was seasonally deactivated in September 1999 (between about km 1 and km 11). The road was inspected in detail during the August field work and several areas were identified that required improved road surface conditions or drainage structures. Four switchbacks are considered high priority sites:

- installing cross-ditches and improving the ditchline at SB-1 to carry runoff around the bend, rather than diverting it toward Bourke Creek;
- deepening the cross-ditches at SB-2 to prevent water from running on the road surface;
- re-establishing 25m of ditchline and armouring the base of the cutslope at SB-4A; and
- installing an additional cross-ditch at SB-5 and creating small ditchpools to settle out sediment.

In addition, regular maintenance is required on all switchbacks to ensure the effectiveness of the cross-ditches, culverts, and ditchlines. Detailed assessments of the switchbacks are presented in Appendix A.

Recommended improvements to the road condition that are considered moderate or low priority include:

- from 2.85 km to 3.70 km the ditches require cleaning to prevent road surface rutting from overflow;
- from 7.75 km to 7.90 km the road needs to be graded as it is eroded and rocky and creates difficult 4x4 access;

- between 5.6 km and 7.9 km the road has several areas of surface erosion and should be graded;
- from 8.05 km to 8.30 km ditches require frequent maintenance to remove slumping cutslope material;
- from 8.3 km to 8.8 km the ditches and culverts require frequent cleaning to remove sands derived from the cutslope (this includes slide S12);
- at 8.75 km (slide S13) the road surface requires repair including reconstruction of the fillslope (Plate 11);
- at 9.35 km the cutslope has failed and the road surface requires improvement for easier passage;
- from 9.40 km to 10.60 km the ditches require cleaning;
- at 10.2 km the road requires surface grading to improve passage;
- from 10.6 km to 11.05 km the road surface is rutted and requires grading, and the ditches require cleaning;
- at 11.5 km the road surface requires improvement for easier access (Plate 13);
- at 12.1 km the road surface is severely rutted and should be graded, and a stream crossing upgrade should be armoured to prevent the stream from running onto the road (Plate 14); and
- at 13.1 km the road surface requires improvement for easier access.

Previously, Wells (1999) identified several activities that should be considered to reduce the likelihood of sediment being generated and deposited into Sitkum and Bourke Creeks:

- 10+050: further improvement of a drainage inlet here is required to pass the upstream ditch flow through it;
- 9+300: if the road is needed for future truck access, a 600 mm pipe is needed in the gully bottom, a curve needs straightening, and existing trees require removal;
- 8+600 (300 m upgrade of the 8.3 km bridge): a permanent repair of a small failure above the road is required, by means of a small, tractor mounted back hoe;
- within 500 m downgrade of the 8.3 km bridge crossing, a few cross-ditches were not well constructed. Seeding is recommended to reduce erosion potential;

- 5+400 and 6+700: two culvert intakes require cleaning;
- 1+350: removal of a tree is required to prevent upslope flow from diverting onto the road; and,
- 0+930: removal of a tree lying across an old slide path about 30 m upslope of the road is required.

These detailed prescriptions were not verified during the August 2000 field program. Nevertheless, the work of Wells (1999) and our own August 2000 observations reported herein indicate that the Sitkum Creek FSR requires additional work to bring it into a satisfactory state of seasonal deactivation.

4.3 OLD SITKUM CREEK ROAD (ROAD 1.0)

In October 1999, the "Old Sitkum Creek Road" (Road 1.0) was permanently deactivated (Plate 15). The deactivation included approximately 1.3 km of moderate pullback of unstable fill, installation of cross-ditches and restoring natural drainage patterns within gullies and draws. The inspection in August 2000 confirmed that the pullback is functioning well and the seeding is establishing on about 40% of the area. However, some additional restoration work is recommended. The following is considered to have the highest priority:

- additional pullback at 1770 m upgrade of the lower junction with Sitkum Creek FSR (at slide S8) due to minor headscarp instability and oversteepened fill material;
- additional pullback at 570 m upgrade of the lower junction (at slide S3) due to minor headscarp instability and oversteepened fill material; and
- installation of a cross-ditch at a gully at 305 m upgrade from the lower junction. This site is flagged for cross-ditch installation, but there is no cross-ditch located here.

Recommended activities with moderate or low priority include:

- screefing of the original road surface between 1280 and 1307 m upgrade of the lower road junction, to help vegetation to become established along the compacted road surface; and
- re-seeding areas that have not yet had vegetation establish.

Access to these sites is restricted to foot traffic, therefore any restoration work must be completed using hand tools.

4.4 BOURKE CREEK

Sediment and debris from the Bourke Creek landslide (B2) in April 1999 has accumulated in Reach 5 of Bourke Creek (at approximately 810 m elevation) in the form of a large stable plug of sediment and debris (Plate 19). Pullback of the remaining fill at the initiating switchback (SB-4) and hydroseeding of the slide track were completed in 1999. The slide track and debris plug were re-examined on foot in August 2000. Some additional prescriptions are recommended to increase the stability of the slide track and lessen the effect on downstream water quality:

- Reseeding the slide face and runout track in the patches that have not established well. The area is 50-60% established with grass and clover, however approximately 0.17 ha of area remains exposed, largely at the bottom of the slide, immediately upstream of the sediment plug (Plates 18 and 19);
- Channeling the flow through the debris plug to a single channel. The creek currently branches around the plug, and is seeping through material undergoing organic decay. This process has increased the concentration of iron-loving bacteria in the water, likely through a combined increase in available carbon and water temperature. The decomposing bacteria remain in the water down to the community intake, resulting in an unpleasant odour associated with the water (Plate 20).

The slide is not accessible by machine except at the headscarp, and these actions must be done by hand.

5.0 CONSIDERATIONS FOR FUTURE FOREST DEVELOPMENT

5.1 INTRODUCTION

Section 5.0 considers the potential for future forest development to impact the hydrologic and/or sediment regimes of the Sitkum, Bourke, and Clayton Creek watersheds, and thereby to affect channel stability, fisheries habitat, and water quality. The potential for impacts is assessed below, as well as the consequence of such impacts, and comments on the current forest development plan are provided.

Impacts on the hydrologic and sediment regimes can be both direct and indirect. Direct impacts are those that can have a direct influence on the stream channels (such as roads, stream crossings, or block boundaries adjacent to channels), and thus on the sediment regime. The potential for such impacts is assessed by considering channel sensitivity. Indirect impacts are those related to ECA and the presence of cutblocks and their associated road systems (which can alter snow accumulation and melt patterns and the peak flow hydrologic regime, and thereby affect channel condition). The potential for indirect impacts is assessed by considering both channel sensitivity and the watershed routing efficiency (the rate at which water is routed from hillslopes to mainstem channels).

As reported in Summit (1997b), historic impacts on study area stream channels have been dominated by direct impacts on the sediment regimes of study area channels, in particular due to landslides associated with roads, rather than impacts on the hydrologic regimes.

5.2 TERRAIN SENSITIVITY

Most of the slides within Sitkum Creek and Bourke Creek watersheds have occurred on terrain consisting of sandy till and/or colluvium over steep bedrock, or in valley-bottom glaciofluvial deposits with a colluvial veneer. The steep to moderately-steep terrain in combination with the sandy material with low cohesion has a high initiation potential for mass wasting events such as debris flows and slumps. During the fieldwork, cutslopes in areas of groundwater seepage were

notably slumping and three open-face slides were observed (S15, S16, and B1). Initiation factors for S15 and S16 were not apparent, but were likely attributed to concentration of surface water associated with small areas of blowdown timber. Future development within the study area should account for the terrain sensitivity, and blocks should be planned to avoid the most sensitive terrain. Detailed terrain sensitivity assessments are recommended for proposed development.

5.3 "RED FLAG" ECA CONSTRAINTS

As reported in Section 3.0, the overall channel response potential for both the Bourke and Clayton watersheds is judged to be "Moderate". However, the consequences of channel change are high (primarily due to water use), and a "red flag" ECA value of 25% is recommended for the both watersheds. It is recommended that the "red flag" apply both to the area above H_{60} , and to the entire watershed, in each case. These recommendations are consistent with the recommendations of Summit (2000a).

For Sitkum Creek, a "High" channel sensitivity in the lowermost two reaches combines with a "High" watershed routing efficiency to generate a "High" channel response potential. Combined with a high consequence of channel change (due to water use and fish habitat), 20% is considered an appropriate "red flag" ECA. It is recommended that the "red flag" value apply both to the area above H_{60} and to the entire watershed. This is also consistent with the recommendations of Summit (2000a).

These recommended "red flag" ECAs are presented in Table 3.2. The table also provides the existing ECA, and the ECA that would exist if the current forest development plan (CP 17) were harvested in the year 2000. Each watershed is sub-divided into Crown and private land, and the table provides the area available to be harvested within the "red flag" ECA constraint. For Sitkum Creek, the area available within the "red flag" constraint is 540.5 ha (324.1 ha above the H_{60} line). For Bourke Creek, the area available within the "red flag" constraint is 30.9 ha (18.8 ha above the

H₆₀ line), and for Clayton Creek, the area available within the "red flag" constraint is 14.0 ha (6.6 ha above the H₆₀ line).

For all three study area watersheds, the current forest development plan respects the recommended "red flag" ECA constraints. For Sitkum Creek, the overall watershed ECA will increase by only 1.6% (from 0.9% to 2.5%), for Bourke Creek, the overall watershed ECA will increase by 7.1% (from 3.5% to 10.6%), and Clayton Creek is not affected by the forest development plan. There are no new roads proposed within the current forest development plan (with the possible exception of a temporary road into proposed blocks 17-1 and 17-75). It is unlikely that the proposed harvesting will affect the hydrologic regime of Sitkum Creek or Bourke Creek. It is not necessary to provide specific advice concerning strategies for peak flow de-synchronization or harvest scheduling, since the likelihood of changes to the hydrologic regime under the current FDP is so low.

5.4 RECOMMENDATIONS FOR SPECIFIC PROPOSED BLOCKS

Comments on the proposed forest development plan were provided in April 2000 (Summit, 2000b). There are four proposed blocks located partially or completely within the Sitkum or Bourke watersheds: 17-1, 17-3, 17-25, and 17-75.

- Block 17-3 is located adjacent to a gully (S2) on the western slope that has been subject to natural historic debris torrents. This proposed block should be amended to minimize the potential for debris flow initiation related to forest harvesting. Specific recommendations have been provided under separate cover by Woods Associates Engineering (2000) and Summit (2000c).
- Because portions of proposed block 17-25 occupy class IV or V stability terrain, and because drainage from the portion of the block within the Bourke Creek watershed could travel across private land before it reaches Bourke Creek, we recommend that a terrain stability field assessment be conducted for sensitive areas within the proposed block, between the block and Sitkum Creek, and between the blocks and Bourke Creek. Drainage conditions at the

switchbacks within the block were assessed during the August 2000 fieldwork undertaken in support of the present report. The recommended improvements (Section 4.0 and Appendix A) should be completed prior to harvesting.

- Blocks 17-1 and 17-75 are located near a seepage zone that has resulted in instability along the cutslopes of the Sitkum Creek FSR (Plate 12). The blocks are designed as small patch cuts within a larger retention area. Woods Associates Engineering (2000) did not identify any stability issues within the block boundary. Summit (2000d) provided additional advice related to possible future roads – such as maintaining natural drainage, operating within the dry season, and deactivating the road immediately following harvesting.
- A contingency plan to prepare for unintended water supply disruptions should be prepared prior to beginning operations.

As reported in Summit (2000a), the forest development plan appears to be consistent with section 2.1 (Water Resources) of the Sitkum Creek Integrated Watershed Management Plan (IWMP) - which covers all three study area watersheds as well as other adjacent sub-units. Section 2.1 of the IWMP also contains some operational requirements, which should be reviewed prior to commencing operations in the study area.

6.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

The condition of the watersheds of Sitkum, Bourke, and Clayton Creeks remains close to that described in earlier reports: Summit (1997b, 2000a). Localized changes have resulted from events such as the Bourke Slide, road instability, and natural debris flows in Sitkum Creek. Generally, the channels are stable throughout the study area, except where disturbed by anthropogenic activity (eg. on the alluvial fan). Landslides within the study area are generally stabilizing, and only two (S12 and S13) are presently rated “highly unstable” (recommendations for mitigation of these slides are provided in Section 4.2). Restoration activity has increased the stability of many of the slides. Sediment derived from slide events has mostly been removed naturally from the stream network,

even within the Bourke Slide (B2), which extremely disturbed Reach 5 of Bourke Creek (Plate 18). The sensitivity of each creek ranges from slight to high, generally increasing with decreasing elevation. Constructive efforts on the Sitkum Creek fan have improved the stability of the channel and reduced the risk of damage during high flow events.

ECAs within each watershed are currently low: Sitkum 0.9%, Bourke 3.5% and Clayton 3.3%. Proposed harvesting will maintain levels below the recommended "red flag" ECA values for each watershed. However, some of the side slopes within the watersheds are sensitive, and forest management must be diligent in and near areas where channel disturbance could occur as a result of forest harvesting activities. There are several restoration opportunities identified in this report that may improve the condition of the watershed.

On the basis of the results and conclusions reported above, the following recommendations are made:

- Field assessments should be completed for all or parts of proposed blocks 17-1, 17-3, 17-25, and 17-75 prior to harvesting (Section 5.3). Some of this work has already been done - results are reported in Woods Associates Engineering (2000), Summit (2000c), and Summit (2000d);
- Drainage and road conditions should be improved along the Sitkum Creek FSR (Section 4.2) prior to harvesting CP 17;
- Drainage should be improved at the switchbacks along the Sitkum Creek FSR to prevent the destabilization of slopes or gullies in the surrounding area from increased runoff (Section 4.2);
- Ditches along a 250 m stretch of Sitkum Creek FSR downgrade of the bridge should undergo frequent maintenance to prevent plugging with slumping cutslope material (Section 4.2);
- About 0.17 ha of the Bourke Slide (B2) in which vegetation has not established (Plates 18 and 19) should be reseeded (Section 4.4);
- Bourke Creek should be channelized through the debris flow plug associated with slide
- B2 (Section 4.4) to reduce the addition of decaying organic material to the water (Plate 20);

- The condition of the deactivation along the Old Sitkum Creek Road should be improved by seeding in areas that have not established, pullback of areas that remain oversteepened, and screefing the surface of the original road segments to aid conifer establishment (Section 4.3);
- To further reduce the natural flood risk on the alluvial fan of Sitkum Creek, protective measures should be implemented at two sites in macro-reach B: at the crossing of Hwy 3A, and at the water intake 160 m upstream of the highway crossing (Section 4.1). These are relatively minor measures which should be implemented by the appropriate agency, within the next couple of years. Future forest harvesting should not be linked to their completion.
- A contingency plan to manage unintended disruptions to the water supply should be developed prior to beginning operations; and,
- Section 2.1 of the Sitkum Creek Integrated Watershed Management Plan should be reviewed prior to commencing operations.

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8.0

GLOSSARY AND ACRONYMS

a.s.l.	Above sea level.
Alluvial Channels	These channels flow through sediments transported and deposited by the stream under the current hydrologic regime. Alluvial channels are classified as: Dune-ripple - has a sand bed, typical bedforms include lower-regime plane beds, ripples, sand waves and dunes. Point bars may also be present. Riffle-Pool - characterised by alternating sequences of pools, bars and riffles typically spaced every 5 to 7 channel widths. Typically associated with a floodplain and a meandering pattern. The bed is typically composed of sand, gravel and cobble sized particles. Cascade-Pool - encompasses the "glide", "riffle", and "rapid" morphologies used in the fisheries literature, and is generally featureless and straight. The bed may be composed of sand, gravel, cobble and boulder sized particles. Step-Pool - confined by valley sides, characterised by longitudinal steps formed by large particles which dissipate much of the water's kinetic energy in the form of turbulence. Flow is subcritical at the pools, and supercritical over the steps. Steep Cascade - confined, with a bed composed of large, randomly placed particles producing jet-and-wake flow.
Alluvial Material	Material transported and deposited by running water.
Annual Peak Daily discharge	The highest daily discharge in a stream recorded over a period of one year.
Anthropogenic	Adjective describing actions caused by human activity.
Bankfull Flow	The discharge that fills a channel but does not spill out onto the floodplain; often assumed to recur with a return period of about 1.5 to 2 years.
Bedrock Channels	Lacks a continuous alluvial bed, and has little or no valley fill. This channel is the result of a transport capacity much higher than sediment supply. Often the result of catastrophic scouring as a result of a debris flow.
Biogeoclimatic Zone	A geographic area having characteristic vegetation with associated climate, soils and animals. In British Columbia, each forested zone occurs under a broadly similar macro-climate and is usually named by one or more of the dominant tree species which are capable of self-regeneration on most of the zone's habitats (e.g., Coastal Western Hemlock, Interior Douglas fir). In B.C., the biogeoclimatic zones are further subdivided into sub-zones, variants, and phases.
Channel Confinement	The degree to which the valley sides restrict the lateral movement of the stream channel.
Channel Coupling	The degree to which sediment produced on the hillslopes is delivered (by landslides or surface wash) to the stream channel without intervening storage on the river floodplain.

Channel Disturbance

The disturbance level is an assessment of the level of anthropogenic disturbance to the stream channel. **Not detectable:** There is no physical evidence of anthropogenic disturbance to the stream channel. **Slight:** While spatially limited disturbances are identifiable, the large majority of the stream reach is undisturbed. Disturbances upslope of the stream channel that may or may not have impacted the channel may be present. This may include such disturbances as stream crossings and logging adjacent to the stream but with a suitable riparian management area retained. **Moderate:** Anthropogenic disturbance is widespread throughout the reach, affecting more than 1/4 of the reach length. Disturbances upslope of the stream channel, where present, likely have impacted the channel. This may include roads parallel to the stream channel, selective logging of the riparian area and/or logging of one stream bank, and occasional landslides reaching the stream channel. **High:** Disturbance is both widespread and severe, affecting more than 1/2 of the reach length. This may include logging of the riparian area, skidding or yarding across the stream channel, channel diversions due to failed or improperly placed culverts, or frequent landslides reaching the stream channel. **Extreme:** Disturbance is ubiquitous, affecting 3/4 of the reach length or more. There is evidence of widespread alteration of the stream channel and/or extensive inputs/removals of sediment or debris from the stream channel. This level of disturbance is only rarely encountered, and may include skidding and/or road construction within the wetted perimeter of the stream, or extensive and severe landslides reaching the stream channel.

Channel Morphology

The characteristic shape and organization of the landforms within the stream channel.

Channel Pattern

The characteristic shape of a river channel, as seen from above (i.e. a map view).

Channel Response Potential

Relates the channel sensitivity and the watershed routing efficiency to determine the potential for a channel to alter its morphology and/or sediment transport regime in response to an incremental increase in ECA (see table below). It may be classified as **High, Moderate** or **Low**.

Potential for channel response due to ECA changes.

		Watershed Routing Efficiency		
		Low	Moderate	High
Channel Sensitivity	Low	Low	Low	Low
	Moderate	Low	Moderate	Moderate
	High	Low	Moderate	High

Channel Sensitivity	This is an assessment of the potential for the channel to change in response to future disturbance. Very Low: The channel is unlikely to change its channel pattern, cross-section, or slope as a result of any level of disturbance. Low: The channel may undergo changes in channel pattern, cross-section, or slope when subject to a high level of disturbance. However, the extent of channel changes will be limited due to immobile boundaries (e.g. bedrock) and/or small volumes of stored alluvial sediment. Moderate: The channel may undergo changes in channel pattern, cross-section, or slope when subject to moderate or high levels of disturbance. The extent of the channel changes may be limited in places due to immobile boundaries and/or small volumes of stored alluvial sediment. High: The channel may undergo changes in channel pattern, cross-section, or slope when subject to moderate or high levels of disturbance. The extent of the channel changes increases with the degree of disturbance, and it not generally limited by immobile boundaries or the extent of alluvial sediment. Very High: The channel may undergo changes in channel pattern, cross-section, or slope when subject to slight to moderate levels of disturbance. The extent of the channel changes may be drastic in response to any degree of disturbance. Such channels are usually associated with deposits of highly erodible, non-alluvial sediments, such as lacustrine silts and fine sands.
Channel Stability	Refers to the average channel width, depth, slope, and sinuosity; these parameters do not change over time in a stable channel, but one or more of them may change in an unstable channel.
Channel Stability Impact Rating	Channel stability impact rating is defined as the degree to which anthropogenic activity has affected channel stability (this is not the same as "channel stability" per se). This impact rating incorporates the influence of both direct disturbance (such as road crossings and riparian logging) and indirect disturbance (such as increased fine sediment supply from roads, and increased peak flows). Note that a naturally unstable channel would receive a low rating if it had not been impacted by human activity. Additionally, a channel that was disturbed by human activity in the past but which has recovered to the pre-disturbance stability level would receive a low rating. The channel stability impact rating was determined by aerial photo examination and field observation. A "low" rating means that anthropogenic changes in stability affect a small proportion of the mainstem length and/or that the change in overall basin channel stability is small. A "high" rating means that a substantial proportion of the mainstem has been affected, and that the channel stability in the basin has been altered.
Clast	A coarse sediment particle, usually larger than 4 mm in diameter.
Colluvium	Material transported across and deposited on slopes as a result of mass movement processes (i.e. primarily by gravity, not running water).
Colluvial Channels	Exhibit only minor sediment transport by fluvial processes, and fluvial processes are not considered to govern the deposition, transport or sorting of the sediment. Debris flows and/or avalanches dominate the sediment transport regime
Dendritic Pattern	A branching pattern of stream channels that resembles the limbs on a tree.
Discharge	Rate of fluid flow expressed as a volume per unit of time (e.g. m ³ /s)
ECA	Equivalent Clear-cut Area. The total area clearcut reduced by an amount that accounts for the hydrologic effects of forest regrowth.
Glaciofluvial Deposit	Material moved by glaciers and subsequently sorted and deposited by streams flowing from the melting ice. The deposits are stratified and may occur in the form of outwash plains, deltas, kames, eskers, and kame terraces.

H ₆₀	The elevation in a watershed above which lies 60% of the watershed area. Peak flows are thought to be more sensitive to forest harvest above H ₆₀ .
IWAP	Interior Watershed Assessment Procedure: a process for assessing the risk that prior harvesting-related activities have impacted a watershed; outlined in a guidebook developed by Ministry of Forests.
Large Woody Debris (LWD)	Fallen trees or pieces of wood with diameter greater than 10 cm (trunk sections, branches or roots) situated in streams or lakes.
Peak Flow Impact Rating	Peak flow impact rating is defined as the likelihood that peak flows (equal to or greater than the annual maximum daily discharge) have been increased by human activity. This impact rating does not imply channel change as a consequence.
Reach	A relatively homogeneous section of a stream having a sequence of repeating structural characteristics (or processes) and fish habitat types. The key factors used to discriminate between reaches are discharge, sediment load, channel pattern, channel confinement, gradient, streambed material and bank material.
Riparian Area	An area of land adjacent to a stream, river, lake or wetland that contains vegetation that, due to the presence of water, is distinctly different from the vegetation of adjacent upland areas. (MoF web page; http://www.for.gov.bc.ca)
Riparian Condition	The degree to which the riparian area has been altered; a riparian area may be natural , may exhibit an extensive buffer or equivalently have been subjected to selective logging , may exhibit a partial buffer , may have been logged to bank .
Riparian Function Impact Rating	Riparian function impact rating is defined as the degree to which natural riparian function has been disturbed. This impact rating incorporates both the level of past disturbance and the level of recovery of the riparian vegetation.
Salmonid	Fish of the family Salmonidae, including salmon, trout, chars, whitefish, ciscoes, and grayling. It generally refers to salmon, trout and chars.
Sediment Delivery Potential	This is the potential for sediment to be delivered to the stream network. There are three sediment delivery potential classes: Low (no or minimal delivery of sediment from roads to any stream system, sediment commonly delivered to forest floor, with no surface runoff during the wet season); Moderate (sediment delivery partially disconnected from the stream network, disconnected by flat terrain and/or discontinuous drainage routes); and High (sediment delivered to stream network directly or via ditch drainage or surface runoff routes). These classifications correspond to a similar system presented in the <i>Interior Watershed Assessment Procedure Guidebook</i> (1999). Low corresponds to class 1, moderate to class 2 and high combines class 3 and 4.
Sediment Erosion Potential	Sediment erosion potential has three classes: Low (road surface armoured and/or re-vegetated, ditches functional and stable, cutslopes stable and/or vegetated, fillslopes vegetated, typical of low-use roads and/or highly erosion-resistant road prism materials); Moderate (road surface stable, little/no rutting on road surface, cutslope stable, only localised cutslope erosion, fillslope generally stable, erosion localised, typical of active forest roads and/or recent temporarily deactivated road sections); and High (rates of erosion of road surface, cutslope and/or fillslope is substantial, little or no stabilising vegetation on the cutslope or fillslope, typical of roads through unstable terrain, roads on erosion-prone surficial materials, roads through seepage zones, and new roads).

Sediment Hazard	This is the combination of the sediment delivery potential and the sediment erosion potential used to describe the likelihood that sediment produced from a road section is delivered to the stream network. Sediment hazard can be Low, Moderate or High .
Sediment Impact Rating	Sediment impact rating is defined as the degree to which human activity has increased the rate of sediment supply to the stream channel, relative to background rates. Sources of anthropogenically-derived sediment include landslides, roads, range areas, and areas in agricultural production. A "low" rating means that the proportion of total sediment delivered to the channel has not been changed by human activity. Where a previous anthropogenic sediment source has been stabilized (e.g. through re-vegetation), a low impact rating would be given. A "high" rating means that the proportion of the total sediment delivered to the channel related to anthropogenic activities has increased. This could have occurred for example through an increase in the frequency and/or magnitude of mass movement events.
Sediment Size	Refers to the b-axis diameter of a particle. Classified as silt (>0.004-0.062 mm), sand (>0.062-2 mm), gravel (>2-64 mm), cobble (>64-256 mm), boulder (>256 mm).
Stream	A stream is any reach; it must have a continuous channel bed; the bed or banks can be locally obscured; and the bed must be scoured by water or contain observable deposits of mineral alluvium.
Sub-Basin	A subdivision of a watershed, usually also watershed of a tributary channel.
Surficial Material	Relatively young, nonlithified sediments, usually of Quaternary age; usually classified as to their genesis, hence fluvial sediments, colluvium, glaciolacustrine sediments, till.
Till	Material deposited by moving ice sheets or glaciers, without subsequent modification by other transport processes. Till is often a diamicton, consisting of a fine matrix (usually sand or silt) and larger clasts (gravel, cobble and boulder-sized particles).
Watershed	An area of land that collects and discharges water into a single main stream through a series of smaller tributaries.
Watershed Advisory Committee	A technical group formed to provide specific watershed information and make land-use recommendations. (MOF/MELP, 1999).
Watershed Routing Efficiency	Watershed routing efficiency is defined as the relative rate of transmission of runoff from an arbitrary point in a watershed to the mainstem channel. It is used in conjunction with channel sensitivity to assess the potential for ECA impacts on the mainstem channel. It is an intrinsic property of a watershed, i.e. it is not related to a particular forest development plan. It is assessed by considering relevant watershed characteristics, including: presence and extent of lakes and wetlands, potential for losses to groundwater (a function of soil permeability and depth), slope gradient, extent of stream network, and extent and location of road network. Watershed routing efficiency is assigned a value of Low, Moderate or High. The typical characteristics of the three classes of watershed routing efficiency are listed in Table 1

Table 1. Characteristics of each class of watershed routing efficiency

	Low	Moderate	High
Lakes & Wetlands	Frequent lakes and wetlands within the watershed, causing attenuation of peak flows from more than 1/2 of the watershed.	Lakes and wetlands may be present, but only cause attenuation of peak flows from 1/4 to 1/2 of the watershed.	Few or no lakes or wetlands, affecting less than 1/4 of the watershed.
Ground water	Soils may be permeable and deep, resulting in significant losses of surface water to groundwater, having much the same effect as lakes and wetlands.	Limited areas of deep, permeable soil. Significant losses of surface water to groundwater may affect parts of the watershed, but not all of it.	Soils are shallow and/or impermeable, with little loss of surface water to groundwater.
Stream network	The stream network may be discontinuous in places, with much of the headwaters unchannelized or drained by indistinct channels.	Relatively extensive channel network with few/no discontinuities. Headwater reaches are well defined.	Extensive channel network, resulting in rapid routing of precipitation or snowmelt from headwaters to mainstem. Headwater channels are well defined and relatively large.
Road network	Road network does not extend the drainage network significantly. High, long cutbanks are rare, and the basin area upstream of the existing cutbanks where subsurface flow is likely captured is small.	Road network extends the drainage network to a degree. Cutbanks intercepting subsurface flow are common, but the basin area upstream of such cutbanks is small (i.e. < 1/3 of the basin area).	Roads extend the drainage network significantly, and cutbanks intercept subsurface flow, affecting a large part of the drainage basin (i.e. greater than 1/3 of the basin area).
Hillslopes	Terrain is generally gentle (5-30%) to moderate (30-50%) slopes.	Terrain is generally moderate (30-50%), with local areas of moderately steep (50-70%) and gentle (5-30%) slopes.	Terrain is generally steep (>70%) to moderate (50-70%) slopes.

Appendix A

ROADS AND SEDIMENT SOURCES

Road Sediment Hazard Survey - Sitkum Creek (Alpine) FSR

Assessment completed in Aug/00

Watershed	Road Name	Zero set	Section Start (km)	Section End (km)	Comments
Sitkum Creek	Sitkum/Alpine	paved road up from HWY	0.00	0.40	paved road thru residential area
	Sitkum/Alpine	start of gravel road	0.00	1.00	minor rutting on surface
			0.70		SB to left (SB-1), Bourke Ck immediately to right
			0.95		SB to right
			1.00		SB to left, road deactivation starts here, XDs frequent, blue gate on right
			1.19		crossing of B1 slide
			1.30		SB to left (SB-2)
			1.70		SB to right, XDs to here have good spacing and armour
			2.05		SB to left, initiation area of slide B1 (SB-3)
			2.85		open gate
			3.25		bottom of Old Sitkum Ck Road to right - closed -, SB to right
			2.85	3.70	surface rutting, high sand content in ditches
			4.19		SB to left, initiation area of B2 (SB-4)
			4.60		SB to right (SB-4A)
			4.90		SB to left (SB-5)
			5.40		Road to turn on right
			5.60		break in slope here makes the road level off
			7.75	7.90	road is very rocky and eroded, difficult 4x4 access
			7.90		top of Old Sitkum Ck Road to left - closed -
			5.60	7.90	road often has surface erosion
			8.05	8.30	slumping cutbank in banded sand, seepage zone
			8.13		slumped cutbank has crossed road surface, staked as "#1" in field
			8.30		bridge crossing
			8.30	8.80	slumping cutbank section, seepage is less pronounced, CMPs in this section are only 300 and will plug easily with cutslope sand
			8.55		cutslope slumping that deposits of floodplain, S12
			8.75	8.80	road failure S13, 2-3 m headscarp in fillslope
			9.35		cutslope failure into gully, transport down gully is limited
			9.40	10.60	cutbank problem ends here, no more slumping, but ditches are shallow and plugging from ravelling cutslope
			10.10	10.20	road eroded by stream crossing, difficult 4x4 access
			10.60	11.05	road surface is rutted from surface flow out of plugged ditch
			11.00	11.25	side slope is wet with seepage, common wet-indicator plants
			11.50		debris flow crosses road, S15, difficult 4x4 access
			12.10	12.20	road surface is rutted from creek at 12.6 running onto road, prescriptions for XD are already marked, difficult 4x4 access
			13.10		debris flow crossing road, S16, difficult 4x4 access
			13.25		mine tailings pond to right, fine sand deposits
				14.50	end survey, remainder of road was seen from helicopter

Note:

SB= switchback

XD= cross-ditch

Road Sediment Hazard Survey - Old Sitkum Creek Road

chainage begins at lower road junction with Sitkum Creek FSR, and works upgrade

Assessment completed Aug/00

Watershed	Road Name	Zero set	Section Start (km)	Section End (km)	Comments
Sitkum Creek	Old Sitkum Ck Rd	at lower junction with Sitkum Ck FSR	0.000	0.240	assessment on foot, road is perm. deactivated with full pullback and seed, gullies are re-established
			0.080		Slide S1, large XD at top of slide to drain slope
			0.240	0.328	original road surface, no pullback, side slopes 70%
			0.305		XD is flagged here in field, marked as 2+522, there is no XD installed however
			0.328	0.333	short section of pull back with re-established gully crossing and seed
			0.333	0.435	original road surface, no pullback
			0.435	0.442	pullback section above small fillslope slump. Deactivation is ok
			0.442	0.460	original road surface, no pullback
			0.460	0.570	pullback section with seeding over 30% of surface
			0.570		Slide S3, cutbank is still slumping a bit, pullback material is still ravelling a bit. Moderate level of activity, headscarp is still 110%, recommend full pullback of road surface here and loading material in cutslope
			0.570	0.804	pullback section with seeding over 30% of surface
			0.804	0.816	Slide S4, reaches creek, cutbank is stable bedrock, low activity
			0.816	0.930	pullback section with seeding
			0.930	0.942	Slide S5, pre-1988 slide, well vegetated, cutslope is stable with bedrock, low activity
			0.942	1.062	side slopes through here are 70%
			1.062	1.095	original road surface, no pullback
			1.095	1.120	large swale that has no evidence of instability
			1.095	1.280	pullback section with seeding, series of wet gullies in this section that have been reestablished
			1.280	1.307	original road surface, conifers are only growing in center and sides of road, not in tire tracks.
			1.307	1.365	pullback section, nicely done
			1.365	1.385	original road surface
			1.385	1.458	pullback section, seeded
			1.458	1.530	original road surface
			1.530	1.583	pullback section, seeded
			1.583	1.617	original road surface
			1.617	1.630	pullback section, seeded
			1.630	1.760	original road surface, with XDs at gullies
			1.760	1.786	Slide S8, headscarp still oversteepened in places, would benefit from further pullback, seeding has not taken well at top of slide, moderate activity
			1.786	1.793	pullback section, seeded
			1.793	2.789	original road surface
			NB	2.185	side slopes here are 40%
			NB	2.230	road gradient lessens here
			NB	2.248	large gully crossing with flow
			NB	2.713	side slopes here are 35%
			2.789	2.791	Slide S11, low activity, reaches creek, pullback is ok
			2.791		end of road at upper junction with Sitkum Ck FSR

Assessment of Switchback Drainage along Sitkum Creek FSR

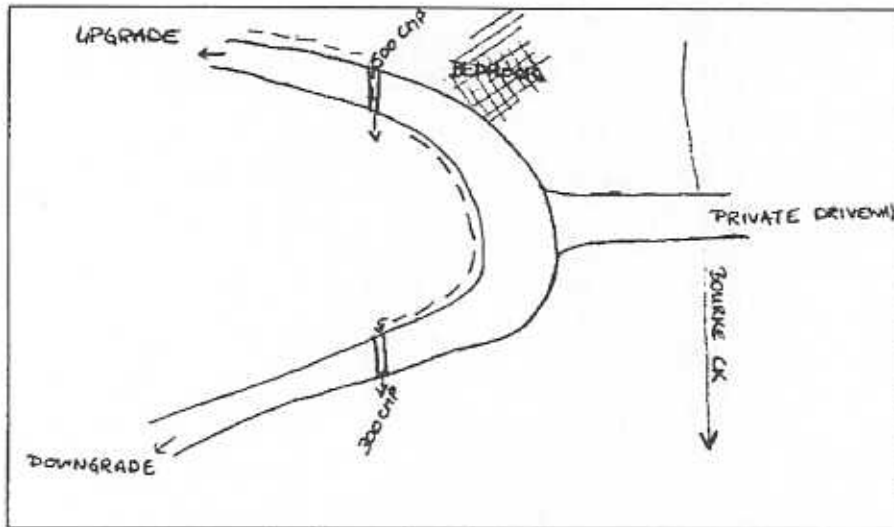
Aug-00

Switchback names are referenced on Map 1.

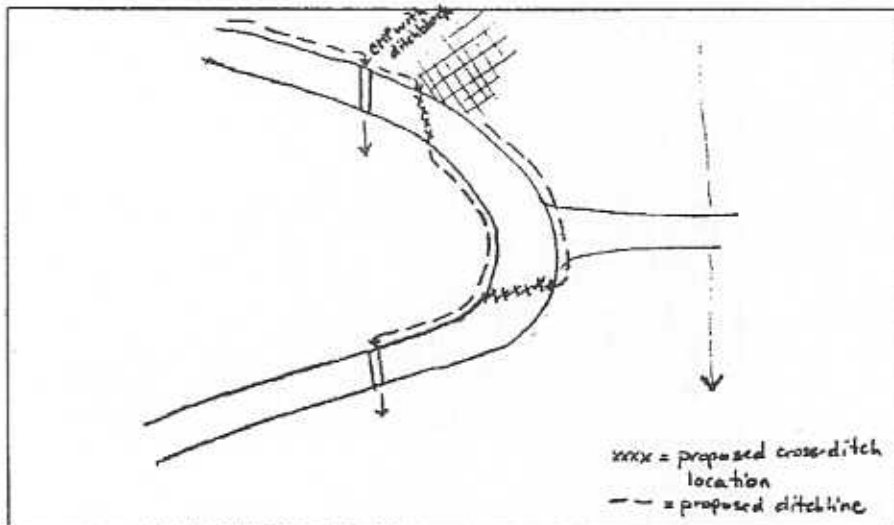
Location	Comments	Recommendations
SB-1	switchback is located on private land	Recommend installing cross-ditch to collect road surface water at 7m downgrade of the 500 CMP above the corner. Also recommend establishing a ditch to the new cross-ditch and then another on the downslope side of the bedrock outcrop to carry runoff around the outside of the bend. On the downgrade side of the private driveway, install an additional cross-ditch to move runoff back to inside ditchline, and then down to the existing cross-ditch below switchback. Conduct regular maintenance on ditches, cross-ditches, and culverts. (see sketch next page)
	flow runs across road surface at corner due to lack of cross-ditch above corner, and lack of ditch on outside of corner	
	drainage is currently moved by CMPs that have not been backed up with cross-ditches	
SB-2	there are 2 cross-ditches located here, both requiring deepening as they allow flow onto road surface	Deepen cross-ditches to prevent road surface flow, or replace with culverts if road is upgraded. Conduct regular maintenance on ditches and cross-ditches.
SB-3	slide B1 initiates 35m below the switchback	Recommend to leave drainage as is, with the small amount of seepage flow directed into a gully on the outside of the switchback. It is better to direct the flow into the gully rather than onto the open slope, due to the sensitivity of the terrain - indicated by Slide B1. Maintain cross-ditches to ensure the majority of runoff is effectively moved around the switchback, and prevented from entering the gully.
	cross-ditches are located above and below the switchback, installed after the slide event	
	presently only 15m of ditch seepage contribute to the gully on the outside of the switchback	
	slope gradients here are 55%	
SB-4	Slide B2 originates on outside of switchback	Conduct regular maintenance on ditches and cross-ditches.
	two cross-ditches are located here, one above the corner, the second 30m downgrade of the corner. They are functioning well.	
	the cutslope at the top of the corner is raveling sandy material	
SB-4A	cutslope upgrade of switchback has slumped and has ongoing raveling in sandy till which is blocking ditch below runoff is draining on road surface	Recommend armouring base of cutslopes and excavating ditch for 25m above the switchback. Conduct regular maintenance on ditches and cross-ditches.
SB-5	three cross-ditches are located at this corner, one immediately upgrade, one at the peak of the corner, and one 60m downgrade of the corner	Recommend installing a cross-ditch 30m upgrade of the lowest existing cross-ditch to separate flow from the corner from that drained downslope by the highest cross-ditch. Also recommend creating a small ditch pool at the lowest cross-ditch to allow sands to settle out before flowing onto forest floor. Conduct regular maintenance on ditches and cross-ditches.
	2 upper cross-ditches are effectively controlling water flow around switchback	
	lowest cross-ditch is filling with sand, and appears to carry quite a bit of water	
	ditches are deep and clean	

Assessment of Switchback Drainage along Sitkum Creek FSR

Switchback SB-1 - Existing Drainage Conditions



Recommendations for Drainage Improvement



Sediment Source Survey

Point Source Summary - Sitkum Creek Watershed

Label	Surficial Material	Reaches Creek?	Cause of Instability	Current Level of Instability	Estimated Area		Estimated Revegetation (%)
					Width(m)	Length(m)	
B1	till	N	Road	L	7	270	70-80
B2	till	Y	Road	M	50	250	30-40 grasses mostly
S1	till	Y	Road	L	15	70	70
S2*	colluvium	Y	Natural	L	15	900	70-80
S3	till	Y	Road	M	25	130	70
S4	till	Y	Road	L	20	110	90
S5	till	Y	Road	L	20	110	80
S6	till	Y	Road	L-M	15	90	70
S7	till	N	Road	L-M	15	80	80
S8	till	Y	Road	M	15	90	60
S9	till	Y	Road	M	25	70	60-70
S10	till	Y	Road	L-M	20	50	70
S10A	till	Y	Road	L-M	10	35	70
S11	till	Y	Road	L	20	50	80
S12	wet till	N	Road	H	100	40	0
S13	wet till	Y	Road	H	17	70	0
S14*	colluvium	Y	Natural	L	15	520	70-80
S15	colluvium	Y	Natural	M	15	840	0
S16	colluvium	N	Natural	M	10	500	0

Note: Refer to Map 1 for location.

Table includes both natural and anthropogenic-related point sources.

*indicates a natural gully that has the potential to transport debris flows, and shows evidence of historic activity

Appendix B

CHANNEL ASSESSMENT

Reach Break Summary for Sitkum, Bourke, and Clayton Creeks

Project : 039-04.02

Aug-00

Stream	Reach No.	Length (m)	Slope (%)	Confined?	Channel morphology ¹	Riparian Condition ²		Large Woody Debris			Bankfull channel dimensions		Dominant bed surface texture ³	D _{max} ⁴ (mm)	Sensitivity ⁴	Stability ⁷	Disturbance Level ⁸
						Left bank	Right bank	Quantity ¹	Stability ⁴	Recruitment potential ⁴	Width (m)	Depth (m)					
Sitkum Creek	MR A	446	8-12	N	CP	2	2	2		3			c,b		4	2	3
	MR B	461	12.0	N	SP	3	3	1	3	3	10.5	1.4	b,c	480.0	4	1	2
	MR C	520	>20	Y	CP	1	1	2		4			b,c		2	1	1
	MR D	1040	12-16	Y	CP	1	1	3		4			b,c		2	1	1
	MR E	460	>20	Y	SP	1	1	3		4			b,c		2	1	1
	MR F	2500	12-16	Y	SP	1	1	3		4			c,b		3	1	2
	MR G	640	8-12	Y	CP	1	1	3		4			c,g		3/2	1	1
	MR H	3460	5.0	Y	CP	1	1	4	3	3	9.3	0.7	b,c	546.0	3/2	1	1
	east reach MR I	3120	15	Y	SP	1	1	5		2			b,c		2	1	1
	west reach MR I	2260	22.0	Y	SP	1	2	4	4	2	0.8	0.1	b,g	359.0	2	1	2
Bourke Ck	1	80	19.0	N	SP	2	2	2		3			c,g		3	2	2
	2	180	15.0	Y	SP	1	1	3	4	3	1.1	0.3	b,g,s	330.0	2	1	1
	3	420	15.0	Y	SP	1	1	2	4	3	1.3	0.2	s,b,c,g	284.0	2	1	2
	4	100	10.0	Y	SP	1	1	1	4	2	1.2	0.4	b,s,g	231.0	3	1	2
	above slide B2	580	40.0	Y	SC	1	1	3	4	3	1.4	0.5	b,c,g	517.0	2	1	1
	within slide B2		50.0	Y	SC	1	1	3	3	3	2.6	0.7	b,c,g	578.0	2	1	5
	6	600	42.0	Y	SC	1	1	4	3	3	2.1	0.1	b,g	372.0	2	1	1
Clayton Ck	1	100	20.0	N	SP	2	3			2			c,b		3	2	2
	2	100	15.0	Y	SP	2	1	2	4	2	1.1	0.3	s,z,b	370.0	2	1	2
	3	100	37.0	N	SC	1	1			2			c,g		4	1	1
	4	220	40.0	Y	SP	1	1	1	4	2	1	0.28	s,b,z	283	2	1	1
	5	120	21	Y	SP	1	1			2			b,c		2	1	1
	6	260	46	Y	SC	1	1			2			c,g		2	1	1

1: dune-ripple (DR), riffle-pool (RP), cascade-pool (CP), step-pool (SP), steep-cascade (SC), colluvial (CL) and bedrock (B); -w indicates LWD-related channel morphology

2: natural (1), extensive buffer/selective logging (2), partial buffer, intact banks (3), logged to bank, substantial revegetation (4), logged to bank, no stabilizing vegetation (5)

3: scarce (1), occasional (2), common (3), abundant (4), over-abundant (5)

4: very low (1), low (2), moderate (3), high (4), very high (5)

5: silt (z), sand (s), gravel (g), cobble (c), boulders (b)

6: estimated from 10 largest particles transported by the stream.

7: the classes are

1 = stable (average channel width, depth, slope, and sinuosity do not change over time)

2 = unstable (average channel width, depth, slope, and sinuosity are changing over time)

8: not detectable (1), slight (2), moderate (3), high (4), extreme (5)

NB: shaded boxes indicate information that could not be accurately assessed during the helicopter reconnaissance or from airphoto interpretation.

Appendix C

PHOTOGRAPHS



Plate 1: View upvalley of Sitkum Creek watershed through channel Macro-reaches H and I.
 Date: 02-Aug-2000 Photograph 2-13



Plate 2: View east towards the Sitkum Creek fan at Kootenay Lake. Highway 3A crosses
 the fan and the Sitkum Face Road is at left.
 Date: 02-Aug-2000 Photograph 3-22



Plate 3: Sitkum Creek Macro-reach D. Step-pool channel with bedrock chutes
and a boulder/cobble bed.
Date: 02-Aug-2000 Photograph 1-20



Plate 4: Sitkum Creek Macro-reach H. A cascade-pool channel with common
bedrock steps.
Date: 02-Aug-2000 Photograph 4-28



Plate 5: Sitkum Creek Macro-reach I east. Step-pool channel with heavy debris loading from avalanche activity.
Date: 02-Aug-2000 Photograph 2-19



Plate 6: Sitkum Creek Macro-reach I west. Sediment accumulation at wooden weir.
Date: 02-Aug-2000 Photograph 2-25



Plate 7: Bourke Creek Reach 3. Step-pool channel below toe of Slide B2. Note sand deposited on channel banks.
Date: 04-Aug-2000 Photograph 5-15



Plate 8: Bourke Creek Reach 6. A steep-cascade channel with colluvial lag boulders.
Date: 03-Aug-2000 Photograph 5-5



Plate 9: Clayton Creek Reach 3. A steep-cascade channel with a cobble/boulder bed.

Date: 04-Aug-2000

Photograph 5-31



Plate 10: Road cutslope approximately 200 m upgrade of the Sitkum Creek road crossing. The seepage zone between sandy till and fine-grained glaciofluvial deposits is evident.

Date: 02-Aug-2000

Photograph 4-16



Plate 11: Road fillslope failure (S13) at gully crossing of Sitkum Creek FSR at 8.75 km. Note 2-3 m vertical headscarp at right.
 Date: 02-Aug-2000 Photograph 4-15



Plate 12: Cutslope slump at 8.13 km along Sitkum Creek FSR. Marked with stake as "#1" in the field.
 Date: 02-Aug-2000 Photograph 4-8



Plate 13: Debris flow (S15) track crosses the Sitkum Creek FSR at 11.5 km,
resulting in 4x4 passage.

Date: 02-Aug-2000

Photograph 4-21



Plate 14: Rutted road surface at 12.1 km along Sitkum Creek FSR.

Date: 02-Aug-2000

Photograph 4-26



Plate 15: Typical view of Old Sitkum Creek road, with full pullback deactivation.
 Date: 03-Aug-2000 Photograph 4-32



Plate 16: Skid trail in cutblock (90% hydrologically recovered) between Sitkum
 Creek FSR and the old road to the burn.
 Date: 03-Aug-2000 Photograph 5-1



Plate 17: Bourke Slide (B2) just upslope of Bourke Creek in Reach 5.
Date: 02-Aug-2000 Photograph 3-15



Plate 18: Bourke Slide (B2) runout zone with well-established grass and clover
seed. Reach 5 of Bourke Creek.
Date: 04-Aug-2000 Photograph 5-20



Plate 19: Bourke Slide (B2) at lower end of runout zone, looking down towards debris jam at toe. No seed has established here. Reach 5 of Bourke Creek.
 Date: 04-Aug-2000 Photograph 5-18



Plate 20: Organic decayed material in side channel around the Bourke Slide debris jam. Channeling the flow through the jam may reduce this buildup.
 Date: 04-Aug-2000 Photograph 5-11

Appendix D
MINUTES OF
WATERSHED ADVISORY COMMITTEE
MEETING

Watershed Advisory Committee (WAC) Sitkum, Clayton & Bourke Watersheds Meeting November 16, 2000
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In Attendance:

Ken Gorsline	Ministry of Forests (MOF), WAC Chair	Warren Ward	Chair, Sitkum Creek Water Improvement District
Gay Nejedly	MOF	Joe Lintz	Bourke Creek
Luigi Iallorardo	Sitkum Property Owner	Brian Guy	Summit Environmental Consultants Ltd.
Kathy Howard	Slocan Forest Products (SFP)	Rob Mitchell	SFP
Steve White	9 mile Resident	Suzy Hamilton	Bourke Creek
Annie Kammerzell- White	Bourke Creek	Earl Hamilton	Bourke Creek
David Toews	Sitkum Creek Improvement District	Alan Davidson	Ministry of Environment Lands and Parks (MELP)

The meeting was called to order at 6:35 p.m. on Nov. 16, 2000.

1) Introduction – Alan Davidson

Forest Practices Code of British Columbia Act has legislated that an Interior Watershed Assessment Procedure (IWAP or WAP) be conducted in community watersheds prior to a Forest Development Plan (FDP) being submitted and that the FDP be consistent with the IWAP. If the FDP is not consistent, a Registered Professional Forester must provide a rationale. The District Manager and the District Environmental Officer must consider all recommendations from the IWAP process.

Initial IWAP meeting was conducted last May, and recommendations were in the minutes. Field assessments were completed last August and results are contained in Summit Environmental Consultants Ltd. Draft report.

2) Presentation of Summit Environmental Consultants Ltd. Draft Report Watershed Assessment: Sitkum, Bourke, and Clayton Creeks – Brian Guy

A pre-WAP meeting was held in May 2000. At this meeting, specific recommendations to review in the 2000 WAP study were identified. The six general objectives for this study were:

- 1) Review channel conditions
- 2) Map erosion and sediment delivery potential for roads
- 3) Provide general and specific advice for forest management
- 4) Investigate macro-reaches C, D & E of Sitkum Creek channel for slide sediment activity
- 5) Assess effectiveness of current measures on Sitkum Creek fan flood risk
- 6) Re-inspect channel of Sitkum Creek fan

Brian reviewed the draft report with the committee.

3) Discussion Items

- MELP will review assessment work and be allowed to sign off amendment to FDP.
- Future WAC updates/meetings with MELP representation may be held at the beginning of IWMP meetings but are to be kept distinct from the IWMP process as the WAC is a legislated process and the IWMP is not.
- MELP to be invited to SFP's presentation of the FDP to the Sitkum IWMP Committee.
(Action Item: MOF (IWMP Chair))
- MOF to organize a field trip to assess potential Bourke Creek restoration work that could be conducted in summer or fall of 2001, if labour is available (possibility for MOF Fire Crews). MELP would like to be involved. Prior to commencing channellizing, restoration and rehabilitation work (re: section 4.4 of WAP report), Bourke Creek residents and MELP should be advised. **(Action Item: MOF)**
- MELP would like to be involved in a field trip in the summer or fall of 2001 to assess works required at oversteepened fillslope on deactivated old mining road at 0+1000m from north end of road (as depicted in photos presented at WAC meeting). **(Action Item: MELP/SFP)**
- Alan Davidson will review the Terrain Stability Field Assessment letter (Summit's August 25, 2000 letter report) (This was done and the report for Block 3 is accepted).
- MELP would like opportunity to review Silviculture Prescriptions for blocks 17-1 and 17-25.

4) Future Planning Considerations

- MELP reserves the right to review the 20% ECA in the future.
- Field work associated with the WAP revealed that portions of the valley slopes with the Sitkum Creek watershed are somewhat sensitive to disturbance. This gave rise to a discussion on future development in potentially high risk areas. MELP provided some examples, after the meeting, of what they considers high risk areas:
 - a) *Roads on Class IV or V terrain with a Class 3 Landslide Induced Sedimentation Hazard (LISH), or*
 - b) *> 20% ECA above Class IV or V terrain with Class 3 LISH, or*
 - c) *>35% ECA above Class III terrain on slopes similar to terrain to the slopes exhibiting natural debris torrents and having a Class 3 LISH.**High risk refers only to the slopes above Sitkum Creek and downstream of the FSR bridge (rationale is that the apex of the fan is sensitive to clouding and the consequence can be very high).*

If high risk development is proposed in Sitkum Creek, the WAC should be given the opportunity to review.

5) Recommendations

- Restoration work on FSR should go forward within the next few years whether it is done by SFP or MOF. Priorities are the two switchbacks closest to Bourke Creek and moderate priority for S12 and S13.

- MOF to pursue funding for FSR restoration work above the 8 km bridge. Sitkum Water Users feels this area is important but priority is still with the FSR switchbacks above Bourke Creek identified in the report. (**Action Item: MOF**)
- Areas, which require restoration, would be addressed concurrent with development or prior to development in the area. Funding for restoration work should be through Forest Renewal British Columbia (FRBC) or Ministry of Forests.
- No high risk development without WAC consideration. (see 2nd bullet in Section 4 (high risk development))

Meeting adjourned: 10:00 p.m.