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MELP

Watershed Assessment

Bjerkness, Lofstedt and Fletcher Creeks

Prepared for

Appropriate Forestry Services Ltd. and

Goose Creek Lumber Ltd.

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SUMMARY

This report presents the findings of a revised and updated Interior Watershed Assessment of the Bjerkness Creek, Lofstedt Creek and Fletcher Creek community watersheds located near Kaslo, B.C. The report also provides an assessment of risk to the streams and some risk reduction recommendations. Two maps have been prepared as part of this study area: Map 1 shows the watershed boundaries and major water intakes as well as the proposed logging development; Map 2 shows the stream reaches and major point sediment sources.

The following table summarizes impact indicators for the three watersheds under existing conditions and following proposed development:

Table 1 Summary of indicators for Bjerkness, Fletcher and Lofstedt Creeks

Indicator	Units	Fletcher			Bjerkness subbasin			Loftstedt subbasin		
		Existing	Proposed	Total	Existing	Proposed	Total	Existing	Proposed	Total
ECA – unweighted	%	3.2	2.3	5.5	7.3	5.5	12.8	12.2	6.2	18.4
ECA –weighted	%	3.3	2.3	5.6	9.9	6.6	16.5	14.3	7.4	21.7
Total major roads	km/km^2	0.165	0.303	0.468	0.272	0.554	0.826	1.924	0.285	2.209
Total minor roads	km/km^2	0.043	0.0	0.043	0.011	0	0.011	0.215	0	0.215
Roads, Interception	km/km^2	0.178	0.303	0.481	0.283	0.554	0.837	2.139	0.285	2.424
Roads on Terrain Stab. Class IV/V	km/km^2	0.118	0.05	0.168	0.055	0.064	0.119	0	0.001	0.001
Roads on soils with High or Very High Sediment Yield	km/km^2	0.032	0.087	0.119	0.128	0.148	0.276	0	0.014	0.014
Density of Stream Crossings	no/km^2	0.219	0.146	0.365	0.206	0.926	1.132	0.97	0.139	0.236
Landslides with connection to stream	no./km	6.0	na	6.0	5.8	na	5.8	0	na	0

Note: 'Proposed' is the increment for each indicator which would be caused by currently proposed forest development as shown on Map 1.

1.0 INTRODUCTION

This report presents a Watershed Assessment of the Fletcher Creek and Bjerkness Creek (including Lofstedt Creek) drainages. Fletcher Creek and Bjerkness Creek are community watersheds serving part of the community of Mirror Lake, B. C. and numerous individual water licensees. Lofstedt Creek is a subbasin of Bjerkness Creek.

The report was commissioned by Appropriate Forestry Services Ltd., Kaslo, B. C. acting for Goose Creek Lumber Co. Ltd. Goose Creek is the operating licensee with timber harvesting rights for a major portion of the Fletcher Creek basin and Bjerkness basin. Meadow Creek Cedar Ltd. and J. Mattes, licensee of Woodlot 438 hold timber harvesting rights for part of the Fletcher Creek basin. Lofstedt Forestry Society, licensee of Woodlot 494, and the Kaslo and District Community Forest Society hold timber harvesting rights in parts of the Lofstedt Creek watershed.

The purpose of the work was to complete hydrological assessments and identify major sediment sources in the Fletcher and Bjerkness watersheds, consistent with, or exceeding, the requirements of the current BC MOF Interior Watershed Assessment Procedure (Version 2, April, 1999). The work included the following:

- In stream channel assessment of a major portion of the Fletcher and Bjerkness stream channels. Helicopter overview of the remainder of the main channels.
- Reconnaissance stream channel checks of parts of Loftstedt Creek.
- Field checks of the location of the northern boundary of the Lofstedt catchment basin.
- Identification of major sediment sources which result in sediment delivery to Fletcher and Bjerkness Creeks.
- Ground based assessment checks of tree height and density in burned areas and logged areas in Fletcher and Bjerkness basins to allow updating of the hydrological recovery estimate.
- Calculation of Equivalent Clearcut Area for existing natural and timber harvest disturbance and proposed harvest in the Fletcher and Bjerkness drainages.
- Calculation of road length, road density and a number of other parameters which could have a hydrological impact.

Field work was completed in September, October and November, 1999, with additional checks in March, 2000.

1.1 Limitations and Reliability

This report and accompanying maps are based on airphoto interpretation, literature review, and field checks. They are intended to fulfil the requirements of the Interior Watershed Assessment Procedure (1999). This study is meant for use in general development planning and is not to be used as the basis for detailed cutblock layout or road layout. The hazard and risk ratings given in this report assume compliance with the B.C. Forest Practices Code and recommendations made in the report. *Follow up ground assessment of terrain stability and sediment delivery hazards is required in all areas where development is proposed on terrain mapped with Class IV or V stability hazard or High or Very High surface erosion hazard*. The authors should be consulted if there are problems of interpretation of this document.

1.2 Previous Assessment Work

Deverney (1996), then with Kokanee Forest Consulting Ltd., carried out a watershed assessment for Slocan Forest Products Ltd. based on the Interior Watershed Assessment Procedure (1995). No other hydrological assessment or sediment source review is known to have been conducted in the Fletcher Creek and Bjerkness Creek basins.

Slocan Forest Products was at the time the major licensee holding timber cutting rights in the Bjerkness and Fletcher Creek drainages. The assessment was a GIS based process which did not include field checks of sediment sources or stream channel condition. The boundary of Lofstedt Creek was defined without field checks and was not accurate.

The terrain of the portion of the Fletcher and Bjerkness watersheds outside Kokanee Provincial Park has been mapped at Survey Intensity Level B by Deschenes and McIntyre (1998) of R. Banting Engineering Ltd. The riparian areas along Fletcher and Bjerkness Creeks were assessed for impacts on fish and wildlife habitat by Lutz et al (1996) with Kokanee Forest Consulting Ltd. The terrain of Loftstedt Creek was mapped at Survey Intensity Level B by Wells and Wallace (1999). Their work also included some spot reconnaissance checks of the stream channels of Lofstedt Creek.

2.0 STUDY AREA

The study area is comprised of the Fletcher Creek drainage basin and Bjerkness Creek drainage basin including the Lofstedt Creek subbasin. These basins are located about 8 km southwest of Kaslo, B. C. as shown on the Location Map, Figure1.

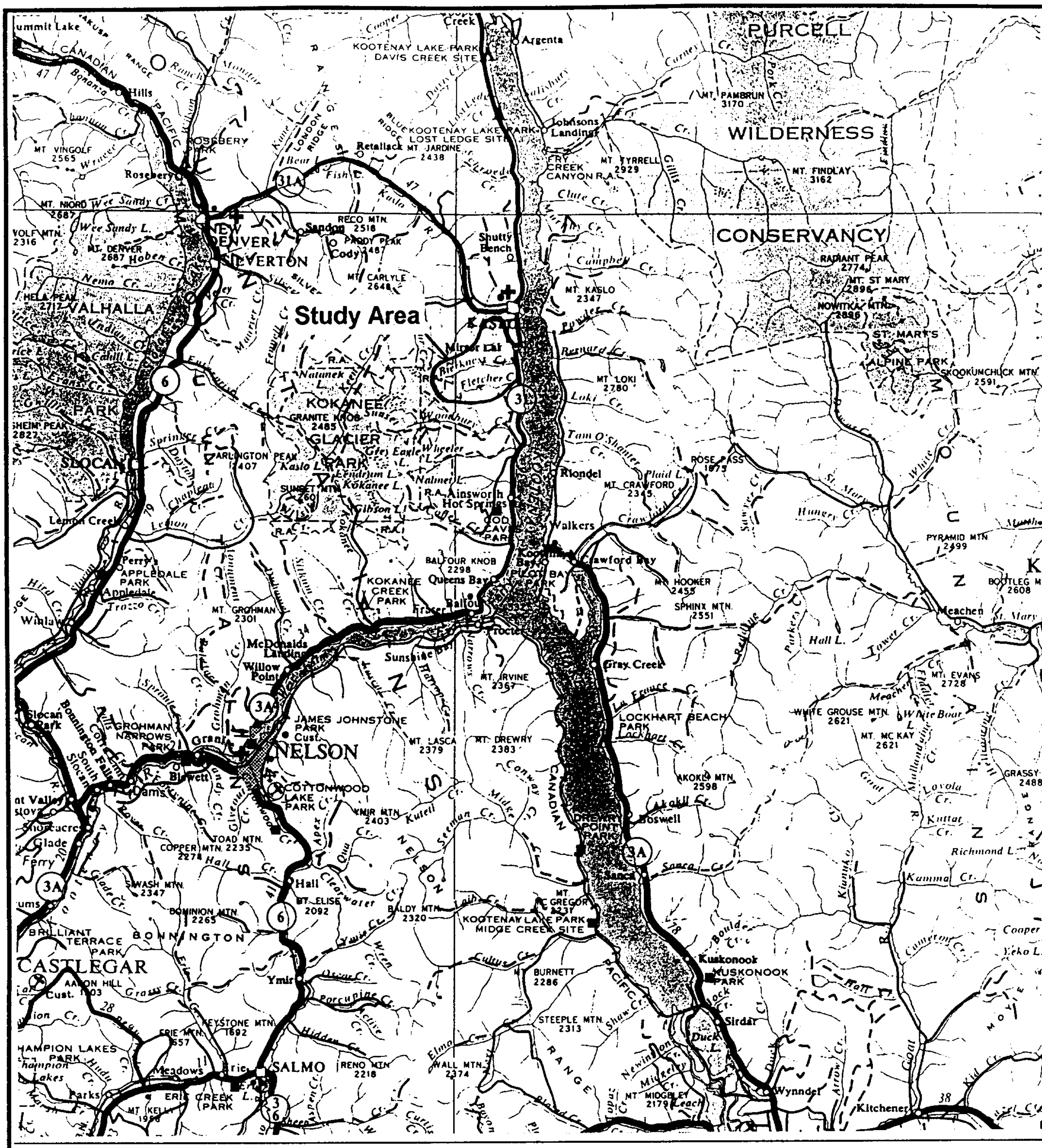
2.1 Bjerkness Basin

The main Bjerkness Creek has an area of 1944 ha and ranges in elevation from 640 m at the point of interest (POI) to 2530 m at the west margin of the drainage. Several small streams drain into Bjerkness Lake at 1910 m elevation. There are many small first and second order tributaries between Bjerkness Lake and an elevation of about 1100 m on Bjerkness Creek. Below 1100 m elevation there are a few small tributaries and Loftstedt Creek, which joins Bjerkness Creek at an elevation of 650 m about 300 m above the point of interest (POI) on Bjerkness Creek. Bjerkness Creek flows almost at right angles to the regional rock strike (trend).

Much of the eastern margin of the Bjerkness basin is defined by a large rock ridge at about 800 -1000 m elevation. Above this ridge the lower middle elevation portion of the drainage is underlain mostly by morainal material on the north side of the creek and a combination of morainal materials with colluvium and some rock ridges on the south. The middle and upper portions of the drainage are dominated by colluvium and rock ridges with minor morainal material.

2.2 Loftstedt Subbasin

The Loftstedt Subbasin has an area of 722 ha and ranges from an elevation of about 650 m at the confluence with Bjerkness Creek to 2000 m. There are two main tributaries which form Loftstedt Creek. The 'North' tributary rises at the north margin of the basin in a draw between two rocky ridges at about 800 m elevation. The 'West' tributary rises on the west side of the basin at about 1900 m on a steep east aspect slope and runs east in a steep gradient channel across the bedrock strike. Its confluence with the North main tributary is on a bench at about 720 m. In addition to the main tributaries there are a number of other small, ephemeral tributaries as shown on Map 2. The Loftstedt subbasin is predominantly underlain by morainal materials but with significant areas of colluvium and rock ridges.



Location Map – Fletcher Creek and Bjerkness Creek Watersheds

Figure 1

Scale 1:600,000

2.3 Fletcher Creek Basin

Fletcher Creek basin has an area of 1369 ha and ranges in elevation from 620 m to 2505 m at the northwest margin of the drainage. A number of small tributary streams in the upper portion of the basin feed Upper Fletcher Lake at an elevation of 1967 m. There are a number of small first and second order tributaries to Fletcher Creek between Upper Fletcher Lake and Fletcher Lake, which is at 1625 m. Below Fletcher Lake there are a few first order tributaries. Fletcher Creek cuts across the regional bedrock strike (trend).

The eastern portion of the Fletcher drainage is underlain by a large, steep rock ridge with an east aspect. Above the rock ridge, up to Fletcher Lake, there is a series of benches underlain mainly by morainal materials, between north south trending ridges of rock and colluvium . Above Fletcher Lake, rock and colluvial materials are dominant, with some morainal material.

2.4 Brewer Spring and Sandon Creek

Brewer Spring and Sandon Creek are small, licensed domestic and irrigation water sources which are on District Lot (DL) 484. They lie on private land outside the present study area. The catchment area for these water sources is not accurately known.

2.5 Heine Brook and McCarthy Spring

These are small, licensed water sources which lie near the west boundary of District Lot 437. They are within the Loftstedt Creek catchment area. Their source area has not yet been delineated.

2.6 Climate and Hydrologic Regime

Annual mean precipitation recorded in Kaslo is 584.2 mm based on Environment Canada weather records from 1912 to 1998. The records show a long term trend to higher mean annual precipitation. A graphical presentation of the annual precipitation is shown in Appendix 1D.There are no known weather records for the Mirror Lake, Bjerkness or Fletcher Creek areas. It is likely that the total precipitation is considerably higher in the headwater areas of the Bjerkness and Fletcher watersheds than at the Kaslo recording station. In the Fletcher basin and the main Bjerkness basin most of the precipitation falls as snow and the hydrological regime is dominated by snowmelt. A significant proportion of both the Fletcher and Bjerkness basins is subalpine and alpine area underlain by rock, colluvium and saprolite, with thin rocky soils and with little or no tree cover. There is very low water storage capacity in these alpine areas which contributes to a 'flashy' flow response in Fletcher and Bjerkness creeks in response to increases in precipitation or rate of snowmelt. In Lofstedt Creek a large proportion of the watershed is at low elevations and most of the drainage has good tree cover with canopy closure of 40-60% . Most of the basin is underlain by thick deposits of surficial material with substantial soil water storage capacity. As a result the flow regime is less dominated by snowmelt and the effects on the flow regime of sudden increases in precipitation or snowmelt are likely to be much less pronounced than in Fletcher and Bjerkness Creeks.

2.7 Licensed Water Sources

The following table is compiled from licensing information for Fletcher, Bjerkness and Loftstedt Creeks as provided on the web site of the Water Management Branch of the British Columbia Ministry of Environment, Lands and Parks in March, 2000. Licensed demand on the creeks is summarized in Table 2.1, below .

Table 2.1 Summary of water license data for study area.

Water Source	Licensing Demand						Total Discharge Demand	
	Domestic and Waterworks authority		Irrigation		Power			
	gallons/day	m^3/day	Acre Feet	m^3	cubic feet/sec	m^3/sec	m^3/sec	litres/sec
Bjerkness Ck	25000	113.65	51.42	6347.2848	10.6	3.23088	3.23260	3232.60
Loftstedt Ck	6000	27.28	167.5	20676.2	0.00	0.00	0.00162	1.62
Fletcher Ck	5000	22.73	11.75	1450.42	0.36	0.109728	0.11008	110.08
Brewer Spring	2500	11.37	2.5	308.6	0.00	0.00	0.00002	0.002
Sandon Creek	0.00	0.00	41.0	5061.04	0.00	0.00	0.00161	1.61
Heine Brook	1500	6.82	5.00	617.2	0.00	0.00	0.00012	0.12
McCarthy Spring	500	2.27	0.00	0.00	0.00	0.00	0.00003	0.03

2.8 Streamflow Information

The limited number of known historical flow records for Bjerkness Creek and Fletcher Creek are summarized in Appendix 1. Most of the records for Bjerkness are based on Water Survey of Canada information. The location of the gauge for the Water Survey records is not known for certain but is believed to have been located close to the present POI as shown on Maps 1 and 2 . A stream flow gauge was installed near the Bjerkness POI in 1999 by the Kaslo and District Community Forest Society; flow information for 1999 is shown in Appendix 1B. The limited records shown for Fletcher Creek in Appendix 1C are from measurements taken by D. Scarlett. The point at which flow was measured on Fletcher Creek is at about 740 m elevation. The provision of flow records by D. Scarlett and the Kaslo Community Forest is gratefully acknowledged. No historical flow data is available for Lofstedt Creek. Measurements of flow on Lofstedt Creek are being taken this spring by the woodlot licensees.

3.0 METHODS

3.1 Determination of Equivalent Clearcut Area (ECA)

Forest Cover Maps

Hydrologic recovery and equivalent clearcut area (ECA) were determined primarily by utilizing existing data on forest cover and regeneration, with confirmation by observations from airphotos and observations made during helicopter checks and ground field work. The method varied, depending on data availability. The primary sources of information included:

- Airphotos (1997, 1939)
- Field transect information

The methods used for determination of ECA are largely from work by Carver and Utzig, 1999 and their use in this report is gratefully acknowledged. The method was originally developed for determination of ECA in the Arrow Creek community watershed near Creston, B. C. Utzig assisted in initial interpretation of the recovery rating of portions of the Bjerkness basin.

For the purposes of calculating ECA, six hydrologic recovery classes were defined as outlined below.

Table 3.1 Definition of classes of hydrologic recovery.

Recovery Class	Hydrologic Recovery (%)
5	100
4	90
3	75
2	50
1	25
0	0

For burned or recently logged openings recovery class was determined using Table 3.2. All recently logged openings in Fletcher and Bjerkness basins were stratified using air photos, and typical stands on each block were ground checked to determine stocking and average stand height. Stand height was found to be less than 10.4 m on all existing logged blocks except those which had been 'high graded'. For the area in the northwest portion of Bjerkness basin, which was burned in 1940, stocking and tree height were measured in a series of plots on a transect across the burn between 2200 m and 1600 m elevation on September 28, 1999. Information was also recorded on terrain and soil types and pre-burn forest stocking on the same transect. Recently logged areas on Woodlot (WL) 494 in Loftstedt Creek were rated based on information on the percentage basal area removed provided by P. Van Allen, woodlot operator. These methods, supplemented by airphoto review, provide a more accurate determination of stand recovery and ECA on logged and burned openings than use of the provincial Silvicultural Information System data and Forest Cover data.

Table 3.2 Hydrologic recovery for recently logged openings with maximum tree height of 10.4 m.

Tree Height (m)	**<3**	**3-4.9**	**5-6.9**	**7-8.9**	**9-10.4**
Stocking (st/ha)			**Recovery Class**		
>1500	**0**	**1**	**2**	**3**	**4**
1250-1500	**0**	**0**	**1**	**2**	**3**
1000-1249	**0**	**0**	**0**	**1**	**2**
750-999	**0**	**0**	**0**	**0**	**1**
<750	**0**	**0**	**0**	**0**	**0**

Table 3.3 Preliminary hydrologic recovery class for stands without sufficient stocking data (not recently logged).

Recovery Class	Crown Closure Class: Elev. ≤1700m	Elev. >1700m	Elev. >2000m
5	≥ 5	≥4	3
3	4	3	2
2	3	2	1
1	2	1	1
0	0 & 1	0	0

Forested polygons with a tree height of less than 10.4 m and without accurate stocking data, or with a preliminary recovery class less than 5, were assessed on the 1997 airphotos to determine final recovery class using Table 3.3. It was found that the typing of forest cover polygons was inaccurate in the area of the large burn on the north side of the middle and upper Bjerkness Creek; the forest cover of all the burn area was reassessed in this study. The general criteria used for classification were soil/terrain characteristics and disturbance history combined with projection from stocking data in similar stands (where available). Airphoto interpretation of soil characteristics, fire history, stand age, tree height and species composition was used to assign recovery. For classification existing forest cover polygon boundaries were used only where they enclosed areas of reasonably homogeneous recovery class.

For forested polygons with tree height >10.4 m a sample of polygons was reviewed in the Fletcher and Bjerkness watersheds. The typing and crown closure were generally found to be accurate except for the large area of mature Spruce Balsam at elevations of 1500-1800 m at the west end of the Bjerkness basin, parts of which were reclassified to a lower canopy closure and hydrologic recovery (higher ECA) than would have resulted from using the forest cover map information. Open stands with ages greater than 100 years were considered recovered if located on excessively coarse-textured, shallow or poorly-drained soils or in areas of very high elevation (>2000 m).

All forest cover polygons in Bjerkness basin and a sample of polygons in Fletcher basin designated non-forested or non-productive were reviewed. Hydrologic recovery/ECA ratings were applied based on airphoto interpretation and, in the Bjerkness burn area, on observations made during field transects. These polygons included forest cover types such as: non-commercial brush, not satisfactorily restocked, non-commercial forest, alpine, alpine forest, non-productive, rock and non productive burn areas. Generally these polygons were found to have been reasonably accurately typed on the Forest Cover map except for some of the polygons in the 1940 burn area in Bjerkness Creek. The rating of crown closure for alpine forest polygons was slightly more conservative in Fletcher Creek than in Bjerkness Creek. In both basins these upper elevation stands are considered to be fully stocked. Where the non-forested or non-productive areas were associated with fully stocked stands with ages >100 years, they were generally designated recovery class 4 or 5. When associated with fire-origin stands of <100 years in age, they were generally assigned a recovery class similar to the adjacent stands, based on airphoto interpretation as described above.

Fully stocked deciduous and mixed-deciduous stands were generally designated recovery class 5 (0% ECA), as it was assumed they are a naturally-occurring portion of the landscape.

Cleared, cultivated or urban polygons were generally designated recovery class 0 (100% ECA). Swamps, fens and lakes were designated recovery class 5 (0 % ECA). Clearing on private land was updated based on clearing visible on 1997 airphotos.

The ECA ratings for the areas in which development is proposed do not include consideration of growth and recovery over the next five-year period.

Variable-Retention Silvicultural Systems

For variable retention silvicultural systems including single tree selection, dispersed partial cuts, strip cuts and small openings, the ECA values were determined using the Interior Watershed Assessment Procedure Version 2 (1999). The ECA weightings given to small openings and partial cuts are shown in Appendix 2. Where partial cuts were at the margin of a class the next higher ECA class was used (e.g. for a partial cut with 60% basal area removal the ECA was rated at 60%. See Appendix 2). For small patch cuts in areas bounded by open or immature stands (e.g. patch cuts adjacent to stands on recovering burned area) a higher ECA weighting was applied than is shown for the size of opening in the table in Appendix 2 to allow for reduced shading effect.

3.2 Sediment Source Assessment

Landslide Induced Sedimentation

Most of the major point sediment sources in the Fletcher Creek and Bjerkness Creek basins are from landslides off the gully walls adjacent to the channels. Landslides were identified during the course of walking the channels on Fletcher and Bjerkness Creeks. Landslide sediment sources which have delivered an estimated volume of material >25 m^3 to the streams are listed in Appendix 3 and shown on Map 2. The landslide size, connectivity to streams, age where known, and other information is also shown in Appendix 3.

Road and Cutblock Erosional Sources

Parts of the road network in the Bjerkness basin were assessed on a reconnaissance basis. A reconnaissance check was made of the very old mining/logging road adjacent to and north of the creek from about 1120 m elevation down to 1100 m (shown on Maps 1 and 2 as 'Old Bjerkness Road'). Reconnaissance checks were also made along parts of the Bjerkness Main road. All of the major roads in the Fletcher Creek basin were assessed. Spot checks of skidroads were made in the Fletcher Creek cutblocks. Not all the road related sediment sources in Loftstedt Creek basin were surveyed, pending an accurate definition of the catchment area boundaries.

3.3 Definition of Watershed Boundaries & Stream Descriptions/Locations

Surface watershed catchment boundaries were determined on the basis of topography derived from 1:5000 mapping (1999) for the lower portion of the Fletcher Creek and Bjerkness Creek basins. For the remainder of the basins 1:20 000 TRIM map information was used. Map information was supplemented with airphoto interpretation. The catchment boundaries are shown on Maps 1 and 2. The boundaries for the western and southern portions of Lofstedt Creek were defined using 1:5000 mapping, TRIM mapping and airphotos. The boundary for the northern portion of the Lofstedt basin is based on ground checks of snowmelt flow made by G. Lay on March 30, 2000 supplemented with information from P. Van Allen, the licensee of Woodlot 494.

The streams presented on the maps are from the TRIM base, supplemented in a few cases with field observations and information from Water Rights maps. The placement of small tributary streams on the TRIM maps is derived only from airphoto interpretation and cannot be counted on to be accurate. Many of the smaller streams shown do not exist and some streams which exist are not shown. Wherever ground checks provided more accurate information it has been included on Maps 1 and 2.

3.4 Stream Channel Assessment Method

Fletcher Creek and Bjerkness Creeks

A hybrid approach to channel assessment was used on Fletcher and Bjerkness Creeks. It was developed by combining most of the methods outlined in the BC MOF Channel Assessment Procedure Guidebook (CAP) (1996) with additional observations and interpretations. The approach involves three steps: identifying reach breaks, conducting field observations, and carrying out interpretations.

Preliminary reaches (homogeneous sections of stream channel) were defined in the office using TRIM maps, airphotos and information from a helicopter overflight of Fletcher and Bjerkness Creeks. Final stream reaches were recognized in the field by their physical characteristics including gradient, channel form, riparian vegetation, bed materials, bank materials, confinement, and hillslope-to-channel coupling. In addition, confluences and major changes in sediment supply were also utilized to identify reach breaks.

Field observations carried out by foot traverse included an assessment of channel disturbance according to the indicators and approach provided in the CAP, and, for selected reaches, additional observations in the form of detailed channel descriptions. On Bjerkness Creek the channel was traversed from an elevation of about 1570 m to 1380 m by D. Putt and R. Duncan and, from 1380 m to the POI at 640 m, by M. Carver and J. Cathro for a total chained distance of 6005 m. On Fletcher Creek the channel was traversed from Lower Fletcher Lake to the POI by D. Putt and R. Duncan, a chained distance of 4478 m. A higher level of detail was recorded for reaches 1 to 6 of Bjerkness Creek and 1 to 8 of Fletcher Creek. The frequency of disturbance indicators observed, supplemented with the detailed descriptions, were used to identify the extent of disturbance existing in each reach.

For the channel assessment, slope distances were measured using a hip chain and plotted on a TRIM map base scaled up from 1:20 000 to 1:10 000 (Map 2). The challenging conditions in and around the creeks made accurate use of the hip chain difficult at times. Careful attention to orientation and terrain features in relation to the airphotos and TRIM mapping provided a means to reasonably correct the cumulative daily discrepancies noted between the hip chain and TRIM mapping. Although it cannot be stated that the location of every sediment source is provided exactly, any deviations will be minor and will not affect map interpretation and use.

Interpretations followed the Channel Assessment Procedure guidelines, supplemented by other quantitative measurements of channel bed, riparian areas and banks. Definitions of these other parameters are provided in Appendix 4A. These data were interpreted to provide additional, more objective measures of channel condition.

The following are some of the variables/indicators used to identify channel condition and sensitivity to disturbance:

Channel instability:

- debris flow/flood activity
- avulsions; multiple channels
- low storage capacity
- low bed stability (high percentage of bed mobility)
- limited bed consolidation
- excessive scour or deposition
- significant sediment wedges
- (annual) step instability
- bank erosion
- dysfunctional wood
- sidewall instability

Channel sensitivity (channels with the following characteristics may be vulnerable to changes in flow regime and sediment regime):

- low sediment storage capacity
- high proportion of mobile sediment load
- low transport capacity (high sediment load relative to available streampower)
- high erodiblity of banks
- gradient (generally lower gradient channels are more prone to disturbance by increases in peak flow and increased sediment inputs)
- low, long term recruitment of large woody debris
- channel step instability
- poorly functioning/low volume of coarse woody debris
- low confinement (stream is not confined to channel)

Table 3.4 describes four non-dimensional indices used to provide further insight into channel stability in sections of the channel for which detailed information was collected.

Table 3.4 Indicators and indices for rating stream channel instability.

Indicator	Description	Index
storage capacity	ratio of bankfull width to bankfull depth	w_b/d_b
transport capacity	ratio of surface to subsurface mean bed grain-size	$d_{50,sfc}/d_{50,subsfc}$
bed stability	ratio of bed grain-size to bankfull depth	$d_{90,sfc}/d_b$
confinement	ratio of gully width (at 1 m) to bankfull channel width	w_{1m}/w_b

Lofstedt Creek

TRIM maps and airphotos were used to establish initial reach breaks but this was of limited value because the stream is very small and the forest cover is dense. Final reach breaks on the Lofstedt mainstem below 770 m elevation were defined based on field observations. Reconnaissance checks of channel and riparian condition, much less comprehensive than those in Fletcher and Bjerkness Creeks, were made on September 28, 1999 on the West tributary (below 770 m elevation) and on the Lofstedt mainstem (to 675 m elevation at the Lofstedt Farm pond at the north end of SL11). Reconnaissance checks were also made on lower Lofstedt Creek from about 75 m north of the crossing of the Kaslo back road to the confluence with Bjerkness Creek on November 8, 1999 and of portions of Reach 3 on March 25, 2000. Few ground checks were made, and reach division was not attempted, on the West Lofstedt and North Lofstedt tributaries.

3.5 Riparian Assessment

The riparian function on most of Bjerkness and Fletcher Creeks was assessed in terms of its effect on channel stability by gauging the availability of wood to the channel (large woody debris (LWD) recruitment potential). The number of trees >25 cm diameter and within 25 m of the channel per 100 m length was estimated or counted to categorize the potential wood supply as low (<10 stems/100 m), moderate (10-30 stems/100 m) and high (>30 stems/100 m). This assessment was done on all reaches in Fletcher Creek and reaches 1 to 6 in Bjerkness Creek. More general observation of wood availability and function was made in reaches 7 to 9 of Bjerkness and on Lofstedt Creek. These assessments also provide some measure of the forest cover and shading of the stream which is a factor in stream temperatures.

Assessment of riparian zone for fish and wildlife habitat was not part of this study. Fish and wildlife habitat riparian values were previously reviewed by Lutz et al (1996).

3.6 Watershed Indicator Information, Hazard Interpretations, Risk Assessment, H 60 Line Determination

Watershed Indicators

Selected indicators were calculated for the watershed units under study. They are defined in Table 3.5.

Table 3.5 Watershed indicators.

Indicator		Definition
ECA – unweighted	%	Equivalent Clearcut Area without a weighting factor
ECA –weighted	%	Equivalent Clearcut Area with areas above the H60 weighted 1.5
Roads, Interception	km/km^2	Total road density *(minor roads weighted 0.6, major skid roads weighted 0.3)*
Total major roads	km/km^2	Total density of major roads
Total other roads	km/km^2	Total density of other roads
Roads on Terrain Stability Class IV/V	km/km^2	Density of roads on terrain with Class IV and V stability (minor roads weighted 0.6)
Roads on Terrain Units with High Sediment Yield Hazard	km/km^2	Density of roads on terrain with High and Very High Erosion Hazard *and* High or Very High Sediment Delivery Hazard (minor roads weighted 0.6)
Density of Stream Crossings	no/km^2	Total density of stream crossings of major and other roads
Landslides	no/km	Landslides with connection to the stream which have delivered $>25m^3$ of material

Hazard Interpretations and Risk Assessment of Proposed Development

Using the watershed indicators and field observations, existing hazards were estimated for each watershed in four classes:

- peak flow
- sediment sources
- riparian function
- channel stability

In each class the hazards are rated as low, moderate, high, or very high.

The risk associated with implementation of the proposed development was assessed in relation to the same four hazard classes.

It is important to note that although, for clarification, the hazard categories are rated separately *all the hazards interact* and must be considered together in evaluating risk. This can be illustrated by the following examples:

- High ECA and resulting higher peak flows in a creek which has a stable channel, with low sediment inputs and low riparian hazard, may cause little disturbance or change in water quality or channel stability.

- A channel in a watershed with low ECA and only natural variability in peak flow may be severely disturbed by large increases in sediment inputs.
- High sediment inputs may not have as severe an impact if the riparian zone is in good condition and the channel is in stable condition prior to the change in sediment supply.

Also, different reaches of the channel have different characteristics and react differently to the same inputs. Changes in one reach affect those in reaches downstream both in the short term and long term. A creek is a complex system.

H 60 Line Determination

The H60 line, above which 60% of the area of the watershed lies, was determined separately for Lofstedt, Bjerkness and Fletcher basins. The line is calculated because snow typically covers approximately the upper 60% of a watershed when streamflow levels begin to rise sharply towards their peaks in the spring. Melting of snow above the line is more likely to contribute to peak flows and the ECA of forest openings above the line is therefore weighted at 1.5 times (e.g. a 10 ha clearcut above the H60 is given a (weighted) ECA of 15 ha).

Although Lofstedt Creek is a subbasin of Bjerkness Creek the confluence of the two creeks is less than 200 m above the major intake (POI) on Bjerkness. The two basins are very different physiographically and hydrologically. Bjerkness is a high elevation alpine dominated basin. Lofstedt is predominantly a low and mid elevation basin. Treating the two basins as a unit tends to mask the characteristics of each, an example being the effect on the H60 line. For the purposes of this study the H60 was calculated separately for the Lofstedt and Bjerkness basins.

4.0 BJERKNESS CREEK (MAIN BASIN)

The Bjerkness Creek drainage area, for the purposes of this study, has been divided into two subbasins, Bjerkness Creek basin and Lofstedt Creek basin. The Point of Interest (POI) for the assessment of the Bjerkness main basin is located at the community water intake for the Mirror Lake Water Users Association. The area above the POI in the main Bjerkness basin is 1944 ha. Bjerkness Creek is classed as an S3 stream under the riparian management area guidelines as shown in the BC MOF Riparian Management Area Guidebook (1995).

4.1 Water License Information

There are 56 water licenses or applications for licenses on Bjerkness Creek. Most of the licenses are held at the POI by individuals and are for domestic use and irrigation. Total licensed water demand is shown in Section 2.7 of this report. There is an application for a water license for power generation with a planned diversion point at about 960 m elevation and there are several individual water license sites on the main creek below the POI. Points of diversion (PODs) are shown on Map 2. The POI as shown on Maps 1 and 2 was located by a GPS survey carried out for Appropriate Forestry Services Ltd.

4.2 Sediment Sources

Landslide Induced Sedimentation

Most of the point sediment sources within the Bjerkness Creek main basin are landslides, which are both natural and related to old mining and logging roads. All the landslides shown on Map 2 were briefly reviewed on the ground in conjunction with the channel assessment. Only those landslides which have connection to the creek channel and which are estimated to have delivered >25 m^3 of material to the creek are shown on the map. More detailed information on the landslide size and material types is shown in Appendix 3A. There are a number of other slides more removed from the channel on the south side of reach 6 and on both sides of reach 7. They do not run directly into the creek and are not shown in the appendix. However, they may deliver some sediment to the creek as a result of surface erosion of the slide tracks. In addition to the slides listed in Appendix 3A there are small sloughs and debris slides <25 m^2 in area which have not been identified individually and are not listed.

There is a significant number of landslides with connection to the creek below the 'Old Bjerkness' road on the north side of Bjerkness Creek between 730 m and 1030 m elevation. This road is visible on 1939 airphotos. The slides are probably related to drainage diversion on the road. The remainder of the slides along the channel are natural. Most of the slides are debris slides. Most of the slides have occurred in the last 40 to 50 years and it appears that many occurred about 20-30 years ago. Some landslides are visible below the road on the 1939 airphotos. A number of the slides have unstable headwalls or actively eroding slide tracks and, given their proximity to the creek, will continue to cause sedimentation. Total volume of material estimated to have been delivered to the creek from the identified landslides is >12 000 m^3. This understates the actual total sediment delivery from slope failures because it does not include volumes from smaller landslides and sloughs not listed in Appendix 3A or from older landslides which are no longer easily identified. The volume estimate also does not include sediment delivery from non point sources such as soil creep and slope 'wash'.

Surface and Ditchline Erosion Sources

A brief reconnaissance of the Bjerkness 'Main' road showed minor road surface and ditchline erosion with little or no connection to the creek except at one crossing as shown on Map 2. Erosion on the 'Old Bjerkness' road on the north side of, and adjacent to, Bjerkness Creek was minor in the section reviewed between 1220 and 1100 m elevation. However, there may be significant surface erosion on parts of this old road below 1100 m elevation.

Snow Avalanche Tracks

There are numerous snow avalanche tracks in the upper portions of the Bjerkness basin which deliver significant amounts of woody debris and sediment to the creeks. Some of the portions of the large 1940 burn area, which in the 1939 airphotos showed as being well stocked with trees, are no longer forested and are now active avalanche tracks. Sediment sources related to snow avalanches were not assessed.

4.3 Channel Assessment

Eleven reaches were defined for Bjerkness Creek between the Point of Interest and the confluence of two small headwater tributaries near the Kokanee Glacier Park boundary at 1691 m elevation. Table 4.1 summarizes the reach characteristics and disturbance levels. The stream has a combination of step-pool and cascade-pool morphology with wood acting as an important structural component of the channels in lower-gradient sections. Note that the composite disturbance summaries somewhat mask the variability within each reach. Table 4.2 provides details on the presence/absence of disturbance indicators as recorded in the field for sub-sections within each reach. The distribution of stream channel reaches is shown on Map 2. Further detailed site descriptions are summarized in Appendix 4B. Figure 2 shows reach breaks and gradient in longitudinal profile. Figures 5 to14, appended, are photos which illustrate the condition of selected reaches of the stream channel.

Table 4.1 Bjerkness Creek - summary of reach characteristics and disturbance levels.

Reach	Cumulative Slope Distance Range m	Reach Length, m (hip chained slope distance)	Reach Elevation (corrected)		Width m (min, max)	Gradient, % (min, max)	Disturbance Rating % of reach							Descriptions
			Lower	Upper			A3	A2	A1	S	D1	D2	D3	
1	POI to 590	590	640	656	*7.7(5,13)*	*6(1,15)*	27	50	23	0	0	0	0	
2	590-1340	750	656	780	*9.1(4.5-24)*	*14(4,24)*	20	27	25	29	0	0	0	
3	1340-2540	1200	780	1060	*8.4(3,20)*	*24(16,35)*	0	4	12	84	0	0	0	B5,B6
4	2540-3290	750	1060	1177	*6.4(2,15)*	*17(5,50)*	0	8	19	67	6	0	0	B4
5	3290-4040	750	1177	1280	*7.0(3,15)*	*12(8,24)*	0	0	1	9	61	9	0	B3
6	4040-4940	900	1280	1381	*7.1(3,12)*	*15(5,90)*	0	0	15	33	21	32	0	B1,B2
7	*4940-5307*	*367*	1381	1439		13 (6, 24)	37	23	7	13	17	3		BP3
8	*5307-5765*	*458*	1439	1557	*4*	30 (7, 80)	0	0	0	40	60	0	0	BP2
9A	*5765-6005*	*240*	1557	1568		4 (3,7)	0	10	70	20	0	0	0	BP1
9B	Not ground surveyed		1568	1580		*3.9 (calc)*	Not surveyed							
10	Not ground surveyed		1580	1614		*6.3 (calc)*	Not surveyed							
11	Not ground surveyed		1614	1691		*12 (calc)*	Not surveyed							

Table 4.2 Bjerkness Creek - Indicators of disturbance as observed in the field. (See also next page.)

✓ - active/frequent indicator; ✚ recovering indicator; O infrequent or moderately active indicator

Reach	Distance from POI	S1	S2	S3	S4	S5	B1	B2	B3	C1	C2	C3	C4	C5	D1	D2	D3
1	0 to 190				O			O	O			✓	✓			O	
1	190-340				O					O	O					✓	
1	340-590			O	O		+	O					O			O	O
2	590-740			O	O			O	+		O		✓		O	O	O
2	740-890			✓			✓		+		O		O		+		✓
2	890-1040								✓								
2	1040-1190			O	O												
2	1190-1340							✓	✓							O	
3	1340-1490																
3	1490-1640			O									O				
3	1640-1790			O							O						
3	1790-1940			✓							O		✓			✓	✓
3	1940-2090			✓												✓	
3	2090-2240			O													
3	2240-2390			O									O			O	
3	2390-2540			✓					+				✓				✓
4	2540-2690								+								
4	2690-2840			O					+							O	
4	2840-2990				+	✓										O	
4	2990-3140																
4	3140-3290			✓	+											✓	✓
5	3290-3440			O	+											O	
5	3440-3590								+							O	
5	3590-3740								+							O	
5	3740-3890														O	O	
5	3890-4040												O				
6	4040-4190				O									O			
6	4190-4340				O				+						O		+
6	4340-4490											+	✓			O	+
6	4490-4640				+	✓							✓			✓	
6	4640-4790					✓					O					✓	
6	4790-4940					✓					O			✓		✓	
7	4940-5065					O								O			
7	5065-5307			✓	O						✓				✓	O	+
7	5307-5405			✓							✓				✓	✓	✓
8	5405-5765					O								O			
9	5765-6005			O	O				O		O		O				

S1	homogeneous bed texture	C1	extensive cascades
S2	sediment fingers	C2	minimal pool area
S3	sediment wedges	C3	elevated mid-channel bars
S4	extensive bars	C4	multiple channels or braids
S5	extensively scoured zones	C5	disturbed stone lines
B1	abandoned channels	D1	small woody debris
B2	eroding banks	D2	LWD function
B3	Avulsions	D3	LWD jams

4.3.1 Reach Descriptions

Reaches 11 and 10

These reaches were not reviewed on the ground. The stream flows in a fairly well confined single channel through mature old growth spruce balsam forest. From brief helicopter observations of the channel no significant channel disturbance was evident.

Reach 9

The lower section of this reach was reviewed on the ground and, as seen from the helicopter, is typical of the whole reach. In the section reviewed the gradient is low (3-4%) and this is reflected in the riffle pool cascade pool channel morphology. Bed materials are predominantly small cobbles and grqvels. The channel is poorly confined and coupling in the reach is low. The reach shows signs of aggradation in the form of minor avulsion and extensive sediment wedges, relatively low pool area and past overbank flooding. Wood forms most of the functioning steps and the steps are stable. There is some old woody debris present which was probably initially deposited in the upper part of the reach by snow avalanches from the large burn area to the north. Some of the sediment present in the reach may also have been from snow avalanche deposits. Other than this the reach does not particularly show (or no longer shows) impacts from the burn. This reach is sensitive to disturbance in years when there are high peak flows because of the low confinement, high width to depth ratio, high volumes of sediment stored in the reach and the high proportion of mobile materials. Significant sediment inputs would also destabilize this reach.

Reach 8

This is a steep, relatively stable reach with a gradient of about 15% in the upper portion steepening to 50-80% in a cascade/falls section in the lower portion. The channel is well confined with mostly stable stone and LWD steps. There are indicators of partial degradation in the form of scour and broken stone lines particularly in the lower, steeper portion of the reach, above the falls. The cascade/falls at the bottom of the reach are over stable bedrock. This reach is relatively insensitive to increased sediment inputs or high peak flows.

Reach 7

Most of this reach, which begins in a bedrock canyon immediately below the falls in reach 8, runs in a gully incised in snow avalanche/colluvial debris fans. There is almost no coniferous riparian cover and there are active avalanche tracks on both sides of the reach through most of the length. The reach is moderately to severely aggraded except for a short degraded section at the bottom of the reach. There are large amounts of woody debris in the reach, most of it old debris probably delivered by snow avalanches, particularly off the extensive burned area to the north. There is some newer large and small woody debris, particularly in the upper part of the reach. Much of the wood, new and old, is non functional. There are both old and new woody debris jams; the old jams are more common and tend to be more stable than the recent jams. Other features showing instability/aggradation include large sediment wedges, small bars and lack of pools. There has been some recent sedimentation into the reach from debris slides on the south side of the upper portion of the reach. There are many older slide scars evident on airphotos on the steep gully sidewalls at the toe of the colluvial fans. (See photos, Figures 9,10).

Reach 6

This step-pool/cascade reach shows signs of a major past disturbance in addition to contemporary disturbance, with both aggradation and degradation. In the top half of the reach, extensive scour, an absence of functioning wood, and diminished pool areas highlight the degradation present. In the bottom half of the reach, aggradation characteristics include a reduction in step frequency and step stability, and extensive bars. There is evidence of recovery from a major flood event 30+ years ago both in terms of large off-channel woody debris piles and vegetating elevated mid-channel bars (see photo, Figure8). Signs of disturbance remain sufficiently modest to see stone lines, moderate-to-good pool extent, and moderate functioning wood. Large lag boulders provide important bed/step stability and are likely related to major debris flow events 200-400 years ago.

Reach 5

Although the width and gradient of this reach are similar to that of reach 6, there are fewer signs of recent disturbance. The large lag material, in addition to the increased presence of bedrock, serves to create a stable bed. (The bedrock exposure may be partially a result of recent scour disturbance though this was not clear.) With the exception of the lower 150 m of the reach, steps were abundant, made of stable rock and often accompanied by abundant pools. There was a lack of functional wood in the reach, probably due to the forest fire (which burned right up to the left bank in much of this reach) and to the major flood event some 30-40 years ago. Major remnant off-channel debris piles remain common in the reach as do revegetating mid-channel bars. At the base of the reach, there is a marked transition to the deteriorated condition of reach 4, with unstable sidewalls, scattered dysfunctional wood, and sediment accumulations behind steps.

Reach 4

The steeper gradient and narrower, confined channel (in comparison to reach 5) are highly coupled to the increase in sidewall instability both in terms of the natural and road-related sediment inputs. Landslide 23, a natural slide (south bank, 30 years old), was by far the largest slide observed with over 5000 m^2 of exposed area and continued (but reduced) activity delivering sediment to Bjerkness Creek. The old road above the left bank has contributed to several landslides reaching the channel due to fillslope failures and possibly drainage diversions. Not surprisingly, the percentage bed mobility increases (to 85%) as a result of the increased sediment supply. The dysfunctional wood is balanced by the presence of lag material which creates some bed stability. Numerous sediment wedges are present in addition to old bar accumulations and channel avulsions now recovering (30-40 years old). A large debris flow deposit at the base of the reach is estimated to be over 500 years old. There is scattered bedrock especially at the base of the reach.

Reach 3

This reach is characterized by a downstream accumulation of large lag boulders (secondary axis > 1 m in width) with a significant input of much finer sediment from landslides throughout the length of the reach. This reach is wider and steeper than reach 4 and is highly coupled to the unstable sidewalls. A total of seventeen slides was observed adjacent to the channel, most of which delivered 100% of their original volume into the creek. It appeared that the majority was caused by the old road immediately upslope of the north bank. Mid-way down the reach, sediment wedges are commonplace and there is a fining of their texture, especially in the subsurface, suggesting an abundance of material for transport. This abundant sediment (gravels and small cobbles) has infilled many of the pools, limiting their extent. The huge early post-glacial lag material in the upper part of the reach, in conjunction with the steep channel gradient, serve to limit the impact of the finer sediment supply in the lower 400-500 m. Wood is not an important channel component in the lower reach because the channel morphology is defined by the large lag material present. (See photo, Figure 6.)

Reach 2

This step-pool reach is the fan of Bjerkness Creek. Channel gradient declines steadily from 24% immediately above the fan to only 7% at the base of the reach. The reduced streampower and the upstream sediment inputs have resulted in considerable instability in this reach. There are avulsed channels in various levels of activity. Downstream, the reach becomes less confined adding to the lateral instability. Old and new debris jams, sediment wedges, a high proportion of bed mobility, lack of pools, braiding, and wood dysfunction/absence highlight the channel instability in the lower sections of this reach. In one location where levees are absent, there is little to prevent the entire channel from breaking through the right bank and taking a completely different pathway to the south. In general, the indicators suggest that there has been much greater lateral instability in the past and that the fan continues to be in a period of recovery. However, given the sediment inputs in reaches 3 and 4, it is expected that these instabilities will continue to some degree.

Reach 1

As the channel approaches the major culvert at the Kaslo Back Road it is more confined but continues to exhibit a wide variety of disturbance types, particularly those indicating bed aggradation such as extensive bars, sediment wedges, minimal pool area and multiple channels. Below the Back Road, the creek appears to have been channeled partly as a result of the road. It lacks wood and pools and is locally braiding in response to the sediment accumulations and bed aggradation (see photo, Figure 5).

Channel Overview

The channel has long steep sections with a lag boulder dominated bed, particularly in reaches 3 and 4, which are stable or slightly aggraded/degraded despite the ongoing and large sediment inputs due to landslides. Although possessing a stable bed, these sections continue to store significant quantities of sediment which could migrate downstream over the next decade. There are also significant amounts of stored sediment in the aggraded sections of reach 7 with lesser amounts in reach 9 and both these reaches are sensitive to disturbance during high peak flows. Due to the high transport capacity of the channel in reaches 3 through 5 most of the sediment inputs into these reaches are quickly transferred to reaches 2 and 1. In reach 2 the sediment inputs have resulted in avulsions and other lateral instability including a significant breach of the main channel in 1964. The channel is subject to further avulsion in years with very high peak flows as a result of the large amounts of material which could migrate downstream and the continued significant sediment inputs from landslides.

4.4 Riparian Assessment

In reach 1 a road has been built and the riparian zone has been clearcut on private land on the south side of the channel between the Kaslo Back Road and the POI. There is little functioning wood in the channel in this reach which is likely in part due to a reduction in supply of LWD. Riparian logging and road construction have taken place in reach 2 but there is currently limited riparian effect from these activities. In reaches 3 and 4 the landslides on the north side of the creek related to the road have reduced riparian cover but there are still ample supplies of LWD to the creek in these reaches. In reaches 6 – 8 the riparian zone on the north side of the channel was strongly impacted by the 1940 fire which burned to the edge of the creek in substantial sections. Following the fire there has been increased snow avalanche activity in the burned area which has also affected riparian recovery. The riparian impacts of the fire in reaches 6 to 8 included removal of cover and, in reaches 7 and 8, significant reduction in the long term supply of anchored large woody debris. In reaches 5 and 6 the impacts on the north side of the channel are partly balanced by the fact that on the south side there is a mature cedar/fir/hemlock stand which contributes substantial amounts of woody debris, ample to maintain the LWD steps which are integral to the channel morphology in these reaches.

4.5 Indicator Results and Ratings of Existing Hazard

Table 4.3 summarizes forest development impact indicators for Bjerkness Creek basin under existing conditions and following proposed development. The existing weighted ECA is at 9.77% and would rise to 16.39% with the proposed development. Most of the existing ECA is a result of the 1940 burn on the northwest side of the drainage.

Table 4.3 Hazard indicator results for Bjerkness Creek main basin.

Indicator	Units	Bjerkness Creek		
		Existing	Proposed	Total
Area	ha	1943.67	n/a	1943.67
Private Land	%	2.1	n/a	2.1
ECA – unweighted	%	7.3	5.5	12.8
ECA –weighted	%	9.9	6.6	16.5
Total major roads	km/km^2	0.272	0.554	0.826
Total minor roads	km/km^2	0.011	0	0.011
Roads, High Sed. Production Pot'l	km/km^2	0.128	0.148	0.276
Road Density (Interception)	km/km^2	0.283	0.554	0.837
Roads on Terrain Stab Class IV/V	km/km^2	0.055	0.064	0.119
Number of Stream Crossings	no.	4	18	22
Landslide density	no./km of stream	6.0	n/a	6.0

Table 4.4 Bjerkness Creek - Hazard ratings and main factors (under *existing* conditions)

Impact Category		Hazard Index	Main Factors
Peak Flow		Low to Moderate	ECA, road density
Sediment Sources		Very High	Landslides, both natural and from old roads. There is also some increase in landslide risk associated with new road construction
Riparian Function		Low to Moderate	Burn on north side of reaches 5,6,7
Channel Stability	Reaches 1,2	High	High proportion of mobile bedload and/or readily mobilized deposits; shallow channel with flood hazard in reach 2
	Reaches 3-11	Low to Moderate	Stable lag boulder controlled channel in reaches 3 to 6 and 8. Reaches 7 and 9 have a higher proportion of mobile bedload and are therefore rated moderately stable.

Note: For clarification the hazard categories are rated separately. However all the hazards interact and are considered together in evaluating risk.

4.6 Risk Assessment of Proposed Development and Remediation Work

Table 4.5. Risk and resulting hazard ratings following proposed development in Bjerkness Creek basin

Indicator		Existing Hazard	Proposed Development	
			Associated Risk	**Resulting Hazard**
Peak Flow		Low to mod	+	Moderate
Sediment Sources		Very High	(+)	Very High
Riparian Function		Low to Mod.	(+)	Low to Mod.
Channel Stability	Reaches 1,2	High	+	High
	Reaches 3-11	Low to Mod.	(+)	Low to Moderate

Notes: Associated risk: o – none; (+) – insignificant increase; + – small but potentially significant increase; ++ – major significant increase.

Table 4.6 Changes in hazard associated with recommended remediation work and road deactivation

Indicator	Hazard (with proposed development)	Recommended Work	Risk Reduction	Resulting Hazard
Peak Flow	Moderate	Road deactivation	insignificant decrease	Low-Moderate
		Channel remediation	significant decrease	
		Slide stabilization	unknown	
Sediment Sources	Very High	Road deactivation	major decrease	High
		Channel remediation	significant decrease	
		Slide stabilization	unknown	
Riparian Function	L-M	All types	insignificant decrease	Low-Mod
Channel Stability – Reaches 1,2	H	Road deactivation	significant decrease	Moderate-High
		Channel remediation	major decrease	
		Slide stabilization	unknown	
Channel Stability – Reaches 3-11	L-M	All types	insignificant decrease	Low-Mod

Risk Assessment Overview

The risk that the proposed forest development will significantly change the quantity, quality or timing of stream flow in Bjerkness Creek is low if it is done adhering closely to the requirements of the Forest Practices Code and the recommendations which follow in Section 4.7.

Peak Flow

The total road density following the proposed development is moderate. The proposed development would result in an increase in weighted ECA to 16.5%. To put the proposed ECA in historical context the weighted ECA of the area burned in 1940 was about 22% (an area of 315 ha.) The 1940 fire was a very hot fire which left few standing tree patches and destroyed most of the humus layers so that the hydrological impacts were analogous to those of a clearcut. In 1940 much of the forest stand in the lower and mid elevation areas of the watershed had not recovered (hydrologically) from the major fire which happened in the basin at the turn of the century. A crude estimate, based on the forest cover the 1939 photos, is that total weighted ECA after the 1940 fire substantially exceeded 30%. The effects of the 1940 fire on the stream channel were to greatly increase the amount of woody debris in the channel, some of which is still evident, and to deliver substantial amounts of sediment to the creek. The impacts of the sediment delivery have been obscured by subsequent landslide sediment deposition. It is also not clear whether the ECA resulting from the burn raised peak flows to a level which significantly decreased the stability of the channel.

The literature on effects of ECA on peak flows shows that when ECA (unweighted) is below 15% in snowmelt-dominated drainages, increases in peak flow are rarely measured because they are either non-existent or they are so low that they are masked within the range of natural variability. At the proposed ECA (weighted) of 16.5% and with proposed road density levels, any potential increases in peak flow are likely to be insignificant in terms of direct effect on suspended sediment levels and water quality. However, although unlikely, such a peak flow increase could cause a small but potentially important increase in the rate of bedload transport to the alluvial fan of the large amounts of stored sediment in the creek, as well as an increase in movement of material on the fan. The fan at some locations is unstable to the point of being subject to avulsion and flooding under existing conditions.

Water Yield

The proposed development is unlikely to have a significant effect on the water yield (total flow) in the Bjerkness Creek basin.

Sediment Sources

The proposed development is unlikely to have a significant long term effect on supply of sediment to the creek so long as careful logging, road construction and maintenance practices are used. This assumes careful attention to minimize sedimentation from road and ditchline sources at stream crossings and that construction and logging will not increase the rate of landslide occurrence with sediment delivery to the creek (see the recommendations in section 4.7 of this report).

Most of the potential impact, particularly in terms of surface erosion sources and to a lesser extent in terms of increased landslide hazard, would result from building the road along the north side of the creek to the back end of the drainage. This proposed road crosses a number of creek tributaries and has a number of sections on soils with high erosion hazard The patchcut blocks proposed on the north side of the creek above the existing landslides 2 to 12 also have the potential to increase instability in an area known to be unstable. The other proposed cutblocks are unlikely to generate significant sediment delivery to the creek.

Riparian Impact

Riparian impacts which might affect the channel stability or water temperature will not be significant. Most of the limited impacts would be at stream crossings on proposed roads.

Channel Stability

The proposed development will not have a significant direct effect on channel stability, with the proviso that road development is carefully done so as to avoid increasing the rate of landslide occurrence. If the ECA and increased road density cause an increase in peak flows, as discussed above, it would cause a very minor reduction in channel stability until the existing sediment load in the creek worked its way through the channel and the fan stabilized. In terms of channel stability by far the largest significant risk factor is a) the high hazard of further landslides off the old road on the north side of the channel in reaches 3 and 4 of the creek as well as b) natural landslide hazard in these same reaches. The risk of channel instability can be significantly reduced by deactivating the Old Bjerkness road on the north side of the channel.

Two specific concerns have been expressed by some water users in the Bjerkness watershed a) that logging development will result in the creek 'drying up' in the section of the creek where the water intakes are located and b) that development will greatly increase the chance of the creek jumping its channel and flooding in the section in reach 2 where the stream runs in a shallow channel. Some specific comments on these risks follow:

Stream Flow Drying Up

Almost the only way streamflow could dry up would be from massive inputs of sediment, presumably from newly triggered landslides, which were transported rapidly into reach 1 of the creek. The present likelihood of this occurring is extremely low and this will not be changed significantly by the proposed development. In the past there have been major inputs of sediment to the creek from landslides and avalanches and times during which the peak flows were much higher than are expected with the proposed development. These did not result in dewatering of the creek.

Flood risk in Reach 2

There is an *existing* high risk of flooding in this reach which can probably be greatly reduced by deepening the channel and building up the levees in the sections where the channel is shallow. There are anecdotal reports of the creek jumping the south bank in this reach in 1964 and flooding onto District Lot 484 (G. Lay, pers.comm.). This avulsion/flood was successfully contained by building up the south bank using a bulldozer. The likelihood is low that logging development would cause sufficient sedimentation to pose significant increased risk. The risk of peak flow increases causing increased flood risk is also low at the proposed levels of development. These risks are addressed in the recommendations made in section 4.7 of this report.

4.7 Risk Reduction Strategies and Recommendations

Road Deactivation and Channel/Landslide Remediation

- Assess and deactivate all the roads on the north side of Bjerkness Creek to help reduce the landslide sediment inputs to the creek. This is a high priority since continued landslide sediment inputs are a major factor in destabilizing the channel. The road adjacent to, and on the north side of, the creek should be deactivated prior to any harvest in upslope areas which might contribute to increased groundwater loading in the areas where there are already landslides. This road deactivation would reduce the hazard of further landslides.

- Field assess the possibilities for channel rehabilitation work which could be done in Reach 2 to prevent flooding at the sites where the channel is shallow. Deepening the channel and building up the channel bank to ensure that the stream remains confined would significantly reduce the immediate risk of flooding. It would also help to moderate the risk, should there be increases in peak flows, by providing a buffer against the possibility of future sediment buildups at these sites. By reducing the potential impact of higher peak flows it would also make ECA a less important factor.

- Field review the active landslides in reaches 3 and 4 to determine if they can be rehabilitated using bioengineering techniques. As noted earlier some of the slides, including the largest one noted, are natural and it is unlikely that they can be effectively stabilized. However, some of the development related slides on the north side of the creek may be amenable to control. Road deactivation and slide rehabilitation will significantly reduce the sediment inputs to the creek and consequently, over time, reduce the flooding risk.

General Planning

- In order to minimize impacts which could destabilize the Bjerkness alluvial fan it is advisable, if a conservative approach is desired, to maintain the weighted ECA at a level not to exceed 15%. A weighted ECA up to the 15% level is very unlikely to change peak flow and would allow further time for natural channel recovery as the present sediment load works its way through the channel. Also, as mentioned above, it is possible to build up the channel levees to prevent flooding where the banks are low in reach 2; this would further reduce the risk associated with high peak flows. Once the road deactivation and channel remediation work are completed an unweighted ECA of 15% is recommended.

The suggested ECA should be reviewed periodically in the light of changes in the channel. A higher ECA may be warranted as the channel stabilizes. Future periodic review of the watershed assessment (which is mandated to happen every 3 years) should include a review of the channel condition to monitor recovery on the fan (reaches 1 and 2) and the condition of reaches 3, 4 and 7 where there is significant stored sediment. ECA of the burned area should also be monitored and hydrologic recovery ratings updated, preferably at the same time as the channel is reviewed. Much of the burn is in a phase of rapid recovery of canopy closure.

- In planning timber harvest, attempts should be made to balance cutting in areas with different aspects and in different elevation bands. This will help desynchronize the effects on spring runoff. Most of the existing ECA in the burn is on south aspects, and some on east aspects, at elevations above the H60. Concentrating timber harvest on areas below the H60 initially would minimize the coincidence of the runoff with respect to that of the poorly-reforested burn areas. If harvest is done in areas above the H60 it can be concentrated on north aspects initially. However, this must be balanced against the fact that increases in snowpack on north aspect openings are greater than those on south aspects. If stand characteristics permit, use small patchcuts and partial cuts, particularly dispersed partial cuts, to help reduce effects on snowpack accumulation and melting patterns.

- Road location and road construction should use a 'best practices' approach. Use the narrowest practical road widths possible (compatible with safety and road alignment requirements) so as to minimize drainage diversion and interception of ground water. Terrain stability assessments and prescriptions for proposed roads are required under the Forest Practices Code in areas of Terrain Stability Class IV and V. They should also be carried out wherever roads are to be built on low gradient stable ground if the road location is above areas where there is potential downslope instability ('flat over steep areas'). This should include a careful review to ensure that drainage is not concentrated. Minimize stream crossings where possible, although this must be balanced against the need for road location on sites which are stable. Particular care is required where roads are proposed to cross small catchments which have a high specific catchment area (high upslope catchment area per unit of contour width – 'funnel' or 'inverted bottle' shape). Bjerkness Creek already has a high concentration of landslides along the channel. Maintenance of slope stability is key to recovery and maintenance of channel stability or, at a minimum, to avoid adding to the natural terrain and channel instability.

- Continue the water monitoring programme. Longer term records of water quantity, timing of flow, turbidity and suspended sediment levels will provide a valuable data base which will help in understanding of, and managing for, minimization of impacts on the stream.

Proposed Development

- Carry out a field terrain stability assessment of the area in and below the proposed patchcuts above landslides 2 to 12 (southern portion of Block 1). The decision about whether, or in what manner, to proceed with these blocks should be contingent on the terrain stability assessment. If timber harvest is possible in this area it is likely that it should be done only at a cut level that does not increase the groundwater loading on the unstable areas below the southern portion of the block. A terrain stability assessment of the northern part of Block 2, which is required under the FPC, should include consideration of possible impacts downslope on the groundwater loading and stability.

- The road proposed on the north side of Bjerkness Creek is for the most part laid out on low landslide hazard terrain as mapped by Deschenes (1998).There may, however, be downslope terrain stability hazards, especially in the road section above reaches 5 and 6; there are more downslope landslides in this section than were mapped. Also the road crosses many small tributary streams and crosses some terrain with a high erosion hazard. A terrain stability and erosion potential assessment should be completed on the ground of the road location to determine erosion and stability hazards. Road development at this location should be contingent on the results of the ground based assessment.

- Ground based assessment of erosion hazard should be completed wherever bladed skid trails or yarding corridors are proposed on terrain with a high and very high erosion hazard and ~~high~~ or very high sediment delivery potential (assessment of skid trails is a Forest Practices Code requirement; assessment of yarding corridors is not).

5.0 LOFSTEDT CREEK

Lofstedt Creek drains a small subbasin, 722 ha in area, and flows into Bjerkness Creek about 200 m above the Bjerkness Creek POI. As part of the Bjerkness Creek community watershed it is classed as an S4 stream. The POI for the watershed is at the confluence with Bjerkness Creek.

5.1 Licensed Water Sources

Most of the points of diversion on the creek are located at the north end of private lot SL11. There is one POD (N3 as shown on Water Rights map 3950A) just west of the SL11 lot boundary and another (Y4) just south of the SL11 lot boundary. Two water licenses are held on the creek, one of which is for diversion at multiple points. Total licensed demand on the creek, and on Heine and McCarthy springs which are within the Lofstedt catchment, is shown in Section 2.7 of this report.

5.2 Sediment Sources

Landslide Induced Sedimentation

No significant landslide induced sedimentation is known in Loftstedt Creek drainage. Because of inadequate road deactivation there is significant potential for landslides on parts of the Bjerkness Creek Main road which are in the Lofstedt catchment.

Surface and Ditchline Erosion Sources

There are erosional sources of sediment along the Kaslo Back Road at two stream crossings as shown on Map 2. The amount of delivery from the ditchlines and road at these crossings is probably <5m^3 annually. There are likely to be small pulses in delivery following grading of the road. Jordan and Fanjoy(1998) in work on the West Arm Demonstration Forest near Nelson, B. C. have shown that sediment delivery to creeks increases sharply each time roads are graded. In years of higher runoff the ephemeral channel which has been diverted down the Back Road ditchline has broken across the road and across the field on SL11 to join Lofstedt Creek (P. Van Allen, pers. comm.). This has resulted in erosion in the field and the delivery of significant sediment volumes to the creek. Elsewhere in the basin there is a significant erosional sediment source at the Bjerkness Main Road crossing of the West tributary. No other significant sources are known but further checking is required of the roads which could impact the North and West tributaries. In most years the absolute volumes of sediment delivered to Lofstedt and the Bjerkness POI from erosional sources in the Lofstedt drainage are very small in comparison to sediment volumes from landslide sources on the mainstem of Bjerkness Creek.

5.3 Reconnaissance Channel Assessment

The creek has been divided into 5 reaches between the confluence of Loftstedt Creek with Bjerkness Creek at 650m elevation and the confluence of the North and West tributaries at 720m. A summary of reach characteristics is shown in Table 5.1 Comments are made on the stream disturbance levels observed.

Table 5.1 Summary of Reach Characteristics - Lofstedt Creek

Reach No.	Channel Length m	Elevation Range M	Average Gradient %	Comments	Peak Flow Sensitivity
1	105	640	1-2	Swampy reach, minor bank erosion, stable to partially aggraded	H
2	510	640-649	2	Mostly stable	L-M
3	230	649-659	4	Mostly stable	L-M
4	810	659-678	2-3	Artificial channel – stable now	M
5	460	678-720	7	Swampy sections; short partially aggraded and degraded sections	M

5.3.1 Reach Descriptions

Reach 5

There are several low gradient swampy sections in this reach, totaling approximately 125 m in length, where stream flow is dispersed over a width of up to 50 m. In the remainder of the reach, flow is on a bench, mostly in a fairly well incised channel on gradients of 6-10%. The channel bed is variable with a mix of muck (silt, clay and organics), sand, and gravel and small and large woody debris. On lower gradients the muck is dominant and on higher gradients there is more sand and gravel. Woody debris content is about 5-10%.

Reach 4

At the top of the reach flow is through an artificial pond about 50 m east of the upper reach boundary. Flow then passes into a single, mostly straight, artificial channel which has been excavated across the field on private lot SL11. The bed of the channel through the field is mostly gravel with some sand and minor cobble. Banks are well grassed and stable. There are very few steps in the channel. At the time of ground checks on September 16, 1999 there was no flow in this reach below the pond. Flow on March 25, 2000 was about 12 -15 l/sec at about midpoint in the reach.

Reach 3

The lower part of this short reach has a predominantly gravel bed, with some sand and cobble. When checked on March 25, 2000 there was strong flow in a series of springs on the north gully wall in the lower portion of this reach. Total flow from the springs was estimated at about 30 l/sec but it was difficult to judge because flow is dispersed over a 10-20 m width. Flow in the main channel above the springs on the same date was about 15 l/sec. The upper portion of this reach was not ground checked.

Reach 2

In the southern portion of Reach 2 the channel is low gradient and poorly confined. North of this section the channel is more confined and runs in a draw below a rocky ridge on the east to about 75 m south of the crossing of the Kaslo Back Road. Above the road crossing there is a fairly well defined main channel in a gully but confinement is variable. Most of the reach is stable to partially disturbed but the channel has been substantially modified/disturbed over a length of about 50 m above and below the crossing of the Back Road. On November 8, 1999 there was no surface flow in the channel north from a point about 75 m northwest of the road crossing.

Reach 1

This is a short reach in a low gradient (1-2%) swampy area. The channel is poorly defined and flow at high water is dispersed across an active floodplain. The channel bed is mostly sand, silt clay and organic matter. There has been some high grade logging of the riparian area. At the time of stream checks on November 8, 1999 flow at the confluence with Bjerkness was about 2 l/sec.

West Lofstedt Tributary

On Sept. 16, 1999 there was no surface flow in the section of this tributary from an elevation of 780 m to the confluence with the 'main' channel. The channel is incised in an old debris flow fan in the lower part of this section. There are no indications of recent debris flows (i.e. in the last 100 years) in the channel.

Channel overview

Most of the creek channel reviewed is stable to partially disturbed. The stream is small, is very low gradient in the lower reaches and has low transport capacity. Wood is integral to channel stability in most reaches. The artificial channel in reach 4 is now stable but is essentially a straight ditch with no stone steps or wood in the channel to help check flow velocity. It is much less resilient to major changes in flow regime or sediment inputs than most of the natural channel.

5.4 Riparian Assessment

In reaches 2 and 5 there has been some highgrade logging of mature trees in the riparian zone but woody debris recruitment has not been significantly affected. In reaches 1 and 3 there has been more logging in the riparian zone and woody debris recruitment and shade cover has been reduced but not severely. The riparian in reach 4 is severely impacted; the stream is in an artificial channel in a cleared field with no opportunity for woody debris recruitment.

5.5 Indicator Results and Ratings of Existing Hazard

Table 5.2 provides impact indicator results for Lofstedt basin. Weighted ECA in this drainage is 14.26%, from logging and private land clearing. With proposed logging weighted ECA rises to 21.66%. The road density at 2.14 km/km^2 is high.

Table 5.2 Hazard indicator results - Lofstedt Creek basin.

Indicator	Units	Lofstedt Creek		
		Existing	Proposed	Total
Area	ha	722.41	n/a	722.41
Private Land	%	16.5	n/a	16.5
ECA – unweighted	%	12.22	6.18	18.40
ECA –weighted	%	14.25	7.39	21.64
Total major roads	km/km^2	1.924	0.285	2.209
Total minor roads	km/km^2	0.215	0	0.215
Roads, High or Very High Sediment	km/km^2	0	0.014	0.014
Roads, Interception	km/km^2	2.139	0.285	2.424
Roads on Terrain Stab Class IV/V	km/km^2	0	0.001	0.001
Number of Stream Crossings		7	1	8

Table 5.3 Lofstedt Creek - hazard ratings (existing)and main factors. **Note: the hazard ratings shown here are interim ratings and subject to change following further field checking.**

Impact Category	Hazard Index	Main Factors
Peak Flows	Moderate	Basin ECA and road-interception density
Sediment Sources (Landslide)	Moderate	There are very few landslides in this drainage but there is a significant potential for landslides on the Bjerkness Road
Sediment Sources (Erosional)	Moderate	There are significant erosional sediment sources on roads which cross the West tributary and, in high runoff years, from the Kaslo Back Road.
Riparian Function	Low to Moderate	No riparian cover on private land in reach 4 where the channel is artificial. Minor disturbance of riparian cover in reaches 1, 2, 3 and 5
Channel Instability	Low to Moderate	

Note: For clarification the hazard categories in Table 5.3 are rated separately. However all the hazards interact and are considered together in evaluating risk.

5.6 Risk Assessment of Proposed Development

(Note: Estimates provided below are interim estimates which are subject to revision following completion of the sediment source and channel assessment)

Table 5.4. Risk and hazard ratings following proposed development in Lofstedt Creek basin.

Indicator	Existing Hazard	Proposed Development	
		Associated Risk	**Resulting Hazard**
Peak Flows	Moderate	(+)	Moderate
Sediment Sources (Landslide)	Moderate	(+)	Moderate
Sediment Sources (Erosional)	Moderate	(+)	Moderate
Riparian Function	Low to Moderate	(+)	Low to Moderate
Channel Instability	Low to Moderate	(+)	Low to Moderate

Notes: Associated risk: o – none; (+) – insignificant increase; + – small but potentially significant increase; ++ – major significant increase.

Peak Flow
Based on information collected to date the risk of channel disturbance and increased sedimentation associated with an increase in peak flows which might result from proposed forest development in Loftstedt Creek is low. If peak flow were to increase by 10% it would likely result in a slight increase in suspended fine sediment and organic matter but not cause significant bank erosion or channel disturbance in the reaches reviewed. This is because the stream is small, flows mostly on low gradients and has limited transport and erosive capacity. A signficant portion of suspended sediment generated in the west and north tributaries settles in the large swampy area in reach 5 and the artificial pond in reach 4, which act as buffers. With higher peak flows there will be some additional delivery of sediment to Bjerkness Creek during the period when there is overland flow connection between reach 4 and reach 3. However the increase in sedimentation will be, in absolute terms, very small and almost all will be in the form of suspended sediment. It will also be extremely small in relation to the wide natural variability in suspended sediment load in the Bjerkness main channel. There is no overland flow connection between upper reach 4 and reach 3 for much of the year. The period during which there is overland flow connection is unlikely to be significantly changed by the increased water yield which might result from the proposed ECA.

Water Yield
The proposed development may result in a slight increase in the water yield (total flow volume) in Lofstedt Creek.

Sediment Source
The proposed development includes a new road crossing of Loftstedt Creek. There will be a short term increase in sedimentation at this crossing but no significant long term increase assuming proper construction practice and revegetation of disturbance. The logging of the blocks proposed is unlikely to cause significant sedimentation.

Riparian Disturbance
There will be minor riparian disturbance at the proposed stream crossing but this will not have a significant effect.

Channel Stability
The proposed development will not significantly change channel stability.

5.7 Risk Reduction Strategies and Recommendations

- Fully deactivate the roads in the drainage which are not in active use, particularly the Bjerkness Creek road which in its current condition is a source of sediment and which, by causing drainage diversion, has significantly increased the landslide sedimentation hazard. Proper road deactivation will also reduce the effects of roads on peak flows by reducing drainage concentration and increasing infiltration of ditchline flow.

- Complete an evaluation of sediment sources and complete the channel assessment

- Complete the Watershed Assessment Report

- See Section 4.7 of this report for general recommendations on roads, harvest methods and hazard assessment which apply also in the Lofstedt drainage.

6.0 FLETCHER CREEK

The Point of Interest (POI) for the assessment is located at the community water intake for the Fletcher Creek Improvement District. Drainage area of Fletcher Creek above the POI is 1369ha. Fletcher Creek is classed as an S3 stream.

6.1 Water License Information

There are a total of 9 licenses on the creek. Most licenses are for diversion at the POI but there are diversion points on the creek both above and below the POI as shown on Map 2. There is a license for water use for generation of power the POD for which is at about 790 m elevation. Points of diversion are shown on Map 2. The location of the intake for the Fletcher Creek Improvement District has been located using GPS and is accurate. The information on the location of other PODs is from Water Rights maps and in some cases is not accurate.

6.2 Sediment Sources

Landslide Induced Sedimentation

Almost all significant point sediment sources within the Fletcher Creek basin are landslides. A large majority of the slides are entirely natural in origin. Increased ground water loading resulting from clearcuts on the south side of Fletcher Creek may have been a minor contributing factor to a few small landslides on the south side of reach 6. Landslide numbers 1 to 26, which have connection to the creek channel and have contributed sediment to the creek, are shown on Map 2. They were briefly reviewed on the ground in conjunction with the channel assessment. More detailed information on the landslide size and material types is shown in Appendix 3B. All the slides listed have occurred in the last 40- 50 years and it appears that many occurred about 20-30 years ago. Relatively few of the slides initiated in the last 10 years. Some of the slides have unstable headwalls and in a few cases debris deposits at the toe of slides are being actively undercut and eroded. Total volume of material delivered to the creek from the landslides is >9000 m^3. This estimate understates the actual total sediment delivery from slope failures because it does not include volumes from smaller landslides and sloughs not listed in Appendix 3B or from older landslides which are no longer easily identified. The volume estimate also does not include sediment delivery from nonpoint sources such as soil creep and slope 'wash'.

Surface Erosion Sources

From a reconnaissance of the main roads it is clear that road surface erosion causes only minor sedimentation in this basin, both in absolute terms and when compared to the volumes of sediment delivered by landslides. There is one source of significance at a road crossing of a tributary to reach 5 on the creek which should be further checked. There is very little erosion and almost no sediment delivery from the logged blocks.

6.3 Channel Assessment

Eight reaches were defined for Fletcher Creek between the Point of Interest and the outlet of Lower Fletcher Lake. The reach breaks are shown on Map 2 and also in Figure 3 in longitudinal profile. Detailed site description data are shown in Appendix 4. Table 6.1 summarizes the reach characteristics and disturbance levels. Table 6.2 summarizes the indicators of disturbance seen in subsections in each reach. The composite disturbance summaries tend to mask the variability within each reach. Figures 11 to 14 are photos which illustrate the condition of selected reaches of the stream channel.

Table 6.1 Fletcher Creek - summary of reach characteristics and disturbance levels

Reach	Cumulative Slope Distance Range m	Reach Length, m (slope distance)	Reach Elevation m		Gradient, % (min,max)	Disturbance Rating							Description
			lower	upper		A1	A2	A3	S	D1	D2	D3	
1	POI to 0+177	177	652	683	*18 (10-26)*	20	60	20	0	0	0	0	
2	0+177 to 0+612	435	683	780	*22*	0	0	0	55	43	3	0	F9
3	0+612 to 1+960	1348	780	1140	*27*	0	0	0	10	80	10	0	F8
4	1+960 to 2+498	538	1140	1255	*20*	0	15	14	5	37	26	3	F7
5	2+498 to 3+046	548	1255	1330	*14*	13	22	25	5	5	23	8	F6, F5
6	3+046 to 3+768	722	1330	1475	*20*	21	29	7	35	8	1	0	F3, F4
7	3+768 to 4+374	606	1475	1620	*24*	7	3	0	31	42	17	0	F2
8	4+374 to 4+478	104	1620	1630	*5 (3-10)*	0	28	35	38	0	0	0	F1

Table 6.2. Fletcher Creek - Indicators of disturbance as observed in the field.

Reach		Location	S1	S2	S3	S4	S5	B1	B2	B3	C1	C2	C3	C4	C5	D1	D2	D3
1	1-1	POI to 177																
2	2-1	177 to 501					✓				✓				O	O	✓	
2	2-2	501 to 612					✓			+	✓				O		✓	
3	3-1	612 to 1763					✓			O	✓	O			✓	+	✓	
3	3-2	1763 to 1823				O	O			✓	✓	✓		+	✓	O	✓	
3	3-3	1823 to 1928					✓				✓	✓			✓		✓	
3	3-4	1928 to 1960				✓				✓			+	O				
4	4-1	1960 to 2231					✓				✓	✓			✓		O	
4	4-2	2231 to 2389			✓	✓				+	✓	✓	O	O				
4	4-3	2389 to 2498					✓				✓	✓			✓		O	
5	3-1	2498 to 2774			O	+	✓				✓	+			✓		+	
5	3-2	2774 to 3046			✓	✓	O			+	✓	✓	+	+	✓	✓	✓	+
6	4-1	3046 to 3191			✓	+	O									✓	✓	✓
6	4-2	3191 to 3318			✓		O			+		+				✓	+	+
6	4-3	3318 to 3473			O		O										✓	
6	4-4	3473 to 3768			✓	O				+		O				✓		✓
7	5-1	3768 to 4013					O										✓	
7	5-2	4013 to 4108			O	O										O		
7	5-3	4108 to 4302					O					O			O			
7	5-4	4302 to 4374			O		O								O			
8	6-1	4374 to 4446			O	O									✓			
8	6-2	4446 to 4478			O	O									✓			

✓ - active/frequent indicator; ✚ recovering indicator; O infrequent or moderately active indicator

S1	homogeneous bed texture	C1	extensive cascades
S2	sediment fingers	C2	minimal pool area
S3	sediment wedges	C3	elevated mid-channel bars
S4	extensive bars	C4	multiple channels or braids
S5	extensively scoured zones	C5	disturbed stone lines
B1	abandoned channels	D1	small woody debris
B2	eroding banks	D2	LWD function
B3	avulsions	D3	LWD jams

6.3.1 Reach Descriptions

Reaches above Lower Fletcher Lake
Because Fletcher Lake acts as a buffer allowing settling of suspended sediment and bedload, and because no development is proposed in the area above the lake, little time was spent in assessment of the area between Lower and Upper Fletcher Lakes. From the helicopter overflight the channels appear mostly stable. There is very little streamflow in some sections. This is probably due to infiltration in solution cracks in limestone bedrock which underlies parts of the channel (D. Scarlett, pers. comm.).

Reach 8
This is a short, moderate gradient reach, below the outlet of Fletcher Lake, which is confined by steep gully walls. There have been significant colluvium and saprolite/rock slides as well as bank sloughing (poorly defined, discontinuous, shallow small slides) in the reach. This has resulted in minimal pool area and dewatering of portions of the channel. Most of the material deposited from the slides is angular colluvium with only a small fraction of fine grained material. There are large amounts of wood in the upper part of the reach which form a woody debris jam that obscures the channel bed. There are also large amounts of woody debris at the outlet of Fletcher Lake. The channel in this section has low transport capacity and a relatively small proportion of sediment deposited in the reach is moved downstream.

Reach 7
This is a steep bedrock and lag boulder controlled reach in which the channel is mostly very confined and relatively stable. Channel morphology is step pool and cascade. Though most of the steps are composed of stones there are also some large woody debris (LWD) steps. Most of the reach is rated partially to moderately degraded with scour and the partial breakdown of stone lines. The scoured sections are separated by short sections where the channel is wider and partially to moderately aggraded. There have been a number of shallow debris slides and rock slides off the steep gully walls in this reach which have resulted in significant deposits of sediment. However, because the gradient is steep and the channel confined most of the sediment inputs have been transported through to reaches 5 and 6.

Reach 6
In the upper portion of the reach the channel is well confined, mostly lag boulder controlled, with some bedrock and with a step pool/cascade morphology. Steps are mostly stone with some LWD. The upper part of the reach has short sections with partial to moderate aggradation alternating with degrading sections in which there is scour and disturbance of stone lines. There have been a number of debris slides off the steep gully walls in the reach including a major slide (slide17 - about 2250 m^3 sediment delivery) which occurred about 20 to 30 years ago. In the lower part of the reach, below slide 17, the channel is still confined but is moderately to severely aggraded with sediment wedges, woody debris jams, pool infilling and a high proportion of mobile bed. There are some functioning LWD steps in this section but they are generally less stable than in the upper part of the reach.

Reach 5
The gradient in this reach is lower and the channel less confined than in reach 6. As a result, the upper part of this reach is moderately to severely aggraded and is characterized by avulsion channels, multiple/braided channels, channel widening, bars, sediment wedges, minimal pool area and little functional woody debris. The lower part of the reach is moderately aggraded on lower gradient sections and moderate to severely degraded on steeper gradient sections. There are some landslides in the reach but the major source of the sediment deposited in the reach is transported in from reach 6 and above. Some of the aggraded portions of the reach are beginning to stabilize as the bars, avulsion channels and sediment wedges revegetate (see photo Figure 13). Much of the woody debris in the reach, which includes lots of small and medium sized as well as large debris, is randomly scattered and non functioning but some newer LWD steps have recently been established. This stabilization is occurring even though there are continued small inputs of sediment from active slides in reaches 6 and 7.

Reach 4
Most of this steep reach is in a deep gully with high coupling. The channel alternates between sections of steep gradient, scoured channel and moderately to severely aggraded sections where gradients are lower

and the channel is not as confined. The steeper sections have a stable, lag boulder and bedrock dominated bed and, where the gradients moderate, there is more stored sediment and mobile bedload and some functioning woody debris. The aggraded sections have extensive side bars and some mid channel bars, minor avulsion channels, sediment wedges, minimal pool area and some channel widening. The sediment deposition is from slides and channel disturbance upstream in reaches 5 and 6 and from a large (~2500 m^3) debris slide/slump in the reach (slide 5, see Appendix 3B) which occurred about 20 years ago. The toe of the slide is being actively eroded and undercut by the creek and there are indications of continuing active creep on parts of the slide track. The larger side and mid channel bars in this reach are revegetating and beginning to stabilize in spite of the continued sediment inputs.

Reach 3
This is a long, uniform and very steep gradient reach with a bed which is lag boulder dominated, with significant sections of bedrock see photo Figure 11. The channel is in a deep gully with sidewalls which are very steep (60-100+%) and which are 100% coupled. The gully sidewalls are mostly bedrock and colluvium, and are mostly stable although there have been some small slides in the lower part of the reach in colluvium and saprolite. Most of the reach is scoured; by the measures of the Channel Assessment Procedure (1996) most of this reach would be classed as moderately to severely degraded. However, because the gradient is so steep it is likely that this reach has equilibrated and it has been rated partially degraded or stable. Most functioning steps are of lag boulders and there is very little functional woody debris. There is little mobile bed material; the channel is very stable and has low sensitivity to increases in peak flow.

Reach 2
This steep gradient reach has a step pool/ cascade channel with lag boulder and bedrock control. Steps are composed mostly of lag boulders. The channel flows in a well defined 10-30 m deep gully with a high degree of coupling to the channel. Most of the reach is scoured and there is little functioning woody debris. Most of the woody debris present in the channel is small and medium size material which has formed very small unstable jams, since the spring freshet. There are small recovering cobble bars in a few sections where the channel widens slightly. This reach is quite stable and has low sensitivity to increases in peak flow.

Reach 1
This is a short reach on the alluvial fan of Fletcher Creek with significantly lower gradients than in the previous reach. Gradient is about 24% at the top reach break and declines throughout the reach. The bottom section of the reach, below the bridge to the private lot on the south side of the creek is moderately aggraded with some infilling of pools. The upper portion of the reach is more severely aggraded as illustrated by the wide channel width and shallow depth (depth is difficult to measure because the channel is very irregular), presence of bars, multiple channels and old avulsion channels. There are indications of major old avulsion (flood) channels on the fan on both the north and south sides of the present channel.

Channel Overview

The Fletcher Creek channel has been subjected to major sediment deposition from natural landslides in the last 40 to 50 years. 35% of the channel length reviewed is moderately or severely disturbed. The large sediment inputs have destabilized the lower gradient reaches of the creek and to a somewhat lesser extent destabilized the fan. There are anecdotal reports of flooding on the north side of the fan prior to 1950, possibly in 1948 which is known to have been a year with very high runoff, and there are indications of other older avulsion (flood) channels on the fan. The steeper reaches of the creek (reaches 2, 3, 7 and much of 4) are stable and resilient, with a high transport capacity. Most sediment inputs into reaches 2 and 3, and to lesser extent in reach 4, are likely to be rapidly transported to the fan area.

The creek is now in a recovery phase from the large pulse of landslide activity 20-40 years ago and there has been considerable revegetation of the bars and sediment wedges and reestablishment of functioning woody debris in the aggraded portions of reaches 4, 5 and 6. There has probably been some recovery of the fan as well although this is not clear. This revegetation and stabilization has proceeded in spite of continued sediment input from small landslides, erosion of landslide tracks and the continuous processes of soil creep.

6.4 Riparian Assessment

Almost the whole of the riparian zone is well stocked with a mature forest stand which provides good shade cover and ample wood to the channel. Wood recruitment and shade cover are limited only in Reach 8, where the gully sidewalls are very rocky, and in the lower part of Reach 1 where there has been private land clearing. The riparian has also been slightly impacted by the many slides in reaches 4 to 7.

6.5 Indicator Results and Ratings of Existing Hazard

Table 6.3 summarizes impact indicators for Fletcher Creek basin under existing and proposed development. The weighted ECA is at 3.34% and would rise to 5.1% with the proposed development. Road indicators are generally low and will remain unchanged with the proposed development.

Table 6.3 Hazard indicator results for Fletcher Creek basin.

Indicator	Units	Fletcher Creek		
		Existing	Proposed	Total
Area	ha	1368.85	n/a	1368.85
Private Land	%	0.0001	n/a	0.0001
ECA – unweighted	%	3.21	2.32	5.53
ECA –weighted	%	3.34	2.33	5.67
Total major roads	km/km^2	0.165	0.303	0.468
Total minor roads	km/km^2	0.043	0	0.043
Roads, High Sed. Production Pot'l	km/km^2	0.032	0.087	0.109
Roads Density	km/km^2	0.178	0.303	0.481
Roads on Terrain Stab Class IV/V	km/km^2	0.118	0.05	0.168
Number of Stream Crossings		3	2	5

Table 6.4 Fletcher Creek – *existing* hazard ratings and main factors.

Impact Category	Hazard Index	Main Factors
Peak Flow	Low	Low ECA, low road density
Sediment Sources	High	Natural landslides
Riparian Function	Low	Healthy riparian zone forest stands in all reaches except reach 8 and the lower part of reach 1
Channel Stability Reaches 1,4,5,6,8	High	Moderately to severely aggraded; high proportion of mobile bedload and/or readily mobilized deposits
Channel Stability Reaches 2,3,7	Low	Stable lag boulder and bedrock channel

Note: For clarification the hazard categories are rated separately. However all the hazards interact and are considered together in evaluating risk.

6.6 Risk Assessment of Proposed Development

Table 6.5 Risk and hazard ratings following proposed development.

Indicator		Existing Hazard	Proposed Development	
			Associated Risk	**Resulting Hazard**
Peak Flow		Low	o	Low
Sediment Sources		High	(+)	High
Riparian Function		Low	(+)	Low
Channel Stability	Reaches 1,4,5,6,8	High	(+)	High
	Reaches 2,3,7	Low	(+)	Low

Notes: Associated risk: o – none; (+) – insignificant increase; + – small but potentially significant increase; ++ – major significant increase.

Risk Assessment Overview

The risk that the proposed forest development will significantly change the quantity, quality or timing of stream flow in Fletcher Creek is low if it is done adhering closely to the requirements of the Forest Practices Code and the recommendations which follow in Section 6.7.

Peak Flow

The proposed development will not have a significant effect on peak flow. The proposed weighted ECA of 5.5% is well below the threshold at which effects on peak flow might occur.

Sediment Sources

The proposed development will cause short term increases in erosional sediment delivery as a result of disturbance at stream crossings but the long term increase will not be significant assuming adequate revegetation and stabilization of the exposed surfaces at the crossings. There is likely to be a small increase in landslide risk and landslide induced sedimentation on the north side of reach 5 as a result of construction of the proposed road and possibly from the logging proposed in Block 5 on the north side of the drainage.

Riparian Function

There will be small impacts caused by tree removal and road construction in the riparian zone at the stream crossing but they are not significant in terms of maintaining channel stability.

Channel Stability

The proposed development is not likely to have a significant effect on channel stability.

6.7 Risk Reduction Strategies and Recommendations

- The general comments on mitigating road related hazards made in Section 4.7 on Bjerkness Creek apply equally to road construction in the Fletcher Creek drainage. It is important to avoid drainage concentration on the new section of road above Fletcher Creek, particularly on the north side of the drainage. A field assessment of surface erosion hazards and mitigation possibilities should be carried out at the stream crossings. Terrain stability hazards should be assessed both on the road and downslope where there are known natural landslides.
- Ground based assessment of possible effects on stability of proposed cutblocks should be completed in areas where timber harvest is planned above locations where there have been natural landslides into the creek, in particular on the southern portion of Block 5. Use of dispersed partial cuts in such situations can reduce groundwater loading but successful use is also dependent on stand characteristics.
- Ground based assessment of erosion hazard should be completed where bladed skid trails or yarding corridors are proposed on terrain with a high and very high erosion hazard and high or very high sediment delivery potential. (Assessment of skid trails is a Forest Practices Code requirement; assessment of yarding corridors is not).
- There should be future periodic review of the watershed assessment including a review of the channel condition to monitor recovery in reach 1 (on the fan) and in reaches 5 and 6 where there is significant stored sediment. This is especially important if there are future proposals for development which would result in the ECA approaching 15-20%.

7.2 Brewer Spring and Sandon Creek

These two water sources are on private DL 484. The Brewer Creek recharge area may include part of the 'face' unit on which logging is proposed in Block 3.

Recommendation

- The source area of Brewer Spring should be checked on the ground and possible effects on the spring of the proposed logging upslope in Block 3 should be evaluated.

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June 20, 2000

8.0 References

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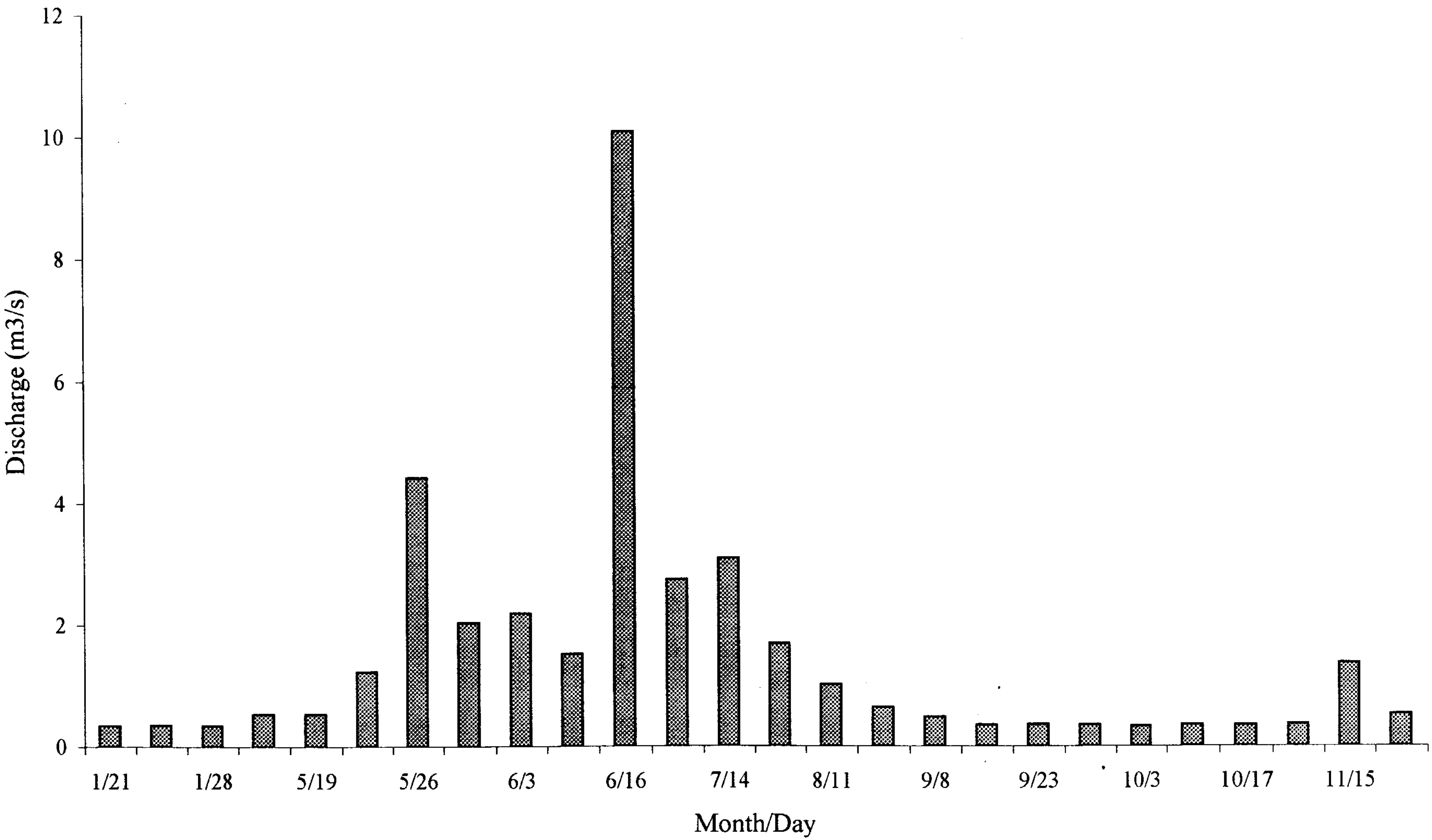
Appendices

Appendix 1A
Summary
Bjerkness Creek Flow Data

Statistic	Unit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Daily Count		124	113	124	127	186	186	217	217	210	124	130	155	1913
D Average		0.196	0.225	0.302	0.447	1.79	2.91	1.3	0.439	0.37	0.292	0.244	0.222	0.825
D Maximum		0.362	0.464	0.493	1.5	5.95	6.14	3.68	1.26	0.957	0.569	0.425	0.379	6.14
D Minimum		0.096	0.15	0.173	0.238	0.292	0.985	0.368	0.17	0.105	0.076	0.062	0.096	0.062
Monthly Count		4	4	4	4	6	6	7	7	7	4	4	5	0
M Std Dev		0.055	0.037	0.074	0.132	0.634	0.794	0.45	0.16	0.188	0.13	0.111	0.06	0.012
M Skew		-1.81	0.517	0.345	0.315	1.35	0.78	-0.085	0.626	0.89	-1.75	-1.03	0.537	1.37
M Maximum		0.236	0.274	0.39	0.583	2.94	4.08	1.93	0.704	0.708	0.388	0.358	0.312	4.08
M Minimum		0.115	0.183	0.229	0.294	1.19	2.11	0.62	0.263	0.129	0.101	0.093	0.146	0.093

Note: This summary is based on records of flow made in 1930, 1931, 1957-59 and 1967-69

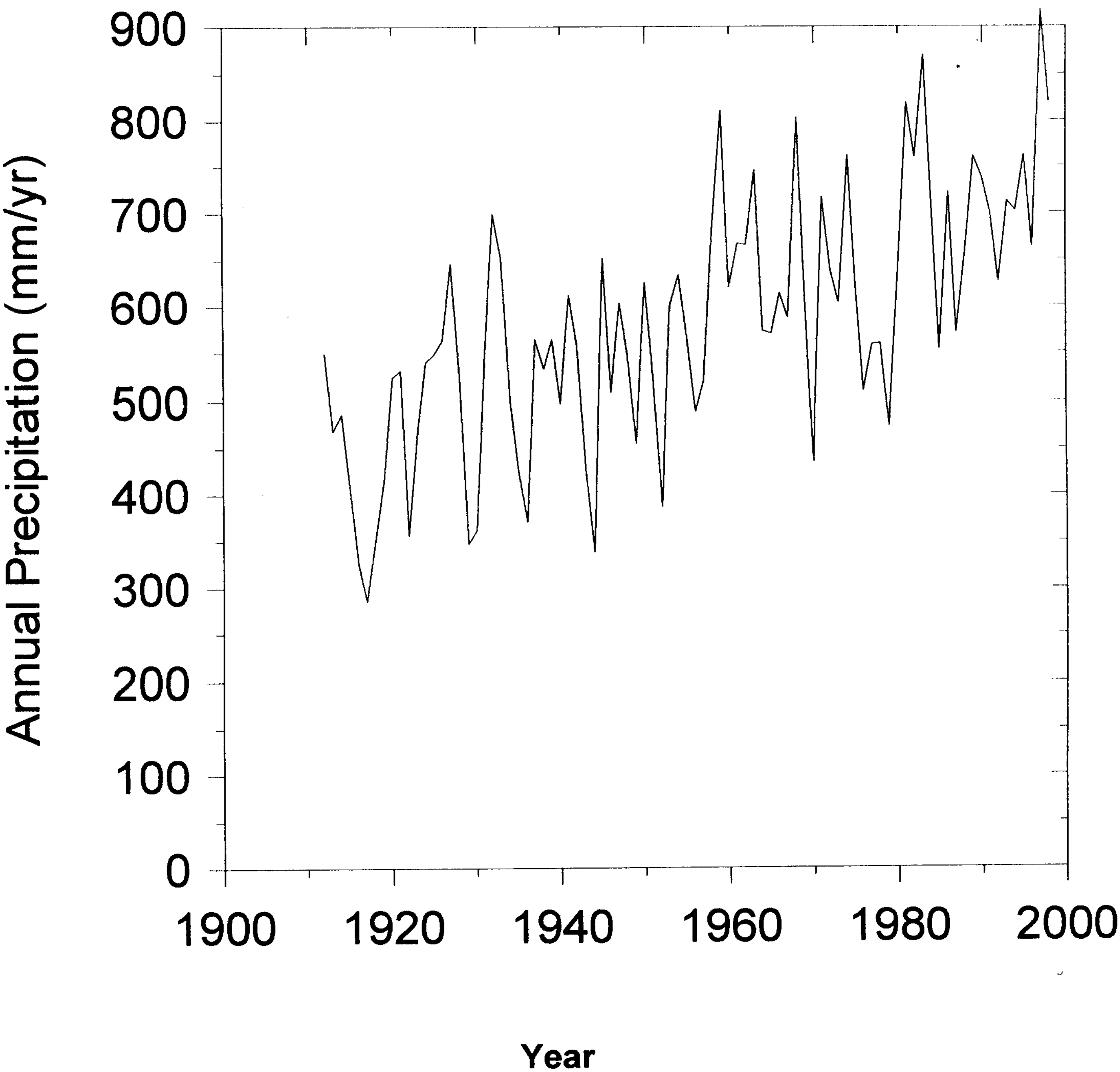
Appendix 1B
Bjerkness Creek Streamflow Volumes -1999



Appendix 1C
Fletcher Creek Streamflow Data
1988-1991

Date	Day no.	Weir Flow ft3/sec	Estimated Leakage ft3/sec	Total Flow ft3/sec	Total Flow m3/sec	Total Flow l/sec
22 Aug 88	234	2.11	0.15	2.43	0.06867	68.67
23 Aug 88	235	1.98	0.10	2.18	0.061637	61.64
29 Aug 88	241	1.98	0.10	2.18	0.061637	61.64
02 Sep 88	245	1.62	0.05	1.70	0.048138	48.14
10 Sep 88	253	1.38	0.05	1.45	0.041007	41.01
18 Sep 88	261	1.38	0.05	1.45	0.041007	41.01
24 Sep 88	267	1.49	0.05	1.56	0.044275	44.28
01 Oct 88	274	2.17	0.15	2.50	0.070623	70.62
09 Oct 88	282	2.11	0.15	2.43	0.06867	68.67
16 Oct 88	289	4.07	0.75	7.12	0.201567	201.57
22 Oct 88	295	3.04	0.30	3.95	0.111842	111.84
30 Oct 88	303	1.95	0.10	2.15	0.060704	60.70
07 Nov 88	311	3.44	0.35	4.64	0.131425	131.43
13 Nov 88	317	2.62	0.25	3.28	0.092683	92.68
20 Nov 88	324	2.21	0.15	2.54	0.071924	71.92
27 Nov 88	331	2.08	0.15	2.39	0.067694	67.69
16 Dec 88	350	1.49	0.05	1.56	0.044275	44.28
24 Dec 88	358	1.25	0.00	1.25	0.035375	35.38
31 Dec 88	365	1.06	0.00	1.06	0.029998	30.00
08 Jan 89	8	1.11	0.00	1.11	0.031413	31.41
15 Jan 89	15	1.10	0.00	1.10	0.03113	31.13
23 Jan 89	23	0.99	0.00	0.99	0.028017	28.02
29 Jan 89	29	0.93	0.00	0.93	0.026319	26.32
04 Feb 89	35	0.92	0.00	0.92	0.026036	26.04
11 Feb 89	42	0.85	0.00	0.85	0.024055	24.06
19 Feb 89	*50*	*0.77*	*0.00*	*0.77*	*0.021791*	*21.79*
26 Feb 89	*57*	*0.77*	*0.00*	*0.77*	*0.021791*	*21.79*
05 Mar 89	*64*	*0.72*	*0.00*	*0.72*	*0.020376*	*20.38*
12 Mar 89	71	1.41	0.05	1.48	0.041898	41.90
18 Mar 89	77	1.19	0.00	1.19	0.033677	33.68
24 Mar 89	83	1.41	0.05	1.48	0.041898	41.90
02 Apr 89	92	1.72	0.10	1.89	0.053544	53.54
08 Apr 89	98	2.47	0.25	4.00	0.1132	113.20
16 Apr 89	106	4.40	1.00	8.80	0.24904	249.04
22 Apr 89	112	7.29	1.50	18.23	0.515768	515.77
29 Apr 89	119	5.79	1.25	13.03	0.368678	368.68
07 May 89	127	9.75	2.50	34.13	0.965738	965.74
14 May 89	134	7.29	2.50	25.52	0.722075	722.07
20 May 89	140	5.79	2.50	20.27	0.5735	573.50
30 May 89	150	4.40	2.50	15.40	0.43582	435.82
03 Jun 89	154	8.91	3.00	35.64	1.008612	1008.61
10 Jun 89	161	10.62	3.00	42.48	1.202184	1202.18
17 Jun 89	168	10.62	3.00	42.48	1.202184	1202.18
13 Jul 89	194	5.07	2.00	15.21	0.430443	430.44
26 Jul 89	207	2.57	1.50	6.43	0.181828	181.83
06 Aug 89	218	0.89	1.00	1.78	0.050374	50.37
04 Sep 89	247	3.29	0.20	3.95	0.111728	111.73
09 Sep 89	252	1.91	0.75	3.34	0.094593	94.59
24 Sep 89	267	2.04	0.10	2.24	0.063505	63.51
06 Oct 89	279	1.17	0.10	1.29	0.036422	36.42
05 Nov 89	309	1.78	0.15	2.05	0.05793	57.93
22 Nov 89	326	3.52	1.00	7.04	0.199232	199.23
09 Dec 89	343	3.36	0.15	3.86	0.109351	109.35
23 Dec 89	357	1.98	0.10	2.18	0.061637	61.64
14 Jan 90	14	1.67	0.10	1.84	0.051987	51.99
04 Feb 90	35	1.06	0.05	1.11	0.031498	31.50
11 Feb 90	42	1.32	0.10	1.45	0.041092	41.09
18 Feb 90	49	1.11	0.10	1.22	0.034554	34.55
25 Feb 90	56	0.82	0.00	0.82	0.023206	23.21
03 Mar 90	*62*	*0.77*	*0.00*	*0.77*	*0.021791*	*21.79*
18 Mar 90	77	1.32	0.10	1.45	0.041092	41.09
26 Mar 90	85	1.59	0.10	1.75	0.049497	49.50
31 Mar 90	90	2.71	0.10	2.98	0.084362	84.36
14 Apr 90	104	2.71	0.10	2.98	0.084362	84.36
30 Sep 90	273	0.86	0.25	1.08	0.030423	30.42
07 Oct 90	280	1.38	0.75	2.42	0.068345	68.34
13 Jan 91	13	1.41	0.05	1.48	0.041898	41.90
24 Feb 91	55	2.04	2	6.12	0.173196	173.20
16 Oct 91	289	1.26	0.15	1.45	0.041007	41.01
06 Oct 93	279	1.07	0.1	1.18	0.033309	33.31
31 Oct 93	304	0.83	0.1	0.91	0.025838	25.84
23 Nov 93	*327*	*0.53*	*0.05*	*0.56*	*0.015749*	*15.75*
16 Jan 94	16	0.93	0.1	1.02	0.028951	28.95

Appendix 1D



Annual precipitation – Kaslo Weather Recording Station

Appendix 2: ECA weighting assumptions (from B.C. IWAP guidebook, 1999)

Not satisfactorily restocked areas:	Clearcut with 0% recovery.
Individual tree selection:	
<20% basal area removal	Assume 100% recovery.
20-40% basal area removal	Assume 0.2 of area harvested (e.g.1 ha of 35% removal = 0.2 ha ECA).
40-60% basal area removal	Assume 0.4 of area.
60-80% basal area removal	Assume 0.6 of area.
>80% basal area removal	Clearcut with 0% recovery.
Small opening: <1 H[a] (<0.05 ha)[b]	Assume 0.5 of area (e.g. 20 x 0.05 ha openings = 1 ha cut = 0.5 ha ECA).
1H-3H (0.05-0.5 ha)	Assume 0.7 of area.
3H-5H (0.5-1.2 ha)	Assume 0.9 of area
Strip cuts:	
<2H (50 m)	Assume 0.6 of area (e.g. 1 ha = 0.6 ha ECA).
2H-3H (50-75 m) width	Assume 0.7 of area.
3H-4H (75-100 m) width	Assume 0.8 of area.
>4H (>100 m) width	Assume 1.0 of area.
Private land:	Include in total sub-basin area and ECA.
Open range:	Include in total sub-basin area, but do not include range land as ECA (most range land is naturally open grassland and should not be tallied as ECA).
Burn sites:	Clearcut with recovery factors for regeneration. If a burn produces a stand similar to a partial cut, use the partial cutting recovery factors.
Large landslides:	Clearcut with the appropriate recovery factors.
Utility corridors:	Clearcut with 0% recovery.

[a] H refers to average tree height.

[b] This assumes a tree height of 25 m. If tree height is substantially greater, opening sizes can be increased by calculating the opening size for circular openings.

Appendix 3 A
Bjerkness Creek Landslides
Reaches 1-9

no.	bank	Distance from PoI	Reach	Exposed Area, m2	Gradient %	aspect	age	activity %	delivery %	depth cm	volume m^3	volume delivered m^3	likely cause
1	North	1645	3	200			25	0	100	50	100	100	road
2	North	1740	3	600		90	30	25	100	40	240	240	natural
3	South	1805	3	200	85	345	10	0	100	50	100	100	road
4	North	1860	3	240	85	175		80	100	80	192	192	road
5	South	1920	3	216	75	150		0	100	100	216	216	natural
6	North	1960	3	500		166	25	2	80	60	300	240	road
7	North	2020	3	500	70	130	25	20	85	70	350	297.5	road
8	North	2065	3	300	75	150		5	85	80	240	204	road
9	North	2110	3	500	75	145		20	100	60	300	300	road
10	North	2145	3	600	70	145		100	100	80	480	480	road
11	North	2210	3	240	90	320	6	100	100	40	96	96	road
12	North	2354	3	1225	60	120		50	5	100	1225	61.25	road
13	North	2520	3	1200	75	175	<5	75	50	175	2100	1050	maybe road
14	North	2540	3	450	70	155	20	10	90	100	450	405	maybe road
15	North	2595	3	120	90		old	0	100	30	36	36	natural
16	North	2605	3	120	90		old	0	100	30	36	36	natural
17	North	2610	3	120	90		old	0	100	30	36	36	natural
18	North	2688	4	150	80	180	25	0	100	30	45	45	natural
19	North	2935	4	400	80	160	45	0	100	30	120	120	maybe road
20	South	2980	4	500	90	360	35	0	100	50	250	250	natural
21	South	3110	4	300	90	300	40	0	100	20	60	60	natural
22	South	3130	4	230	100	350	20	80	100	50	115	115	natural
23	South	3170	4	5500	90	20	30	20	100	120	6600	6600	natural
24	North	3190	4	300	70	170		0	100	30	90	90	road
25	South	3290	4	200	60	10	25	0	100	30	60	60	maybe road
26	North	3300	4	144	100	185		50	100	40	57.6	57.6	unknown
27	North	3340	4	450	75	183	25	1	80	30	135	108	natural
28	North	3565	5 ?		70	197		10	100	?	?		maybe road
29	North	3580	5	100	75		10-15	0	100	30	30	30	maybe road
30	South	3600	5	150		347	10-15	0	100	30	45	45	natural
31	North	4200	6	350			50	0	100			0	natural
32	South	4389	6	300			15-20	0	30			0	natural
33	South	4800	6	500			20	90	100	50	250	250	natural
34	South	5035	7	750			10-20	50	10	50	375	37.5	natural
35	South	5160	7	200			20	10	100	50	100	100	natural
36	North	5740	8	50			20	0	100	60	30	30	natural
												12088	

Appendix 3B
Fletcher Creek
Landslides and Major Erosional Sediment Sources

No.	bank	Dist from POI	Reach	Age	SlideArea	Depth	Delivery	Volume	Vol delvy	Material	Activity
		m	No.	yrs	m^2	cm	%	m^3	m^3		%
1	South	917-947	3	<40	1500	30	90	450	405	Cv	
2	South	952-957	3	<40	300	30	90	90	81	Dv	
3	North	991-999	3	<40	64	50	90	32	28.8	Cv	
4	South	1098	3	<40	64	50	90	32	28.8	Cv	
5	North	2364-2379	4	20	1000	250	90	2500	2250	Mb	20
6	South	2498-2548	5	30-40	1200	100	90	1200	1080	Cv	
7	South	2582	5	<5	80	100	100	80	80	FG	100
8	North	2714-2727	5	20	325	100	100	325	325	Mb	
9	South	2903	5	<40	48	90	70	43.2	30.24	Cv	
10	South	3058	6	<40	64	100	60	64	38.4	Dv	
11	North	3093	6	<40	500	50	75	250	187.5	Dv	
12	South	3134	6	<40	200	50	75	100	75	Cv	
13	North	3134	6	<40	150	100	80	150	120	Cv	
14	North	3143	6	<40	48	70	90	33.6	30.24	Dv	
15	South	3190	6	<40	450	70	80	315	252	Cv	
16	North	3244-3252	6	<40	56	50	90	28	25.2		
17	North	3288-3318	6	20	1500	150	100	2250	2250	Mb,Cv	
18	South	3358-3383	6	10-20	625	100	90	625	562.5	Cv, R	
19	South	3568-3577	6	<40	108	100	90	108	97.2	Cv	
20	North	3731	6	<40	375	50	100	187.5	187.5	Cv, R	90
21	South	3828-3858	7	<40	800	50	90	400	360	Cv, R	
22	South	3893-3908	7	<40	300	50	100	150	150	Dv	
23	South	3973-3983	7	<40	200	50	90	100	90	Dv	
24	North	4233-4244	7	<40	250	50	90	125	112.5	Cv	
25	North	4248-4268	7	<50	200	50	90	100	90		
26	South	4388-4425	8	<50	340	50	90	170	153	R, Cv	
27	Erosional source at road crossing of tributary stream								50	Mb	
								Total	8684.88		

Appendix 4 A
Definitions of Channel Assessment Terms (from Carver and Putt, 1999)

gradient
gradient of the reach as measured between its end points; a minimum or a maximum is recorded only where a departure of at least 10 m exists

width (w_b) and depth (d_b)
based on bankfull height; bankfull height is based on a combination of changes in vegetation, gradient, and the surface

w1m
width of the gully at a vertical position one metre above the channel bed

coupling
coupling indicates the degree to which the channel can be affected by sidewall activity

overbank (%)
percentage of the full length of the reach containing evidence of overbank flows

classes of bank erosion
% of total bank length with evidence of bank erosion in each class
Nil - no cutting is evident.
< 0.5 - cutting affects less than half of d_b
0.5 - 1.0 - cutting affects between a half and a full d_b
> 1 - cutting affects a height more than d_b

bed composition (by %)
the percentage of the bed composed of each of the following
LB - large boulders (> 100 cm on the b axis)
SB - small boulders (25 -100)
LC - large cobbles (15 - 25)
SC - small cobbles (7.5 -15)
CG -coarse gravels (2.5 - 7.5)
FG - fine gravels (0.25 - 2.5)
sand
muck - includes silt, clay & fine organic matter
forest floor
wood
bedrock
subsurface flow
Mobile sizes are summed to determine the % of the bed which is mobile.

brightness (%)
percentage of the clastic bed which appears bright: newly exposed, lacking vegetation & organic stains

clinging vegetation
the abundance of the clastic bed which is covered with by moss or algae
N None - clinging plants are rarely found anywhere in the reach.
S Sparse - plants are found but their occurrence is spotty. They are almost totally absent from rocks in the swifter portions of the reach and may also be absent in some of the slow and still water areas.
C Common - plants are quite common in the slower portions of the reach but thin out or are absent in the swift portions of the stream.
A Abundant - Clinging plants are abundant throughout the reach from bank to bank. A continuous mat of vegetation is not required but moss and/or algae are readily seen in all directions across the stream.

angularity 1, 2
four classes of angularity observed in the reach:
A Angular - flattened faces with sharp edges and corners

SA Subangular - slightly rounded points of intersection of subrectangular faces; surfaces smooth and flat
SR Subrounded - well rounded in two dimensions
R Rounded - well-rounded in three dimensions; surfaces smooth

scour, deposition
the percentage of the area of the entire bed which is affected by each of scour & deposition (includes pools and bars on the channel margins)

packing
the degree of imbrication/consolidation of the bed (of both the wood and the clasts):
None - rocks in loose array, moved easily by less then high flow conditions and move underfoot while walking across the bottom
Loose - moderately loose without any pattern of overlapping. Most elements might be moved by average high flow conditions.
Mixed - moderately tight packing of particles with fast water parts of the cross-section protected by overlapping rocks. These might be dislodged by higher than average flow conditions, however.
Tight - an array of sizes are tightly packed and wedged with much overlapping which makes it difficult to dislodge by kicking.

annual d50 & d90
The part of the clastic bed which appears bright is assumed to move in the Mean Annual Flood ("Annual"). The d_{50} and d_{90} of this material is recorded as seen on the surface. The d_{50} is the b axis of the 50th percentile of the size distribution of this material by weight. (The d_{90} is larger, corresponding to the 90th percentile of the same distribution.)

step height >75, 25-75, <25
the height of the steps in three height classes

step rk, wd, rt, rw
the extent to which each of wood, rock, roots, and rock/wood forms the steps

step stability
S Stable
U Unstable
M Mixed stability

step composition
rock
wood
rock and wood
roots

Appendix 4 B
Bjerkness Creek
Detailed Channel Site Description Data
Reaches 1 to 6

Site No.	Reach No.	Length m	Elev m	Flow l/s	Gradient (%) rep	min	max	Width (m) rep	min	max	Depth (cm) rep	min	max	Ratio w/d	Bed Composition (% of total) LB	SB	LC	SC	CG	FG	S	M	W	BR	Mobile (%)	Brght (%)	Cling	Ang 1	Ang 2
1	3	150	860	700	24	18	35	8	6	15	45	20	120	18	20	*55*	**10**	**10**	**3**	**2**	0	0	0	0	43			sr	sa/r
2	3	150	1012	800	20	16	24	8	4	15	30	10	70	27	15	*45*	**20**	**10**	**6**	**2**	**1**	0	0	1	54	10	c	sr	sa
3	4	150	1160	450	6	4	15	16	8	24	50	10	150	32	4	*16*	**26**	**25**	**15**	**10**	**1**	0	0	3	85	30	s/a	sr	sa/r
4	5	150	1219	700	14	10	24	7	3	15	45	20	65	16	5	*4*	**4**	**3**	**2**	**1**	**1**	0	0	80	13	25	c->a	sr	sa
5	6	150	1300	500	9	5	10	6	4	8	30	10	50	20	3	20	**30**	**20**	**13**	**12**	2	0	0	0	75		c->a	sr	sa
6	6	150	1338	200	7	5	35	8	3	12	20	10	50	40	1	5	5	**3**	**3**	**2**	**1**	0	0	80	9	30	c	sr	sa

Site No.	Reach No.	Sco %	Dep %	Pack	Sfc (cm) d50	d90	SubSf d50	00y fc d9	fc/Su 50 rat	Ratio d_{90}/D	Ratio 100/1	Step F	Step Compositi W	M	St	Step tab	W1m (m) rep	min	ax	Ratio w_{1m}/w_b
1	3	15		m/t	20	40	1	80	0.5	1.8	2.0	h	0	5	95	s	11	8	20	1.4
2	3	10		t->m	18	40	1	70	0.6	2.3	1.8	h	0	10	90	s	10	8	18	1.3
3	4	35		l/m->t	12	35	3	60	0.6	1.2	1.7	h	80	20	0	s	10	5	18	0.6
4	5	10		m	15	50	4	80	0.6	1.8	1.6	h	0	5	95	s	12	7	20	1.7
5	6	30		m	12	25	4	80	0.3	2.7	3.2	h	5	25	70	s	12	9	25	2.0
6	6	20		m	7	10	1	50	0.2	2.5	5.0	m	0	10	90	s	12	8	18	1.5

Site No.	Reach No.	Coupling (%) C	PC	Un	Obnk %	Bank Cutting (%) Nil	<.5	.5-1	>1	Cut Ends	oo CDM	Wood Stand	Wood Span
1	3	80	20	0	0	100	0	0	0	s->c	c	h	12
2	3	70	10	20		99	0	1	0	s	c	h	6
3	4	95	5	0	0	100	0	0	0	s	s		
4	5	90	10	0	0	100	0	0	0	n	c	h	4
5	6	60	40	0	1	98	0	0	2	n	c	h	5
6	6	100	0	0		98	0	0	2	n	m		1

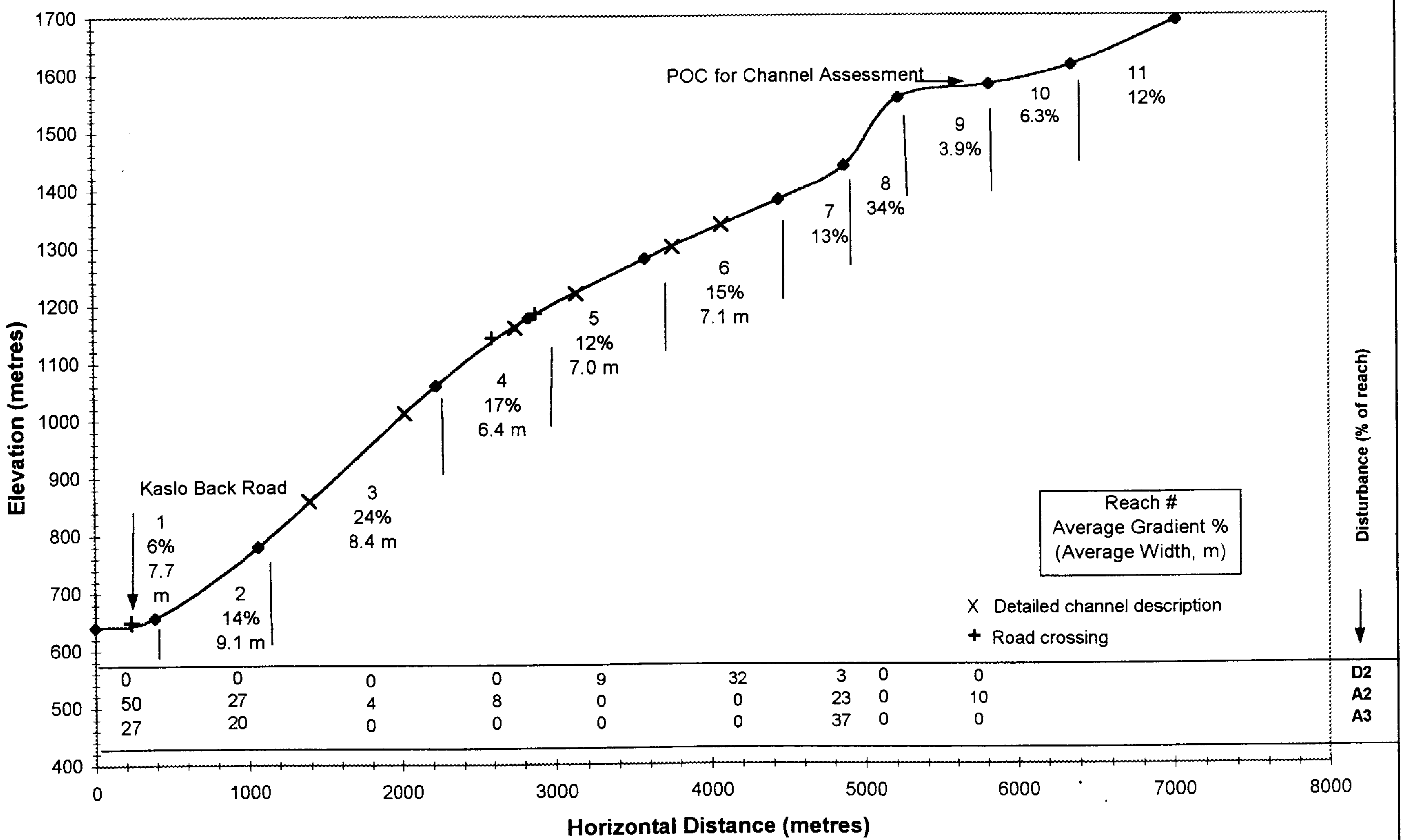
Appendix 4 C
Fletcher Creek
Detailed Site Description Data
Reaches 2- 8

Site No.	Reach No.	Length m	Elev m	Flow l/s	Gradient (%) rep	min	max	Width (m) rep	min	max	Depth (cm) rep	min	max	Ratio w/d	Bed Composition (% of total) LB	SB	LC	SC	CG	FG	S	M	W	BR	Mobile (%)
F1	2	100	765	100	25	10	36	8	6	14	60	40	90	13	60	15	10	8	3	1	tr	0	1<1	2	25
F2	3	100		300	29	22	34	5.8	4.5	8.5	55	40	80	11	55	10	6	5	3	1	tr	0	0	20	20
F3	4	100	1180	170	36	15	60+	6.5	5.8	12	60	40	100	11	40	18	14	6	3	1	0	0	0	18	30
F4	5	100	1275	120	14			5.5	3.3	8.2	35	25	55	16	27	16	17	20	10	6	tr	0	1	3	60
F5	5	100	1300	20	12			6	5	7?	25	15	20	24	10	15	20	25	19	9	1	0	1	0	75
F6	6	50		40	25			4	3	8	50	35	80	8	28	15	15	20	13	5	2	0	1	1	58
F7	6	100	1470	70	18			7	5	11	45	35	50	16	30	20	20	15	10	4	1	0	tr	0	75
F8	7	85	1600		30			6	5	7	40	30	70	15	20	10	30	25	9	3	0	0	0	3	68
F9	8	50	1630	20	5			4	3	6	40	30	55	10	5	10	15	32	25	10	2	0	1	0	80

Site No.	Reach No.	Sco %	Dep %	Pack	Sfc (cm) d50	d90	SubSfc d50	100yr Sfc d90	Sfc/Sub d50 ratio	Step Fr	Step Composition Wood %	Mix %	Stone %	Step Stab.	W1m (m) rep	min	ax	Ratio w_{1m}/w_b	Cou C(%)	Coup PC(%)	Wood Stand	Ang 1	Ang 2	Cling Veget	Brght (%)
F1	2	80		l-m	11	29		~55		h			high	s	18	12	35	2.3	80		high	sr	r	s	60
F2	3	85		l	15	34		~60		h			100	s	14	9	28	2.4	90		high	r	a	s-n	60
F3	4	70	3	l	12	33		~60		m	17%		83	s	15	8	35	2.3	90		high	sr	r	s	50
F4	5	60	20	l	9	28		55		m	76%		24	m	15	12	30	2.7		70	high	sr	sa	s-n	70
F5	5		80	m	8	24	6	40	1.3	l	low		high	u	25	15	50	4.2		20	high	sa	sr	s	50
F6	6	80	60	l	9	26		45		h	low	low	high	m	18	9	30	4.5	90		high	sa	sr	s-c	40
F7	6	0	60	l-m	10	24		45		h	low		high	m	18	10	50	2.6		60	high	sr	sa	s	55
F8	7	50	10	l-m	10	25	7		1.4	h	low		high	s	12	7	20	2.0	100	0	high	a	sa	s	70
F9	8	15	65	l-m	8	18		30		l	75		25	s	7	5	12	1.8				a	sa	s	30

Figures

Figure 2: Longitudinal Profile of Bjerkness Creek



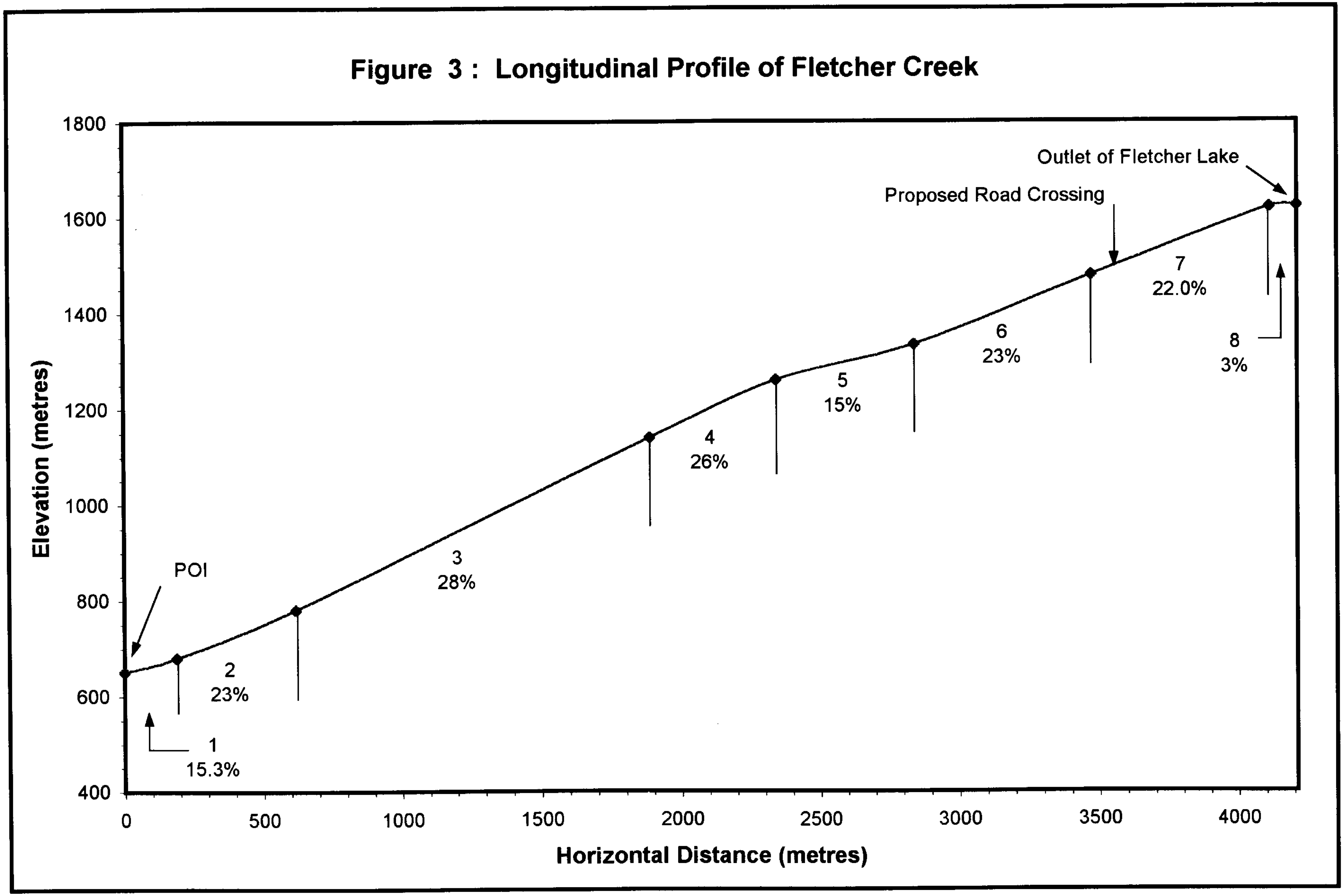


Figure 3 : Longitudinal Profile of Fletcher Creek
Elevation (metres)
1800
1600
1400
1200
1000
800
600
400
Horizontal Distance (metres)
0
500
1000
1500
2000
2500
3000
3500
4000
Outlet of Fletcher Lake
Proposed Road Crossing
POI
1
15.3%
2
23%
3
28%
4
26%
5
15%
6
23%
7
22.0%
8
3%

a) Step-pool morphology (SP_r, SP_b and SP_b-w; after Church 1992)

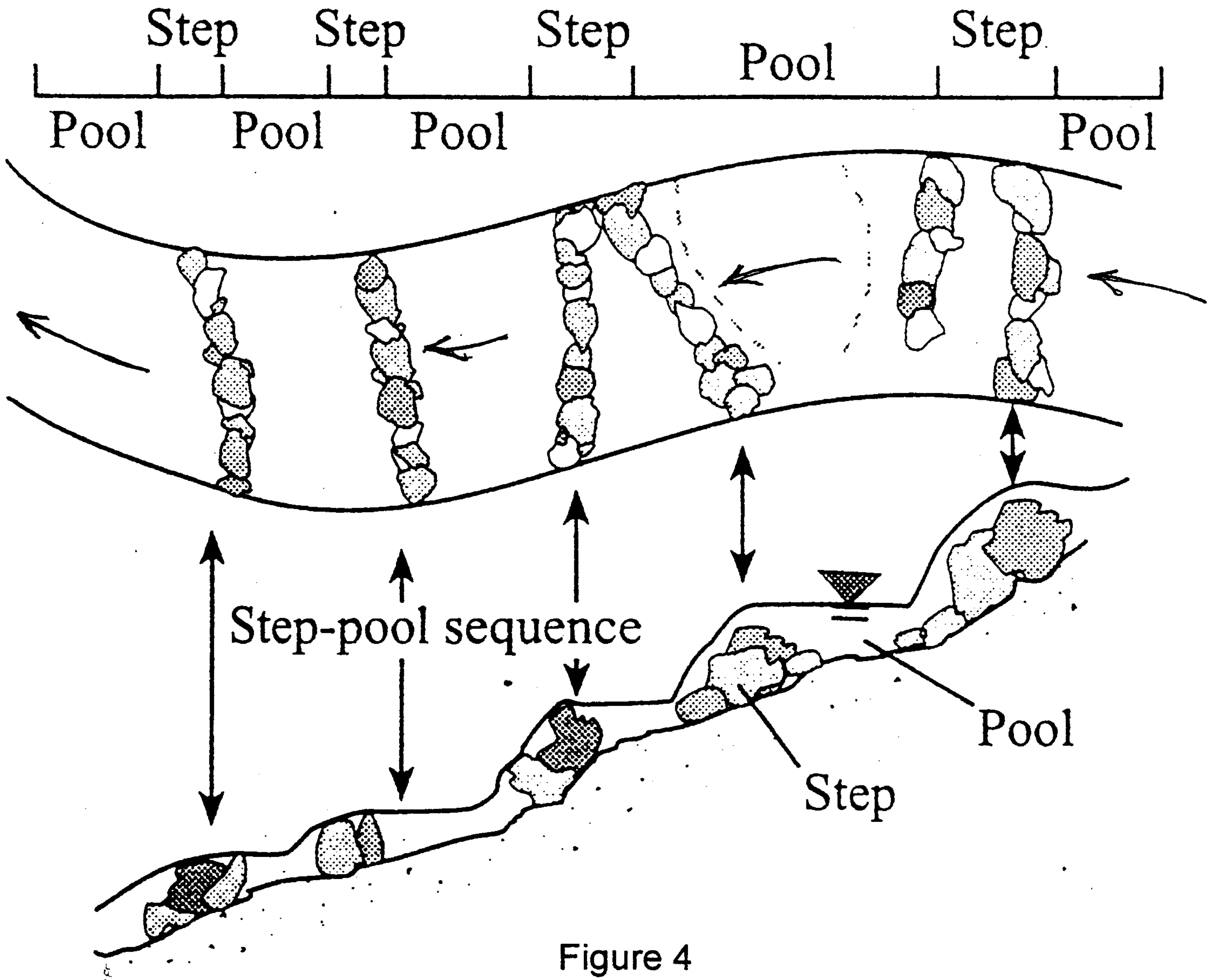


Figure 4

Figure 5 – Bjerkness Ck. Reach 1 – just above the POI. Extensive bar area

Figure 6 Bjerkness Creek, Reach 3 – 1+810m. Large lag boulder dominated channel. Note small slide on north bank

Figure 7 – Bjerkness Ck. Reach 5 – 3+390. Aggraded section with large sediment wedge

Figure 8 Bjerkness Creek, Reach 6 – 4+590m. Recovering bars.

Figure 9
Bjerkness Ck. - 5+207
Old woody debris jam. Note extensive bars and landslide scar in background (slide is not numbered – little sediment delivery to creek)

Figure 10 Bjerkness Creek
Reach 7 – 5+150 to 5+400
Extensive bars and large amounts of woody debris. Unnumbered landslide in background, landslide No. 35 in foreground

Figure 11 Fletcher Ck. Reach 3 – 1+975. Large lag boulder dominated channel

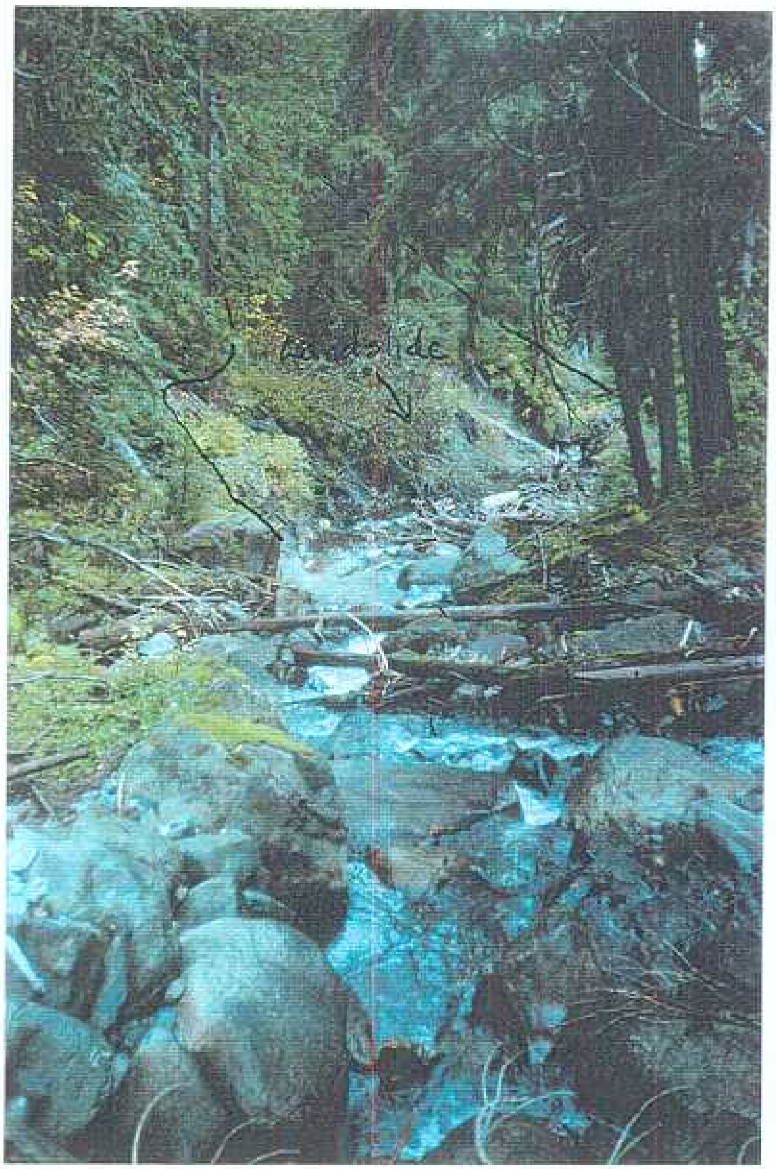


Figure 12 Fletcher Creek Reach 5 - 2+824 Lag boulder dominated channel in foreground. Slide No. 5 in background – note erosion at toe of slide

Figure 13 Fletcher Ck. Reach 5 – 2+943. Aggraded channel. Note revegetation on mid channel bar

Figure 14 Fletcher Creek, Reach 6 – 3+443. Aggraded section – material is from landslide No 17.