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Ted Fuller

DRAFT REPORT:
PRIOR TO TECHNICAL MEETING #2

SPAHATS CREEK
Watershed Assessment

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EXECUTIVE SUMMARY
for Spahats Creek Watershed Assessment

Integrated Woods Services Ltd. was contracted by Slocan Group, Vavenby Division (Slocan), to complete a comprehensive watershed assessment for the Spahats Creek watershed. Slocan provided the funding for this project.

The objectives of the detailed watershed assessment were to:

1. expand on the previous Level 1 Interior Watershed Assessment Procedure report,
2. field assess the current stream channel conditions within the watershed,
3. assess the sensitivity of the stream channels to impacts from forestry activities,
4. identify opportunities for upslope and in-stream watershed restoration activities, and
5. provide recommendations regarding future forestry development within the watershed.

In summary, the proposed Forest Development Plan in the Spahats Creek watershed has a **low** risk of impacting the aquatic resources within the watershed, in relation to changes in peak flow magnitudes, sediment supply and LWD supply. This does not reflect potential impacts to channel morphology and aquatic resources that can result from harvesting within riparian areas or from increases in sediment supply.

The conclusions of this watershed assessment are as follows:

1. The current level of forest harvesting in the watershed is very low (6.5% ECA) with a projected ECA increase to 8.5% by 2004.
2. The proposed forest harvesting plan is acceptable with a **low** risk to aquatic resources, in the Spahats Creek watershed.
3. Road deactivation or upgrade activities need to be completed on the six moderate and high risk sites identified in the Sediment Source Survey.
4. Road deactivation needs to be completed as soon as possible after the proposed blocks are harvested.
5. Maintenance of natural drainage patterns needs to be given extra attention, particularly where development occurs in gentler areas situated above steep terrain. good point
6. Future harvesting must be conducted with recognition that many stream channels and hillslopes in the watershed are inherently sensitive to disturbance and that most gentle terrain is situated upslope of steep unstable terrain.
7. The Ministry of Transportation and Highways may want to consider removing part of a large woody debris jam in lower reach 6 to re-align the channel into its original channel, to potentially improve channel stability upstream of the Clearwater Valley Road.
8. The regulatory agencies need to develop clearly defined management objectives and levels of acceptable risk for the watershed.
9. A re-assessment should be completed prior to the ECA exceeding a 'Red Flag' ECA of 20%.
10. Refer to the recommendations of the Watershed Advisory Committee.

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1.0 INTRODUCTION

Integrated Woods Services Ltd. was contracted by Slocan Group, Vavenby Division to complete a comprehensive watershed assessment for the Spahats Creek watershed. This watershed was selected for further study based largely upon a past peak flow event (1999) that resulted in a failure of the Clearwater Valley Road between Clearwater, BC and Wells Gray Provincial Park. Slocan Group provided funding for the project.

The objectives of the detailed watershed assessments were to:

1) expand on the Level 1 Interior Watershed Assessment Procedure (IWAP) reports,
2) field assess the current stream channel conditions,
3) assess the sensitivity of the stream channels to impacts from forestry activities,
4) identify opportunities for upslope and in-stream watershed restoration activities, and
5) provide recommendations regarding future forestry development within the watershed.

2.0 METHODOLOGY

The watershed assessment was completed utilizing methodologies that satisfy the requirements of the newest (April 1999) Watershed Assessment Procedure (WAP), developed under the Forest Practices Code of BC Act. This newest WAP is intended to "consider the cumulative effects of forest practices on the aquatic environment" and includes a field verification component. The procedure combines analysis of stream channel and upslope watershed conditions, an assessment of stream channel sensitivities and provides recommendations regarding proposed Forest Development Plans (FDP).

Background information used in these watershed assessments included the results of the completed Level 1 IWAP (MoELP, 1997) and the 'Spahats Creek and Candle Creek Clearwater Valley Road Crossing Hydrology Study' (May, 1999). Soil maps, terrain resource inventory mapping data, forest cover maps and aerial photographs were also used as information sources for this report (see Appendix B). Additionally, water license and fisheries data was obtained from the Ministry of Environment, Lands and Parks to provide a comprehensive source of information for the project.

Field assessments were conducted exclusively on the ground as the stream channels are readily accessible throughout the watershed. The stream reaches to be assessed were determined by channel characteristics, riparian condition, proximity to known or suspected sediment sources and accessibility. Both the Channel Assessment Procedure (Government of BC, 1996) and the Rosgen (1996) stream classification system (see Appendix C), were utilized to classify stream channel morphology and to evaluate channel sensitivity, while the Channel Assessment Procedure (CAP) was used to classify the stream channel disturbance levels. A "risk assessment approach" (see Appendix D) was developed and utilized to provide an assessment of the level of risk that forestry activities have had/will have on the aquatic resources within the watershed. The longitudinal profile and watershed report card are presented in Appendices E and F, respectively.

3.0 WATERSHED LOCATION AND GENERAL INFORMATION

The Spahats Creek watershed is located east of the Clearwater River, approximately 10 km north of the town of Clearwater, BC. The total area of the watershed is 6394 hectares. Elevations in the watershed range from 450 metres (m), at the confluence of Spahats Creek and the Clearwater River, to 2449 m and 2532 m at the summits of Raft and Trophy Mountains, respectively. Spahats Creek is comprised of eight reaches, the lower six of which were assessed. Reaches 7 and 8 occur in the upper watershed in sub-alpine and alpine areas and these reaches were not assessed.

Issues of importance in the watershed include concerns about public safety and protection of infrastructure (i.e. roads and bridges). A failure of the Clearwater Valley Road crossing at Spahats Creek occurred in July of 1999 during a summer storm event. Stream channel stability and fisheries values throughout the drainage are also issues of importance. Spahats Creek Provincial Park is located adjacent to the Clearwater Valley Road and visitors utilize hiking trails, scenic viewpoints, campsites and day-use areas. Wells Gray Park (Protection Resource Management Zone 18) encompasses a significant portion of the watershed on the north side of the valley (Kamloops LRMP, 1995). Visually sensitive areas are located in the Clearwater River Corridor (Protection Resource Management Zone 5). Important wildlife habitat within the watershed includes critical moose (*Alces alces*) winter range adjacent to the Clearwater River and a small amount of caribou (Rangifer tarandus caribou) habitat at higher elevations. The Spahats watershed is situated within the Clearwater Landscape Unit, which has a low biodiversity emphasis. No forest health concerns have been identified in this watershed recently.

4.0 WATERSHED CHARACTERISTICS

Holland 1976

4.1 Physiography, Hydrology and Climate

The watershed is located within the Shuswap Highlands physiographic region (Gough, 1988) and the Columbia Mountains hydrologic zone (Coulson and Obedkoff, 1998). The watershed lies within a transitional area between the drier Southern Interior zone and the wetter Columbia Mountains hydrologic zone. The annual peak flow regimes of watersheds in this hydrologic zone are dominated by nival flows (i.e. spring snowmelt), though autumn rainfall events can also contribute significant amounts of water to these catchments. The H_{60} line[1] for the watershed was determined from a digital terrain model and is calculated to be 1655 m.

Water Survey of Canada (WSC) stream gauge data are available for only a short time period (1981-1986) for Spahats Creek[2]. The maximum recorded daily discharge for the period of record was 21 m^3/s on May 28, 1986[3]. This time period is not of sufficient length to provide enough data for reliable flood frequency analysis. WSC stations with long-term data are located on the Barriere River[4] and Harper Creek[5], both of which are located within zone 13. Review of data (up to 1995) for these streams indicates that flood events greater than the 100-year event occurred in the Barriere River in 1972. A similar magnitude peak flow event occurred in Harper Creek in 1974. In the Barriere River (downstream of Sprague Creek), the 1974 peak flow was approximately a 20-year event. At the mouth of the Barriere River the 1974 peak flow was a 50-year event[6]. Both of these streams drain considerably larger areas than Spahats Creek however. Significant flood events also occurred in most streams throughout the region in 1997 and 1999.

Widespread intense rainfall events occurred in the immediate area in July of both 1997 and 1999. The 1999 rainfall event (July 7 and 8) resulted in a peak flow event that is calculated to have exceeded the 100 year peak flow magnitude (May, 1999). This flood event resulted in the failure of the Clearwater Valley Road after the twin pipe-arch culverts became plugged, stream flow overtopped the road surface and the downstream road embankment failed.

[1] the elevation isoline above which 60% of the watershed is situated
[2] WSC gauge station 08LA021
[3] from 'Spahats Creek and Candle Creek Clearwater Valley Road Crossing Hydrology Study' (May, 1996)
[4] WSC gauge station 8LB069 (below Sprague Creek) and 8LB020 (at the mouth)
[5] WSC gauge station 8LB076 (near the mouth)
[6] flood frequencies determined from the BC Streamflow Inventory datasheets (March 1998)

As outlined in Table 1, the mean total annual precipitation in the area varies from 421 mm at Blackpool (just south of Clearwater, BC) to 709 mm at lower elevations in the Spahats watershed. Annual precipitation in the upper Spahats watershed likely approximates that recorded at the Blue River atmospheric stations. The average water equivalent of the snowpack on Trophy Mountain on May 1 is approximately 600 mm. On May 1, 1999 the water equivalent of the snowpack was 960 mm (May, 1999).

Table 1: Climate Stations, Station Elevations and Mean Total Annual Precipitation**

Location and Station #	Elevation of Station	Mean Total Annual Precipitation (mm)
Clearwater - Candle Creek: 116A655*	701	545
Clearwater - Spahats Creek: 116JF55*	869	709
Clearwater: 1161655	466	570
Clearwater - Moul Creek: 1165210	713	625
Clearwater - Hemp Creek: 1163450	640	583
Clearwater - Blackpool: 1161FN5*	421	512
Clearwater - Axel Creek: 11661F55	716	629
Blue River A: 1160899	683	988
Blue River North: 1160900	689	1139
Vavenby: 1168520	445	673

* short-term record
** excerpt from May, 1999

Recent research suggests that climatic and hydrologic patterns across Canada have been significantly changing over the last 25 years (Whitfield and Cannon, 2000). Trends in climatic and hydrologic variation across Canada were evaluated by a number of authors for the decades 1976-1985 and

1986-1995. The following trends were observed in the southern interior of British Columbia: 1) higher temperatures in all months except February, 2) increases in spring precipitation and decreases in summer precipitation, 3) higher spring stream flows and lower summer and fall flows, 4) an earlier onset of spring run-off (Whitfield and Cannon, 2000).

4.2 Aspect, Slopes and Surficial Materials

The watershed is aligned in an east-west fashion and aspect within the drainage generally has a strong north or south component. Slopes vary from moderately rolling to very steeply sloping throughout the Spahats watershed. Slopes in the valley bottom, in the mid to upper watershed, vary from gently rolling to hilly (Kowall, 1980). Areas with unstable terrain comprise 26% of the watershed area, based on slopes over 60% and/or labels of Es or E2s in the forest cover database. Slope categories (by percent slope) were determined from a digital terrain model and are presented in Table 2.

Table 2: Slope Categories for the Spahats Creek Watershed

Slope Category (%)	Area (ha)	Percent of Watershed Area(%)
0-10	435	7
11-25	1808	28
26-60	2791	44
60+	1360	21
Total	6394	100

Numerous types of surficial materials occur within the Spahats watershed. Fluvial materials (a relic fan) occur adjacent to reach 3 of the stream. Downstream of this reach, Spahats Creek is entrenched in a rock canyon (i.e. reach 2) and the stream then flows over a rock waterfall (i.e. at the reach 1-2 break). Non-cohesive fluvioglacial materials occur adjacent to the stream channel of Spahats Creek throughout the watershed from reach 4 to reach 7. Colluvial deposits occur on and/or adjacent to the steep valley walls throughout the watershed. Morainal deposits occur in areas of varying terrain types, including some steep valley slopes. The soils derived from morainal materials predominantly occur in upland areas in the western part of the watershed. Terrain dominated by rock, with shallow soils derived form colluvial deposits, are predominant in the northeast and southeast of the watershed particularly in alpine areas (Kowall, 1980). Approximately 25% of the watershed is located at or above tree-line, in areas with relatively impermeable colluvium and bedrock (May, 1999).

4.3 Other Watershed Attributes

Wildfire, pests, pathogens and windthrow are natural disturbance regimens associated with the upland ecosystems found within the watershed. Any of these disturbances can potentially affect stream channels via changes in rates of watershed run-off, large woody debris recruitment to the channel or sediment production/transport. Four different biogeoclimatic subzones or variants are present in the watershed. An Interior Cedar-Hemlock variant (ICHmw3) occurs at lower elevations, a cooler Interior Cedar-Hemlock variant (ICHmk2) occurs at mid-elevations and an Engelmann Spruce-Subalpine Fir variant (ESSFwc2) occurs at higher elevations. The alpine-tundra parkland subzone (ATp) occurs at the highest elevations. High intensity, stand-initiating fires generally resulted in the cycling of forest stands in the ICH subzones present in the watershed. These ecosystems generally consisted of a landscape mosaic of even-aged regenerating stands ranging in size from a few hectares to thousands of hectares. The ESSFwc2 ecosystem generally consists of uneven-aged or multi-storied even-aged stands that historically experienced small disturbances, resulting in the death of individual trees or small patches of trees.

Changes in watershed hydrology and sediment production have been documented in watersheds, following the occurrence of wildfires (Cheng, 1980; Cheng and Bondar, 1984). A number of burns have been documented in the Spahats Creek drainage over the last 60 years. The total area mapped as burned within the watershed is approximately 319 ha (5% of the watershed area). Most of the mapped burns have no known date or occurred prior to 1950. Eleven polygons are identified as burned in the forest cover database and ten of these are located on the south side of the watershed. The burns are located adjacent to numerous ephemeral tributary streams and range from lower elevations to sub-alpine areas.

5.0 SEDIMENT SOURCE SURVEY

A Sediment Source Survey (SSS) for Road 10 and Trophy Mountain was completed in August 1997, under the direction of the Ministry of Environment, Lands and Parks. Relevant information contained in that document was utilized in this report, in addition to a SSS completed for this watershed.

In summary, two high risk road segments (600 m), one moderate risk road segment (500 m), three moderate risk road crossings, seven debris torrents/mass wasting events and four large sediment sources were identified in the Spahats Creek watershed. Remedial works for the sediment sources are discussed in Section 8.2.

Two high risk sites were identified, totaling approximately 600 m of road. High risk site #1 (~400 m long) occurs along Road 10 and includes a debris torrent which initiated in the fill slope adjacent to the road (MoELP, 1997). High risk site #2 consists of approximately 200 m of road (Road 80.01[7]) that has been extensively eroded by an ephemeral stream. This site is currently impassable with any type of motorized vehicle.

A total of 500 m of moderate risk road and three moderate risk stream crossings were identified in the Spahats watershed. Moderate risk site #1 is comprised of 500 metres of spur road "A" (see photo) where an unmapped stream flowed down the road causing extensive erosion (MoELP, 1997). Moderate risk site #2 requires debris to be removed from the tributary stream crossing and a cross ditch to be installed. Moderate risk site #3 occurs where a road crosses an alluvial fan below a debris torrent (see photo). Water was noted running down the road during the overview flight. Moderate risk site #4 occurs on a tributary to Spahats Creek and consists of erosion of the road surface adjacent to the crossing (see photo).

Seven relatively recent debris torrents/mass wasting events were identified in the watershed (see Appendix G). Three of these mass wasting events are included either as large sediment sources (1) or road related problems (2). Three of the mass wasting events occur where no stream channels are mapped.

[7] this road is numbered for the purpose of this report only

A total of four large, sediment sources with the potential to directly affect stream channel morphology in Spahats Creek were identified in the SSS. Areas identified as rock in the forest cover database and talus slopes not coupled to stream channels were not included in the sediment source survey. All four large sediment sources identified in the SSS are directly coupled to reach 4a. One sediment source (SS #1) is of natural origin, one is road related (SS #2) and two of these sediment sources may be forestry related. SS #3 occurs approximately 25 m downslope of an existing forest road and SS#4 occurs downslope of a cutblock in a gentle over steep terrain scenario (see photos).

6.0 WATERSHED RISK ASSESSMENT WORKSHEETS

Table 3: Equivalent Clearcut Areas and Peak Flow Indices[8]

Watershed	ECA (%)		Peak Flow Index (PFI)	
	Fall 2000	**Fall 2004**	**Fall 2000**	**Fall 2004**
Spahats Creek	6.5	8.5	0.07	

Note: Net Area for Reforestation of proposed harvesting is 84.0 hectares

Table 4: Proposed Forestry Development

Watershed	CP-Block	Silviculture System	Net Area (ha)	Gross Area (ha)
Spahats	430-1	3 pass CCR*	135.0	377.0
Spahats	429-1	CCR	19.0	19.0
Total			**154.0**	**396**

* CCR = clearcut with reserves

[8] ECA and PFI calculations are based on gross areas for proposed development

Table 5: Characteristics of the Assessed Stream Reach Segments

Stream & Reach	Dominant morphology and disturbance levels*	Rosgen Stream Types	Stream reach sensitivity to:			Hillslope connectivity
			Increased peak flows (1 to 5)	Increased sediment supply (1 to 5)	Decreased LWD supply (1 to 5)	
Spahats-1	SP: 2-3	A-Aa+	2	2	2	Low-Mod.
Spahats-2	Rock canyon	A	1	1	1	Low
Spahats-3	CP-SP: 2-3	B-Ba	4	4	4	Mod.
Spahats-4a	CP-SP: 1-2	B-Aa+	4	3	3	Mod.-High
Spahats-4b	CP-SP: 1	Ba-A	3	3	3	Moderate
Spahats-5	CP-SP: 1	B-Aa+	3	3	3	Mod.-High
Spahats-6	CP: 1-2	B-Ba	3 (4)[9]	4	4	Moderate

* Disturbance Levels:
- 0 = stable
- 1 = partial disturbance
- 2 = moderate disturbance
- 3 = severe disturbance

Sensitivity

i.e. 1 = 'Very Low' sensitivity
5 = 'Very High' sensitivity

[9] high sensitivity (i.e. 4) is associated with the avulsions in the lower stream reach

Table 6: Effects of Forestry Activities in the Watershed and Risk to Aquatic Resources

Stream & Reach	Probability that forestry activities will cause changes to[1]:			LEVEL OF RISK to the aquatic environment caused by changes to[2]:			Dominant land use activity[3]
	Peak flows (1 to 5)	Sediment supply (1 to 5)	LWD supply (1 to 5)	Peak flows	Sediment supply	LWD supply	
Spahats-1	1	1	1	A	A	A	park
Spahats-2	1	1	1	A	A	A	park
Spahats-3	1	1	1	B	B	A	park
Spahats-4a	1	4	1	B	C	A	FH
Spahats-4b	1	2	2	B	B	B	FH
Spahats-5	2	2	1	B	B	A	FH
Spahats-6	2	3	3	B(C)[10]	C	D	FH/LG

[1] Probability of change = The probability that past or proposed forestry activities will change any of the three channel morphology controlling processes.

i.e. 1 = 'Very Low' probability of change outside of natural limits
5 = 'Very High' probability of change outside of natural limits

[2] Level of risk: A = Very Low; B =Low, C = Moderate, D = High, E = Very High

[3] Land-use: A/R = agriculture/ranching
LG = light grazing
HL = historical logging
FH = forest harvesting

[10] a moderate level of risk is associated with the avulsions in the lower stream reach

7.0 INTERPRETATIONS AND RECOMMENDATIONS

7.1 Watershed Management Objectives and Defined Level of Acceptable Risk

The watershed management objectives have not been specifically defined by regulatory agencies for the Spahats Creek watershed. Public safety and protection of infra-structure are assumed to be the primary management objectives. Achievement of these objectives will require prevention of accelerated stream bank and bed erosion, particularly along the mid- reaches of the mainstem channel. It is also assumed that management objectives include maintaining and/or enhancing the fish habitat that exists within the watershed. The acceptable level of risk for this watershed has not been specified by regulatory agencies.

7.2 Existing Channel Conditions

Spahats Creek experienced significant flood events in both 1997 and 1999. The July 1999 event was estimated to be greater than a 100-year flood event (May, 1999) and resulted in the wash-out of the Clearwater Valley Road crossing over reach 3 of the stream. The channel disturbance levels observed in the mainstem of Spahats Creek during the field assessment reflect these recent events which have impacted the stream channel throughout the watershed. The channel disturbance associated with these recent extreme events has rendered most stream reaches more sensitive to future disturbance than they would be otherwise.

Reach 1 of Spahats Creek is dominated by step-pool (boulder) morphology and is moderately to severely disturbed (see photos). The channel is severely downcut throughout much of the reach and is generally highly entrenched. Indicators of channel degradation include extensive scouring and abandoned channels. Indicators of channel aggradation include large sediment bars and wedges, bank erosion, channel widening and channel braiding. Large woody debris jams were also noted in a number of locations. Accelerated erosion of non-cohesive stream bank materials will likely continue to occur at higher flows.

Reach 2 has cascade and step-pool morphology (with chutes and falls) as the stream flows through a highly entrenched rock canyon. The stream channel in this reach was not waded, as there is no way to safely access the channel. Stream bank materials appeared to be bedrock and boulders and little channel disturbance was apparent from the edge of the canyon.

Reach 3 of Spahats Creek is situated on fluvial fan deposits and what appeared to be relic channels were observed in the field. A side channel begins adjacent to a large woody debris (LWD) jam, approximately 280 m upstream of the temporary bridge crossing at the Clearwater Valley Road. The side channel terminates at a corrugated metal culvert about 15 m south of the temporary bridge. Reactivation of this side channel and one located further upstream are cited as concerns in the hydrology study previously completed for the Spahats Creek drainage (May, 1999). The assessed segment of the stream reach was evaluated as moderately to severely disturbed. Channel disturbance indicators noted in this stream reach included extensive channel scouring (down to bedrock in some locations), extensive bank erosion, channel widening, large elevated bars, debris jams, sediment wedges and disturbed stone lines (see photos). The severest disturbance occurred directly upstream and downstream of the Clearwater Valley Road.

Reach 4 was further sub-divided into reaches 4a and 4b after initial field assessments were conducted. A bedrock controlled channel constriction is located just downstream of a deactivated stream crossing on Road 80.01 (the bridge was removed in 1998), in the middle of reach 4. This location was chosen to subdivide reach 4, based on differences in channel entrenchment, valley coupling and channel disturbance levels. Four of the large sediment sources identified in the sediment source survey are directly coupled to reach 4a. SS #3 is not evident on the 1997 aerial photographs and may have occurred during the July 1999 flood event. This mass wasting event appeared to have blocked the stream channel and likely resulted in a temporary damming of the stream (see photo). Disturbance levels in reach 4a were generally moderate with lesser areas that were highly disturbed. The highly disturbed areas were associated with SS #3 and #4. Only low levels of disturbance were noted in reach 4b, though only a limited amount of channel length was assessed on the ground (see photo). Observations of channel conditions were made throughout the watershed during the overview flight however. The tributary stream from Gwem Gwem Lake joins Spahats Creek at the upstream end of reach 4b. The channel of this tributary was assessed within the Silvertip Falls recreation site and it was assessed as both laterally and vertically stable at present (see photo).

Reach 5 of Spahats Creek was assessed near the upstream terminus of the reach. Forestry development upslope of reach 5 is limited to two small openings that were juvenile spaced in 1979. Road 80 is the only road or skid trail that traverses the valley, upslope of this stream reach. Only low levels of disturbance were observed in this stream reach (see photo). An increased level of disturbance was noted for approximately 50 m downstream of the confluence of Spahats Creek and the unnamed tributary which flows in at the reach 5- 6 break. This tributary, which has very little forestry development within its catchment area, had partial to moderate disturbance levels. Disturbance levels upstream of Road 80 appeared to be related to LWD loading from the mature (to decadent) riparian forest. A multi-channel pattern developed downstream of the culvert but returned to a single channel pattern upstream of the confluence with Spahats Creek.

Disturbance levels in reach 6 of Spahats Creek varied with location in the watershed. Moderate to severe levels of disturbance were observed in the lower steam reach. A large woody debris jam was located approximately 130 m upstream of the reach 5-6 break (see photo). Numerous logs with cut ends were observed in the jam, in addition to an extensive amount of tree tops and small woody debris. The greatest portion of the stream flow now is transported through a recently established channel to the north of the original channel. This channel flows through opening 21, polygon 218 at it's upstream end and through mature forest further downstream. The original channel is largely blocked off by debris and sediment but still transports some water (see photo). Overland flow occurs to a significant extent to the south of the original channel through the riparian forest. Channel sensitivity at this site has been increased by the disturbance associated with the LWD jam. Additionally, harvesting of trees to the stream edge occurred in 1977 in a number of locations adjacent to reach 6. Destabilization of stream banks may occur as tree roots decay over time. Reduced levels of disturbance were observed upstream of the zone of influence (approximately 4-5 bankfull widths) of the debris jam. Only low levels of disturbance were observed near the Road 80 crossing further upstream in reach 6. The stream currently takes on a multi-channel form for a short distance in this reach (~ 50 m downstream of Road 80). There is potential for an avulsion or new side channel to form at this location, upstream of a relatively small debris jam.

7.3 Recommendations for the Forest Development Plan

7.3.1 Peak flow risks

There are a number of concerns related to potential peak flow increases in the Spahats Creek watershed. These concerns include the existing levels of stream channel disturbance observed throughout much of the watershed and the current sensitivity of many stream reaches to peak flow increases.

The channel types occurring in the watershed are largely of the 'Ba, A and Aa+' types, within the Rosgen (1996) stream classification system. The 'B' type channels are described as moderately entrenched systems with moderate sinuosity, moderate width/depth ratios and channel gradients of 2-4%. Channel morphology is dominated by rapids and irregularly spaced pools (i.e. cascade-pool morphology). The 'B' type channels are usually quite stable both vertically and laterally. The 'Ba' type channels typically exhibit the characteristics of the 'B' type channel but have channel gradients of 4-10%. The 'A' type channels are highly entrenched, low sinuosity systems with low width/depth ratios, step-pool morphology and gradients of 4-10%. The 'A' type channels are generally stable if channel materials are dominated by boulders or bedrock. These systems are high energy and exhibit a high sediment transport potential. In-channel sediment storage is often relatively low in these systems. The 'Aa+' (>10% gradient) channel types are described as high energy, step-pool morphologies with chutes and waterfalls. These systems may be influenced by large woody debris (LWD) which can play a significant role in the storage of sediment. These channel types have a naturally high sediment supply and can be highly sensitive to changes in stream flow magnitudes and/or sediment supply increases (Rosgen, 1996).

The existing ECA (and its corresponding peak flow index) is not a significant concern in regards to potential peak flow increases throughout most of the watershed. The existing levels of forest harvesting have a very low to low probability of increasing peak flow magnitudes in the Spahats Creek watershed. The ECA associated with the existing and proposed development has only a very low probability of increasing peak flows in reaches 1 to 4b and a low probability in reach 5 and 6 of the stream. When combined with channel sensitivity ratings, the peak flow risk in these reaches (i.e. reaches 1-6) is considered to be **low** or **very low**. A **low** level of risk associated with peak flow increases exists for most of reach 6, however this risk increases to **moderate** at the channel avulsion in lower reach 6.

Road densities above and below the H_{60} line are not presently a concern in the Spahats Creek watershed. Potential changes/alterations in natural drainage patterns and run-off rates are a concern when high road densities exist within a watershed, in addition to increased sediment production and delivery. Maintenance of natural drainage patterns should be given extra attention where development occurs in gentler areas situated above steep terrain.

The proposed harvesting in cutting permit 430, block 1 is proposed as removing about 35% of the gross area utilizing primarily an aerial harvest method except for an approximate 30 ha patch that will be harvested using a cable harvest method. These harvest methods can minimize channel disturbance if cross stream falling and yarding is minimized. From the perspective of managing for peak flow increases and accelerated stream bed and bank erosion, the proposed forestry development has a **low** risk level in most reaches of the Spahats Creek watershed. The avulsion in reach 6 increases the risk level in that reach to **moderate**.

7.3.2 Sediment supply risks

Reaches 1 and 2 are relatively insensitive to increases in sediment supply due to their physical characteristics such as channel gradients, stream power and channel materials. The remaining reaches were evaluated as being moderately to highly sensitive to sediment supply increases. Reach 3 occurs on fluvial fan deposits and lateral channel stability is a significant concern, particularly with regards to protection of infra-structure at the Clearwater Valley Road crossing. Part of the rationale for the high sensitivity rating for reach 3 is the disturbed nature of the stream channel in this reach. Reaches 4a, 4b, 5 and 6 were all rated as moderately sensitive to an increased sediment supply. The sensitivity of lower reach 6 was rated as high due to the presence of the channel avulsions.

The probability that past or proposed forestry activities have increased the coarse-textured sediment supply in the Spahats watershed varies between stream reaches. Reaches 1 to 3 were rated as having a very low probability of forestry related increases in sediment supply, while reaches 4b and 5 were rated as having a low probability. Reach 4a has a number of large sediment sources that are directly coupled to the stream. Sediment source #2 is definitely related to the construction of an old forestry road. Sediment sources (SS) #3 and #4 may be related to existing forestry development. The head scarp of SS #3 occurs approximately 20 m below an existing road and SS #4 initiates downslope of an existing cutblock. Reach 4a was therefore rated as having a high probability of forestry related sediment supply increases. Reach 6 was rated as having a moderate probability due to the channel avulsions which occurred in lower reach 6 and a number of debris torrents which have occurred on the north side of the valley on tributary streams located within silviculture openings 21 and 24. Review of the aerial photographs indicates that the disturbance in these tributary channels appears to be greatest within the existing cutblocks.

Road densities (km of road /km^2 of area) in the Spahats watershed will not exceed 0.6 km/km^2, which is considered low[11], following implementation of the proposed forest harvesting plan. As summarized in the sediment source survey, 0.5 km and 0.6 km of existing road were assessed as moderate and high risk, respectively. It is recommended that road maintenance and/or road deactivation activities be undertaken to reduce sediment delivery to stream channels from the existing road network in the watershed.

The number of existing stream crossings (45) in the watershed is relatively high. Any unnecessary crossings should be deactivated to reduce potential sediment delivery to stream channels. Only 0.7 km of new road construction is proposed in the Forest Development Plan. New road construction has the potential to increase the supply of fine and coarse-textured sediment to the watercourses in the watershed. Revegetation applications to exposed soils within 12 months of disturbance needs to occur to ensure that erosion and subsequent sediment transport is minimized during the first few years of active service, when sediment yields are typically high.

Levels of risks associated with an increased sediment supply related to forestry development are **very low** in reaches 1 and 2, **low** in reaches 3, 4b and 5 and **moderate** in reaches 4a and 6. The number of debris torrents and mass wasting in the watershed indicates that valley side slopes are often unstable. Development adjacent to tributary streams and/or existing debris torrents (i.e. CP 430) should be undertaken with regard for these inherently unstable areas.

In summary, the proposed forest harvesting does not pose more than a **low** risk to aquatic resources, relative to an increase in coarse-textured sediment supply, in all stream reaches except reach 6. The proposed forest harvesting poses a **moderate** risk to aquatic resources in reach 6.

[11] as outlined in the Interior watershed assessment conversion table (Government of BC, 1995)

7.3.3 LWD supply risks

Large woody debris (LWD) is important in many reaches of Spahats Creek for controlling sediment storage, energy dissipation and stable channel morphologies. The role of LWD is reduced in reaches 1 and 2 due to their channel characteristics. Channel stability and fisheries values in the middle and upper stream reaches are dependent on an adequate supply of LWD over the long-term. This is why reaches 3-6 are rated as moderately to highly sensitive to decreases in LWD supply.

Riparian forests are intact and highly functioning, with regard to stream channel processes, throughout the lower and mid-reaches of the watershed (i.e. reaches 1, 2, 3, 4a, 4b and 5). Harvesting has occurred in a limited number of areas (total length ~500 m) adjacent to Spahats Creek in reach 4b. In all places it appears that a riparian buffer strip was left adjacent to the stream.

Riparian areas in the upper watershed (i.e. reach 6) have been affected by past forest harvesting. Logging to one stream bank occurred at a number of locations over a total distance of approximately 800 m. Riparian function has been greatly reduced or eliminated at many of these sites. Destabilization of stream banks and reduced LWD recruitment to the stream channels are the primary concerns related to potential stream channel changes. Debris loading is also a concern as bank erosion and channel avulsions can result from altered flow patterns. The debris jam at the lower end of reach 6 contained numerous logs with cut ends and what appeared to be logging slash.

In the Spahats Creek watershed, the levels of risk to aquatic resources associated with LWD supply decreases are **very low** in five reaches and **low** in one reach. The risk to aquatic resources caused by decreases in LWD supply is rated as **high** in reach 6.

The location of the proposed forest harvesting in the Spahats Creek watershed will not result in reductions in LWD supply to the mainstem stream channel and is therefore acceptable.

7.3.4 Cumulative effects and summary of risks

Protection of aquatic resource values in the watershed is dependent on the minimization of accelerated stream channel disturbance and the maintenance of water quality. The protection of infra-structure and the maintenance of public safety is a primary concern. Fisheries values in the middle and upper stream reaches are also a concern.

The proposed forest harvesting will result in an ECA increase of 2.0% in the Spahats Creek drainage, raising the ECA to 8.5%. The net area of the proposed harvesting is 84.0 hectares. The extent and location of the proposed harvesting activities will not generate a level of risk to aquatic resources greater than **low** in reaches 1 to 5 in the peak flow risk assessment category. As the existing and proposed forest harvesting is concentrated in the upper watershed, the risk associated with peak flow increases is rated as **low** to **moderate** in reach 6.

The level of risk to aquatic resources associated with an increase in the supply of coarse-textured sediment is generally **low** in the watershed. Reach 4a has a **moderate** risk rating for sediment supply increase due to the presence of a number of slope failures directly coupled to the stream channel. Reach 6 was also rated as having a **moderate** risk of an increased sediment supply associated with forestry development. The proposed forest harvesting does not pose more than a **moderate** risk to aquatic resources, in regard to increased coarse-textured sediment supply.

The calculated risk to aquatic resources resulting from decreased LWD supply is **very low** or **low** in five of six assessed stream reaches. The risk to aquatic resources associated with a decreased a LWD supply is rated as **high** in reach 6. However, the location of the proposed forest harvesting in the watershed should not result in reductions in LWD supply to the mainstem stream channel and is therefore acceptable.

Overall, the cumulative effect of changes to peak flows, sediment supply and LWD supply that could result from implementing the proposed Forest Development Plan is judged to be a **low risk** in the Spahats Creek watershed.

8.0 WATERSHED RESTORATION OPPORTUNITIES

8.1 In-Stream Works

No moderate or high priority opportunities for in-stream works were identified within the Spahats Creek watershed. This is largely due to the steep stream channel gradients that are found throughout the watershed.

A low priority project exists in Reach 6 where a debris jam has directed the creek out of its former channel and to the north where it flows through mature forest. The new channel was a significant source of sediment. It would be possible to remove debris from the jam to re-establish the channel back into its former more stable channel, however this is considered a low priority as manipulation or removal of debris jams is not highly recommended.

8.2 Upslope Works

There are opportunities for cost effective, meaningful watershed restoration activities within the upland portions of the watershed. Four moderate and two high risk sites totaling 1.1 km of road length were identified in the watershed. Four of these sites involve stream crossings and no distances were totaled for these sites. As many stream reaches are highly sensitive to increases in coarse-textured sediment supply, minimization of accelerated sediment inputs to stream channels in the watershed would be beneficial with respect to channel stability and protecting aquatic resources.

9.0 CONCLUSIONS

The conclusions of this watershed assessment are as follows:

1. The current level of forest harvesting in the watershed is very low (6.5% ECA), with a projected ECA increase to 8.5% by 2004.
2. The proposed forest harvesting plan is acceptable with a **low** risk to aquatic resources, in the Spahats Creek watershed.
3. Road deactivation or upgrade activities need to be completed on the four moderate and two high risk sites identified in the Sediment Source Survey.
4. Road deactivation need to be completed as soon as possible after the proposed blocks are harvested.
5. Maintenance of natural drainage patterns needs to be given extra attention, particularly where development occurs in gentler areas situated above steep terrain.
6. Future harvesting must be conducted with recognition that many stream channels and hillslopes in the watershed are inherently sensitive to disturbance and that most gentle terrain is situated upslope of steep unstable terrain.
7. The Ministry of Transportation and Highways may want to consider removing part of a large woody debris jam in lower reach 6 to re-align the channel into its original location, to potentially improve channel stability upstream of the Clearwater Valley Road.
8. The regulatory agencies need to develop clearly defined management objectives and levels of acceptable risk for the watershed.
9. A re-assessment should be completed prior to the ECA exceeding a 'Red Flag" ECA of 20%.
10. Refer to the Watershed Advisory Committee recommendations at the front of this document.

PERSONAL COMMUNICATIONS

missing references

May, 1999

MoELP, 1997

Rosgen 1996

Govt of BC 1996 ✓

Kamloops LRMP 1995

Whitfield and Cannon 2000

REFERENCES

Beaudry, P.G. and B. Floyd. 1996. Effects of Riparian Management Strategies on Streamflow, Suspended Sediment, and Channel Morphology of Small Streams in Central British Columbia. Annual Progress Report FRBC Research Award OP96070-RE. Ministry of Forests, Prince George.

Beaudry, P.G. and A. Gottesfeld. *(submitted for publication).* Effects of Forest Harvesting on Stream Morphology in the Central Interior of British Columbia. Ministry of Forest, Research Branch Working Paper, Victoria, B.C.

Cheng, J.D. 1980. Hydrology effects of a severe forest fire. *In:* Proceedings Symposium on Watershed Management. Am. Soc. Civil Eng. New York. pp. 240-251.

Cheng, J.D. and B.G. Bondar. 1984. The impacts of a severe forest fire on streamflow regime and sediment production. *In*: Proceedings Canadian Hydrology Symposium No. 15. NCR Canada, Assoc. Comm. On Hydrology. Univ. of Laval, Quebec. June 10-12, 1984.

Coulson, C.H. and W. Obedkoff. 1996. British Columbia Streamflow Inventory report. British Columbia Ministry of Environment, Lands and Parks: Water Inventory Section. Victoria, British Columbia.

Gough, N.A. 1986. Soils of the Bonaparte River-Canim Lake Map Area. British Columbia Ministry of Environment and Parks, Technical Report 24. Ministry of Environment and Parks. Victoria, British Columbia.

Government of British Columbia. 1995. Channel Assessment Procedure Guidebook. British Columbia Ministry of Forests. Victoria, British Columbia.

Government of British Columbia. 1996. Interior Watershed Assessment Procedure Guidebook. British Columbia Ministry of Forests. Victoria, British Columbia.

Hogan D.L., Bird, S.A. and S. Rice. 1996. Stream channel morphology and recovery processes. *In:* Carnation Creek and Queen Charlotte Islands Fish/Forestry Workshop: Applying 20 years of Coastal Research to Management Solutions. Hogan et al. (Editors) 1996. B.C. Min. Forests, Research Branch, Victoria, British Columbia. Land Management. Handbook. No. 41.

Knighton, D. 1984. Fluvial Forms and Processes. Edward Arnold. London. 218 p.

Kowall, R.C. 1980. Soil and terrain report for the Seymour Arm Area. Bulletin No. 17. Resource Analysis Branch. British Columbia Ministry of Environment. Kelowna, British Columbia.

Rosgen, D. 1995. Applied River Morphology. Wildland Hydrology. Pagosa Springs, Colorado.

Sullivan, K., Lisle, T.E., Doloff, C.A., Grant, G.E. and L.M. Reid. 1986. Stream Channels: the link between forest and fishes. *In*: Streamside Management Forestry and Fisheries Interactions. E.O. Salo and T.W. Cundy. Eds. University of Washington, Institute of Forest Resources, Contribution No. 57, pp 39-96.

APPENDICES

APPENDIX A

Photographs

APPENDIX B

Philosophy of the Risk Matrix Approach

PHILOSOPHY AND APPLICATION OF THE RISK ASSESSMENT APPROACH

The risk assessment approach establishes a level of risk of detrimental impacts to the aquatic resources that may be caused by forestry activities. The risk assessment is based on the evaluation of two components and the use of a *Risk Matrix*. The first component of the risk assessment evaluates the sensitivity of a particular stream reach to a change in a specific hydrologic or geomorphic process. This assessment is qualitative and is ranked on a scale of 1 to 5 (i.e. Very Low to Very High). An example would be that: "a bedrock-controlled channel has a 'Very Low' sensitivity to changes in peak flows".

The second component assesses the probability that forestry activities within the watershed will significantly change some specific hydrologic or geomorphic process. The assessment is also qualitative and the probability of change is ranked on a scale of 1 to 5 (i.e. Very Low to Very High). An example of this type would be: "there is a 'Very High' probability that there will be a significant increase in snowmelt generated peak flows if 100% of the forest above the H_{60} line is harvested in an Interior watershed".

The risk assessment value is generated by combining the "sensitivity" rating with the "probability of change" rating on the Risk Matrix. The risks are also scaled from Very Low to Very High. Risk matrices have been developed for three categories of watershed processes: 1) changes in peak flows, 2) changes to the sediment supply and 3) changes to the supply of large woody debris (LWD). The "sensitivity" and the "probability of change" ratings are established by analyzing the assessment information collected from maps, aerial photographs, fieldwork and other relevant data.

This risk assessment procedure works very well to satisfy the requirements of the newest Watershed Assessment Procedure (released April 1999). On page 11 of this document it states that: "the Hydrologist will use the report card, together with the field assessment maps, to develop hazard ratings for peak flow, sediment sources, riparian function and channel stability. He or she will then use these ratings in making specific recommendations for the Forest Development Plan".

The results of the risk matrix approach provide an assessment of the real level of risk to the aquatic resources in a specific watershed. This is very different than the original "hazard indices" provided by the Level 1 Watershed Assessment Procedure (Government of BC, 1996). While the hazard indices only assessed potential hazards, the risk matrix provides an assessment of the real level of risk that exists for a specific watershed. The real risk is based on detailed field work, past and proposed land-use activities, specific characteristics of the watershed, the channel assessment and the local climate and hydrology. In the old Interior Watershed Assessment Procedure (IWAP), this type of detailed approach was intended to be used only on those watersheds that were identified as having a "medium" or "high" potential hazard (i.e. a Level 1 hazard index greater than 0.5) and disturbed stream channels. This type of detailed analysis was previously termed a Level 3 watershed assessment. The new WAP does not identify different levels of assessment, but rather directs the hydrologist to complete one comprehensive assessment (Government of BC, 1999). The field component of the new procedure is based on reconnaissance-level assessments, however.

Resource values and management objectives for the watershed will determine the level of risk that is acceptable. The acceptable level of risk is a management and socio-economic decision made by resource agencies, based on specific watershed management objectives that are set prior to beginning the assessment. The acceptable level of risk is not a technical decision made by the consulting hydrologist in isolation. However, in general, forest harvesting activities that generate "Very Low" or "Low" levels of risk should not negatively impact aquatic resources.

A "moderate" level of risk (i.e. the gray zone between low and high) needs to be carefully interpreted in the context of the management objectives. For example, if there are very high or unique fisheries values in the watershed (bull trout, for example) and the acceptable level of risk has been defined as low, then some changes to the Forest Development Plan should be considered. These changes should focus directly on the particular "hazard" that has been identified as creating the unacceptable level of risk. For example, if the LWD risk is moderate because of past forest harvesting activities, then the goal should be to reduce the LWD risk, but not necessarily by reducing harvesting. This may be achieved by initiating something like riparian area planting through the Watershed Restoration Program (WRP). If the peak flow risk is moderate then this may lead to specific rate of cut constraints, or possibly re-distribution of cutblocks within the watershed. It is important to remember that the type of constraint imposed must be directly related to the management objectives in the watershed and the acceptable level of risk identified by the resource agencies. Broad, non-specific constraints are generally not effective and may result in activities that don't necessarily protect the aquatic resources in an effective manner.

"High" or "Very High" levels of risk (in any one of the three particular categories) suggest that past and future harvesting activities could lead to significant negative impacts to the aquatic resources. In such cases, the Forest Development Plan may have to be re-designed, if the level of risk is deemed unacceptable to meet the specific management objectives for a particular watershed. Another possibility is to initiate restoration activities in older, harvested areas to mitigate the effects of proposed harvesting activities.

It is of the utmost importance to understand that the management decisions that are made relative to the results of the "risk assessment" must be made in the context of clear and specific watershed management objectives. These objectives are generally defined by the resource agencies (i.e. Ministry of Forests, Ministry of Environment, Lands and Parks, Department of Fisheries and Oceans, Ministry of Health).

Table 1: RISK MATRIX[1] for *PEAK FLOW CHANGES*

		Sensitivity of the stream reach to increases in peak flows				
		1	**2**	**3**	**4**	**5**
Potential for increased peak flows	**1**	A	A	A	A	B
	2	A	B	B	C	D
	3	A	B	C	D	D
	4	A	B	C	D	E
	5	A	C	D	E	E

[1] "Risk" refers to the level of risk imposed on aquatic resources from past and proposed forestry activities in the watershed. The risk matrix on this page only considers the risks associated with increases in snowmelt generated peak flows. These flows are the channel forming flows for most of the areas in the Interior region of British Columbia. The five levels of risk are defined as follows:

A = Very Low
B = Low
C = Moderate
D = High
E = Very High

- The sensitivity of the stream reach to increases in peak flows is a subjective designation. It is determined based on the results of the field-based channel assessments and the morphological characteristics of the reach such as stream gradient (s), stream width (W_b), bed and bank materials, size of largest stream bed particle (D), stream depth (d) and entrenchment ratio (ER). The level of disturbance in the reach is also assessed, using the methodology proposed by the Government of BC (1996). The reach is also classified using the system proposed by Rosgen (1996). The Rosgen classification system is also used to assist in the designation of the sensitivity of the stream reach.

➢ The potential for increased snowmelt generated peak flows was assessed based on the amount of forest harvesting and hydrological recovery in the watershed (i.e. ECA), the distribution of cutblocks within the watershed, the general aspect of the proposed cutblocks and the relative proximity of the cutblocks to a watercourse. Although no strict algorithm was developed to make this assessment, the following general rules and conceptual model were applied:

a) A Peak Flow Index less than 25 yielded a "very low" potential for increased peak flows (i.e. a value of 1).

b) A Peak Flow Index between 25 and 39 yielded a "low" potential for increased peak flows (i.e. a value of 2).

c) A Peak Flow Index between 40 and 54 yielded a "moderate" potential for increased peak flows (i.e. a value of 3).

d) A Peak Flow Index between 55 and 70 yielded a "high" potential for increased peak flows (i.e. a value of 4).

e) A Peak Flow Index greater than 70 yielded a "very high" potential for increased peak flows (i.e. a value of 5).

f) If most of the proposed cutblocks had a southerly aspect then the designation would be more conservative (e.g. an ECA of 25 with south aspect cutblocks could yield a "moderate" potential).

g) Based on the concepts of "variable source area" and "preferential flow', if most of the cutblocks were located close to streams, then the designation would more conservative.

h) The conceptual modeling is based on recent research results that have been obtained in watershed research trials in the Prince George Forest Region (Beaudry and Gottesfeld, in press; Beaudry and Floyd, 1999).

Table 2: RISK MATRIX[1] for *SEDIMENT SUPPLY CHANGES*

		Sensitivity of the stream reach to increases in sediment supply				
		1	**2**	**3**	**4**	**5**
Potential for increased delivery of sediment	**1**	A	A	A	B	B
	2	A	A	B	B	C
	3	A	B	C	C	D
	4	A	B	C	D	E
	5	A	C	D	E	E

[1] "Risk" refers to the level of risk imposed on aquatic resources from past and proposed forestry activities in the watershed. The risk matrix on this page only considers the risks associated with increases in sediment supply to the stream channel. The amount of sediment delivered to a stream channel can play a large role in shaping the channel, as it must respond to the amount of water and sediment it transports. Channels tend to become wider, shallower and less sinuous where the influx of coarse material has been appreciable (Knighton, 1984; Sullivan et al., 1987; Hogan et al., 1998). The five levels of risk have been defined as follows:

A = Very Low
B = Low
C = Moderate
D = High
E = Very High

- The sensitivity of the stream reach to increases in sediment supply is a subjective designation. It is determined based on the results of the field-based channel assessments and the morphological characteristics of the reach such as stream gradient (s), stream width (W_b), bed and bank materials, size of largest stream bed particle (D), stream depth (d) and entrenchment ratio (ER). The level of disturbance in the reach is also assessed using the methodology proposed in Government of BC (1996). The reach is also classified using the system proposed by Rosgen

(1996). The Rosgen classification system is also used to assist in the designation of the sensitivity of the stream reach.

- The potential for increased delivery of sediment to the stream channel was assessed based on the density and location of roads, the number of stream crossings, the surficial materials in the watershed, the local climate, stream density and the level of coupling of the hillslopes to the stream channel. The sediment source survey completed by *Integrated* Woods Services Ltd. was also used to assess the potential for increased delivery of sediment to the watercourses.

Table 3: RISK MATRIX[1] for *LARGE WOODY DEBRIS SUPPLY CHANGES*

		Sensitivity of the stream reach to decreases in large woody debris supply				
		1	**2**	**3**	**4**	**5**
Potential for decreased supply of large woody debris	**1**	A	A	A	A	A
	2	A	A	B	C	C
	3	A	B	C	D	E
	4	A	C	D	D	E
	5	B	C	D	E	E

[1] "Risk" refers to the level of risk imposed on aquatic resources from past and proposed forestry activities in the watershed. The risk matrix on this page only considers the risks associated with decreases in the supply of large woody debris to the stream channel. Many small, low gradient stream channels are very dependent on the supply of Large Woody Debris (LWD) for the maintenance of stream channel diversity and complexity and ultimately maintaining good fish habitat. The removal of the riparian forest, either through forest harvesting, grazing or agriculture, can have a significant detrimental impact on the long-term stability and productivity of the stream channel. The five levels of risk have been defined as follows:

A = Very Low
B = Low
C = Moderate
D = High
E = Very High

- The sensitivity of the stream reach to decreases in the supply of LWD is a subjective designation. It is determined based on the results of the field-based channel assessments and the morphological characteristics of the reach such as stream gradient (s), stream width (W_b), bed and bank materials and stream depth (d). The methodology proposed in Government of BC (1996) and the stream classification system proposed by Rosgen (1996) are used as tools to help determine the level of sensitivity to a significant decrease in the supply of LWD to the stream channel.

- The potential for a significant reduction in the supply of LWD to the stream channel was assessed based on the level of riparian harvesting that has occurred along the mainstem of the stream channel. This riparian harvesting could be as a result of past forest harvesting activities (i.e. prior to enactment of the Forest Practices Code of British Columbia Act) or grazing or agriculture.

APPENDIX C

List of Aerial Photographs and Maps Utilized

Aerial Photographs Utilized:

1975

BC7790: No. 27-30, 66-73, 122-127

1997

30BCC97068: No. 167-170, 200-205
30BCC97072: No. 22-28, 105-109
30BCC97081: No. 207-209, 222-225

Maps Utilized:

Forest Cover and TRIM Mapsheets

82M.053, 82M.063

Soil Maps

82M/NW (Soil and Terrain Report for the Seymour Arm Map Area)

APPENDIX D

Longitudinal Profiles

APPENDIX E

Watershed Report Cards

APPENDIX G

Watershed Assessment Map

APPENDIX F

Field Forms 1 and 2