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Acknowledgements

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I have enjoyed working in the Bulkley Forest District. The staff allowed me to work at a level of professionalism I had not yet experienced. I hope to return to Smithers for my next Co-op summer work term.

Executive Summary

Land use and management in the Upper Zymoetz River catchment has been at issue in the Bulkley Forest District's McDonell Resource Planning Area (MRPA) since forestry development began there in 1989. The catchment area is of significant concern to British Columbia Environment (BCE)[1] and angling organizations such as the Steelhead Society because the catchment feeds into the Upper Zymoetz River, one of only five Class I angling waters in B.C. Timber resources in the catchment are also of value, however, inclusions of sensitive terrain make current and planned harvesting operations an issue because of the potential affect on the Class I angling water attributes of the Upper Zymoetz River. This report will address issues concerning the Class I angling water attributes of the Upper Zymoetz River, focusing on terrain sensitivity in the MRPA west of Serb Creek.

The Class I angling water designation applies to the Upper Zymoetz River from Limonite Creek in the Kalum Forest District, to its headwaters at Aldrich Lake in the Bulkley Forest District. Primary management objectives for Class I angling waters include control of access, protection of water quality and a pristine wilderness experience. The Bulkley Forest District's McDonell Resource Management Plan (MRMP) does not fully meet these objectives. Consequently, the MRMP should be revisited. Class I attributes of the Zymoetz River appear to have been compromised in several locations in the Bulkley and Kalum Forest Districts. Wilderness areas have been proposed by BCE, the Steelhead Society, and the Prince Rupert Protected Areas Team (RPAT) Protected Areas Strategy (PAS) study to protect a portion of the Class I angling water stretch of the Upper Zymoetz River in both districts.

For inter-agency agreement (between BCE and the Ministry of Forests) regarding land management direction of the Zymoetz River catchment to be successful, three key issues must be addressed. First, BCE has designated the Upper Zymoetz River as a Class I angling water without providing a clear definition of what that designation implies. Currently, management objectives for the Upper Zymoetz River Class I angling water are being decided at a district level by the Land and Resource Management Plan (LRMP) planning processes of the Bulkley and Kalum Forest Districts. However, unless there is communication between the Community Resources Boards of both districts, their LRMPs may contain different management objectives for the same Class I angling water. BCE, which sits at both tables, should recommend a clear Class I angling water definition and management objectives to the CRBs of both districts. CRBs of the Bulkley and Kalum Forest Districts could then decide if they wish to maintain the Class I angling water designation of their portions of the Upper Zymoetz River through consensus management direction. Presently, BCE recommends that Class I angling water guidance should come from a discussion paper written by T. W. Chamberlin (1990) entitled "Land Use Implications of Class I and II Classification of Angling Waters" (APPENDIX A). Second, communication should also occur between the CRBs of the Bulkley and Kalum Forest Districts regarding any proposed wilderness areas within the Upper Zymoetz River

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[1] British Columbia Environment (BCE) is part of the provincial Ministry of Environment, Lands and Parks (MELP). MELP was formerly the Ministry of Environment (MoE).

catchment. A wilderness corridor would ensure protection of the Class I angling water attributes of the Upper Zymoetz River. Third, terrain sensitivity west of Lee and Mulwain Creeks must be evaluated to determine potential impacts timber harvesting and road construction may have on the Class I angling water attributes of the Upper Zymoetz River. A forestry development zoning system has been developed for this purpose using terrain stability and surface erosion potential maps produced by Denny Maynard, M.Sc., P.Geo, in 1994. This issue is addressed in section 3.0 of this report. The forestry development zoning map legend and base criteria can be found in APPENDIX B. Accompanying maps must be provided separately due to their size. Mr. Maynard's report has been provided in APPENDIX C of select copies of this report. Terrain sensitivity is a concern in the entire Upper Zymoetz River catchment, not just the contentious area west of Lee and Mulwain creeks.

A brief discussion on forestry practices in the Zymoetz River catchment is included in section 4.0. Although timber harvesting within unstable and steep terrain is becoming more common in the Bulkley Forest District, a cautious approach is still necessary. Even without logging or road building activities present, many examples of instability leading to natural mass movements can be found. The Upper Zymoetz River catchment, with its Class I angling water and sensitive terrain, requires forestry practices that specifically address its unique characteristics.

This report and accompanying maps will contribute information necessary to achieving a consensus decision concerning the extent of resource development able to take place in the Upper Zymoetz River catchment without compromising its Class I angling water attributes. As both the Bulkley and Kalum Forest District Land and Resource Management Plans (LRMPs) are still in the process of finalization, the opportunity now exists to co-ordinate management direction concerning the Zymoetz River and its Class I angling water attributes. Conclusions on these matters must be arrived at by the Community Resources Boards (CRBs) along with the Interagency Planning Team. This report will be presented to the Bulkley Valley CRB for strategic planning consideration.

The Upper Zymoetz River and Tributaries

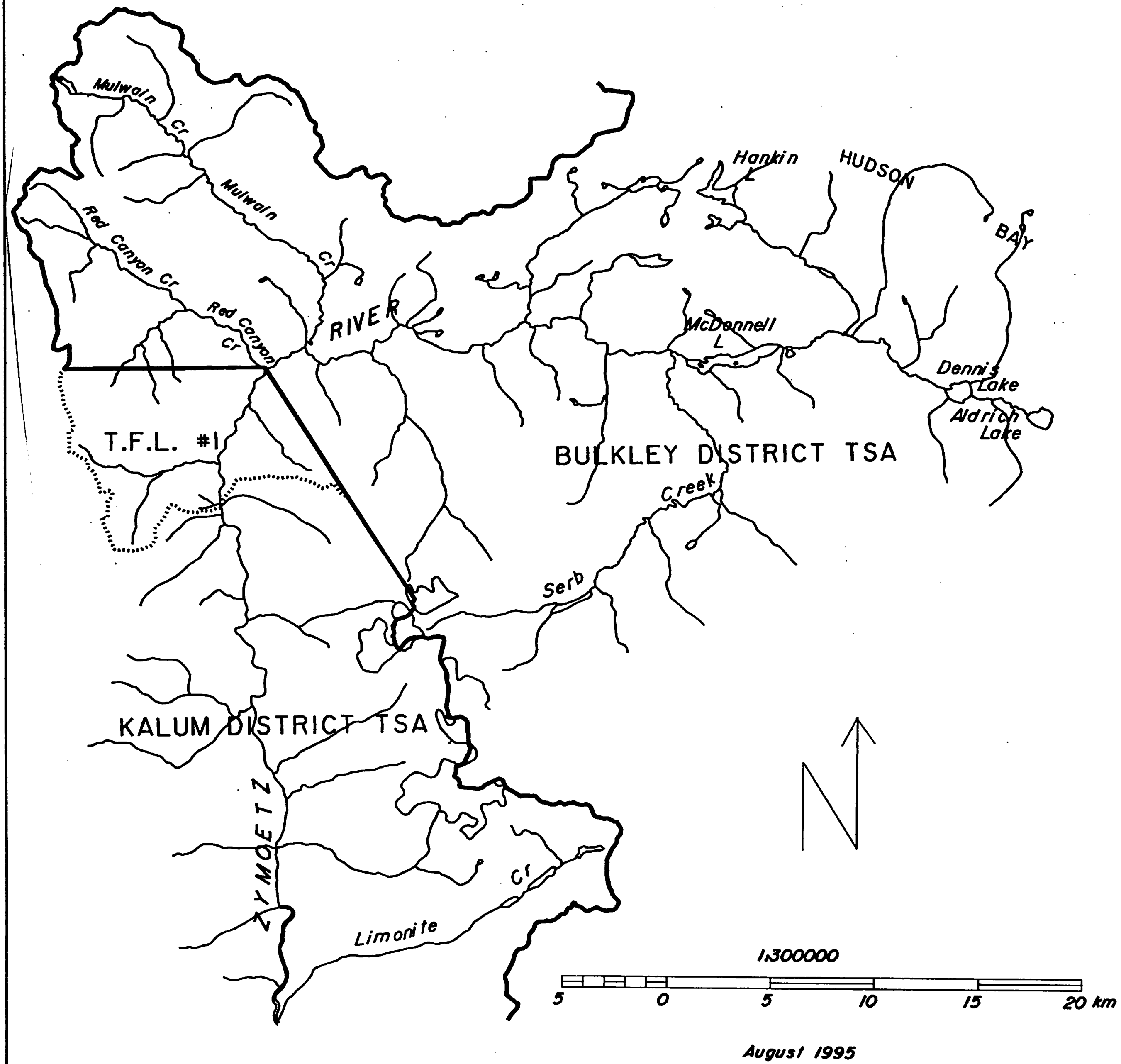

Figure 1.0) The Class I angling water designation of the Upper Zymoetz River applies to the portion of the river upstream of Limonite Creek (Wildlife Act 1990). In the Bulkley District T.S.A., forestry development is currently restricted west of Mulwain and Lee Creeks until outstanding issues are resolved by the Bulkley Forest District and B. C. Environment. Forestry development zoning maps have been produced (maps are provided separately from this report) for the Bulkley District's Upper Zymoetz River catchment west of Serb Creek so that the issue of terrain hazard may be resolved.

1.0 INTRODUCTION

Resolution of conflicting resource values in the Upper Zymoetz River catchment is currently of concern in the Bulkley Forest District's McDonell Resource Planning Area (MRPA)[1]. As timber harvesting activities push farther into the catchment, the risk of compromising the Class I angling water[2] attributes of the Zymoetz River increases. Inclusions of geomorphologically sensitive terrain in this otherwise stable landscape pose a natural hazard to forestry operations and the Class I fishery of the Zymoetz River, further complicating issues.

This report will address issues concerning the Class I angling water designation of the Zymoetz River. Attributes associated with the Zymoetz River's Class I angling water designation, conflicting resource values, and outstanding interagency issues are discussed. A zoning system for timber harvesting and road construction has been developed using terrain stability and surface erosion potential maps[3] to guide planning in the MRPA west of Serb Creek. Finally, forestry practices in the sensitive terrain of the Upper Zymoetz River catchment are briefly discussed. This review should assist planners by providing comprehensive information needed to decide the future and nature of resource development in the Upper Zymoetz River catchment.

[1] The MRPA is a planning unit (#12) within the Bulkley Forest District Timber Supply Area.
[2] A Class I angling water can also be referred to as a Class I fishery

2.0 BACKGROUND

2.1 The Zymoetz River and its designation as a Class I angling water

From its headwaters at Aldrich Lake, the Zymoetz River runs west through the McDonell Resource Planning Area (Unit 12) in the Bulkley Forest District Timber Supply Area (TSA). Also known locally as the "Copper" River, it exits the Bulkley District at its western most extent. Here it bends sharply to the south flowing through neighbouring Tree Farm Licence #1 (TFL #1)[1] into the Kalum District TSA.

The Upper Zymoetz River contains an excellent variety of fish habitats. Pools, riffles, glides, back channels, good water quality and clean spawning gravel make this an exceptional river for one of the last healthy summer run steelhead populations in the world[2]. The river provides essential habitat for this threatened stock. The Zymoetz summer steelhead run first enters the upper river in August and continues through to late fall. Unlike Pacific salmon, steelhead overwinter in the river to spawn in May and then return to the ocean. Some, about twenty percent, survive to spawn again in subsequent years[2]. Sockeye and coho salmon, Rocky Mountain white fish, rainbow and cutthroat trout, and dolly varden are also present in this length of the Zymoetz and throughout its catchment[3].

This upper stretch of the Zymoetz River is internationally known for its pristine setting and exceptional angling opportunities. It is a valuable resource to local anglers, angling guides and related businesses as a recreational fishing destination. Before the 1990's, road access to the Zymoetz was limited above Limonite Creek. Anglers and their

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[1] Tree Farm Licence #1 is currently administered by Skeena Cellulose. In September of 1995, TFL #1 will officially fall under the management direction of the Kalum Forest District (Kathy Stuart, personal communication, July 1995). The Kalum Land and Resource Management Plan already includes TFL #1 in their planning process.

[2] This information was obtained from an open letter from D. Webb (representing the Northwest Chapter of the Steelhead Society of British Columbia) to John Cashore (then Minister of Environment) in 1993. The latter can be found in MoF File # 12600-25, Vol. 2, 01/01/91 to present.

[3] This information was obtained from an open letter from J. Culp (representing the River's Edge fishing lodge guiding services, Terrace B.C.) to Elaine Wright (then District Biologist, Bulkley Forest District) in 1992

guides were commonly flown in for their wilderness fishing experience. This lack of access discouraged localized over-utilization of the fishing resource by limiting the number of anglers fishing on the river. A high quality wilderness experience was therefore insured.

The limited access and unaltered nature of the upper stretch of the Zymoetz River, complimented with a world class fishing experience, prompted the B.C. Environment to designate it as a "Class I angling water" on April 1, 1990. The Zymoetz River must maintain "unblemished water quality, an unmodified visual landscape and an abundant diversity of natural flora and fauna" (Chamberlin 1990, p.2) if it is to remain as a Class I angling water. It's pristine wilderness quality is fundamental to this Class I designation. Currently, it is one of only five such streams in the province of British Columbia.

2.2 Conflicting resource values within the Zymoetz River catchment

The Upper Zymoetz drainage area contains other important resources in addition to its highly valued Class I fishery. Recreational opportunities in the area's scenic trails, lakes and tributaries go far beyond fishing. Some examples include hiking, skiing, horse riding, canoeing and kayaking, snow mobiling and mountain biking. Important ecosystems containing valuable wildlife habitat are distributed throughout. Forming corridors along the Zymoetz River ecosystem and its tributaries (already discussed in section 2.1), riparian ecosystems provide streams with an input of food and nutrients for fish while providing habitat for an unusually high diversity of plants and animals. Wetland habitat is important to a great variety of wildlife species (MRMP 1992, p.76). Lake and alpine ecosystems also provide habitat opportunities, adding to the diversity of the area.

The technical gap analysis[1] undertaken by the Prince Rupert Protected Areas Team (RPAT) revealed that the Copper River Valley has very high (VH) conservation values and moderate (M) recreation values relative to other proposed areas of interest within the

[1] The gap analysis is a systematic application of goals and criteria to determine what resources or values are currently protected and what needs to be protected (Protected Areas Strategy, Policy Document, 1995).

Nass Ranges ecosection[1]. Constraints on the percentage target available for protected areas within the Prince Rupert Forest Region, has made it necessary for even high ranking areas of interest to be prioritized according to provincial significance and representation. Consequently, the Prince Rupert RPAT has suggested to the Bulkley and Kalum South Land and Resource Management Plan Community Resources Boards[2] retaining a reduced area along the Zymoetz River corridor as a Protected Areas Strategy (PAS) Study Area (I. Ronalds, personal communication, August 1995). This corridor was rated as having high (H) conservation values (Protected Areas Strategy, Policy Document, 1995).

The RPAT also undertook a preliminary assessment of timber and mineral values within the high-ranking area of interest. In the Zymoetz River corridor PAS Study Area, mineral values are rated as being H and timber values are rated as being VH. For the larger Zymoetz valley PAS Study Area, timber values are H (I. Ronalds, personal communication, August 1995). This assessment determines timber values from the percentage of operable timber in a given area. A VH timber value rating is given if greater than 75% of a given area is considered to contain operable timber. Land with 50 to 75% operable timber by area is considered to have H timber values (A. Wheatley, personal communication via L. Vanderstar, July 1995).

The 1992 McDonell Resource Management Plan assessed timber in the Copper Resource Area (REA 5)[3] as being of moderate value. This was determined qualitatively based on market values at the time (R. D. Mitchell, personal communication, July 1995). Market values have since increased, allowing the inclusion of previously marginal timber.

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[1] An ecosection is the smallest land unit within the Ecoregion Classification system, a system of ecological classification based on landform and climate that divides the province into large physiographic units. Other physiographic units include ecoprovinces, ecoregions, and ecosections. (Protected Areas Strategy, Policy Document, 1995)

[2] The Kalum South and Bulkley Community Resources Boards (CRBs) provides land allocation and management direction for the Land and Resource Management Planning (LRMP) process.

[3] Resource Emphasis Area (REA) 5, also known as the Copper Resource Area, is a planning unit within the McDonell Resource Planning Area. It forms a corridor along the Zymoetz (Copper) River from the confluence of Serb Creek in the east, to TFL #1 in the west. (see MRMP, 1992)

The Bulkley TSA Site Class Inventory map (MoF 1995) for the area indicates that the majority of the Upper Zymoetz catchment is made up of low (L) site classes. Within the immediate river corridor, this changes to include more poor (P) site classes with some medium (M) and infrequent good (G). A low site inventory class is the lowest rating in this system and means that for the leading tree species, less than twelve metres growth will be added to its height every fifty years. The highest rating of "good" means that this rate can more than double. Site class is a measure of the productivity or growing potential of the site and thus also an indication of its potential timber value.

Mineral and Timber resources in the Zymoetz River catchment are of importance, but have not yet been developed to their full potential. As timber and mineral extraction planning and activities proceed further into the Upper Zymoetz River catchment, the potential for conflict with other resource values increases. This is especially true along the Zymoetz River corridor and its tributaries.

2.3 Outstanding issues concerning the Zymoetz River Class I angling water

When the Bulkley Forest District announced in 1989 its intention to develop access to the north and south of the Copper River west of Serb Creek, B.C. Environment (BCE) expressed concern. Although it had not officially been designated as a Class I fishery at the time, it was well recognized by members of BCE and local anglers as having the attributes of one. As forest harvesting operations commenced in the area, and as the public became aware of these activities, objections began to be heard from local residents, recreational facility owners and their clients, anglers, angling guides and organizations.

By 1990, the McDonell Resource Committee had been formed to address concerns about development in the McDonell Resource Area west of Serb Creek. Members were invited by the Bulkley Forest District and represented a diverse range of resource uses in the area. Government representation consisted of personnel from the Ministry of Forests' Bulkley District and Prince Rupert Forest Region, B.C. Environment, the Federal Ministry of Fisheries and Oceans, and the Ministry of Energy, Mines and Petroleum Resources. The public and private sector were represented by a local recreation user and cabin owner, a guide and outfitter, a representative of the Copper River Ranch, a small business operator and a Bulkley Road User Committee member. Under the direction of the District, the committee began to develop a comprehensive resource plan for the area. In this plan, the McDonell Resource Area is divided into twelve Resource Emphasis Areas (REAs). REAs west of Serb Creek and within the Zymoetz River catchment include the Coal (4), Copper (5), Caribou (6), Serb (7), Seven Sisters (11), and Mulwain (12) (MRMP 1992).

As work on the McDonell Resource Management Plan (MRMP) progressed, discord developed between BCE and MoF representatives. Simply put, the plan's management direction concerning the Zymoetz River was at issue. BCE did not believe that adequate safeguards or protection existed to ensure the maintenance of the Class I angling water attributes of the Zymoetz River. The Ministry of Forests' Bulkley Forest District defended the plan (MoF File #12600-25, Vol. 2, 01/01/91 to present). However, upon a close inspection of the MRMP, it was determined that it did not fully meet all of its own objectives for the management of the Class I fishery.

Although stating that no timber harvesting will take place in the area visible from the Zymoetz river, the MRMP does allow for logging to occur elsewhere within REA 5. In addition, "preserving the immediate foreground viewshed from the river and maintaining a near wilderness experience for fishermen using the river" is listed as one of the most significant issues addressed by the plan (MRMP 1992, pp.42 & 43). BCE requested that "no operational forestry development" should occur within REA 5[1]. Further, it is questionable whether a "near wilderness experience" can be maintained by preserving only the "foreground viewshed". According to Chamberlin (1990, p.2), "an unmodified visual landscape" is a criteria of a Class I angling stream. It therefore stands to

[1] This information was obtained from an open letter from G. Wolfe (BCE Fish and Wildlife Branch) to Colin Harivel (then Public Involvement Co-ordinator, Bulkley Forest District), in March 1992

reason that modification of even the background viewshed would affect the attributes associated with the Class I angling water designation of the Zymoetz River.

Officially, the Class I angling water designation applies to that portion of the river above Limonite Creek (Wildlife Act 1990). However, road access does exist at two different locations east of Caribou Creek where the river has been crossed. The first crossing exists less than one kilometre north-east of Dennis Lake. The second bridge, located approximately one kilometre east of Caribou Creek in the Copper Resource Emphasis Area, is equipped with a removable span. The intent of the removable span is to restrict access to the south side of the Zymoetz River during the September and October opening of the Class I fishery "if required" to do so (MRMP 1992, p.42). The MRMP also states in the same paragraph that for REA 5, "access to the area will be restricted by not allowing access structures".

If access is defined as being within 1 km of a road (Chamberlin 1990, p.3; & BVCRB CMD, June 19th 1995, p.57), then access exists for almost the entire stretch of the Zymoetz between Caribou Creek and Dennis Lake and again west of Caribou Creek where the McDonell Main crosses Sandstone Creek. In TFL #1, the Kleanza Creek Road comes within 1 km of the Zymoetz River at several locations. The road becomes visible at km 40 where a slump has fallen into the river and exposed it (see Figure 2.1). A branch at km 54.5 of the Kleanza Creek Road comes within five minutes hiking distance to the Zymoetz River. Below Limonite Creek, road access and other visual forestry operations have resulted in a lower, Class II angling water designation for the Zymoetz.

Outside of the McDonell Resource Planning Committee, concerns regarding the implications of forest harvesting activity to the Class I angling water were expressed by the Steelhead Society, the Terrace and District Angling Guides Association and the River's Edge Fishing Lodge. The main concerns of these three groups are collectively stated by Jim Culp of the River's Edge Fishing Lodge in a letter written to the Bulkley Forest District on March 3rd, 1992. Paramount to their request is that the MRMP recognize, in accord with the Kalum District, a minimum sixteen kilometre stretch of the Copper river as a "protected area". It was also stated that this protected area should include large "Development Free Zones" along the river and tributary streams to preserve water and wilderness qualities. Later, on July 6th, 1993, a revised version of this proposal was sent to then Minister of Environment, John Cashore, from the North West Branch of the Steelhead Society. In this letter, Doug Webb outlines an area centred around Red Canyon Creek's confluence with the Zymoetz. From this point it extends seven kilometres upstream into the Bulkley district and seven kilometres downstream into the Kalum District following the Zymoetz River. This proposed protected area would then extend north and south of the Zymoetz to include the catchments of all its tributaries. Mr. Webb also suggested that this area could be used to link the Seven Sisters Wilderness Area with the Howson Wilderness Area. Currently, it is questionable whether even a 14 km corridor of pristine wilderness still exists along the Zymoetz River to be protected (see Figure 2.2).

BCE's principle concerns were summarized in a letter from its Regional Fish and Wildlife manager, Allan Edie, on February 23, 1993. Written to Guenter Stahl, District Manager of the Bulkley Forest District, Mr. Edie made the following points:

- We view this section of the Zymoetz as providing one of the finest wilderness steelheading opportunities remaining in the province, if not the world.
- It is our position that a portion of the Zymoetz River drainage should remain in a wilderness state. This includes a corridor along the river for the length of the Class I water (into TFL 1 outside your Forest District), and the areas west of Lee and Mulwain Creeks to the limit of the Bulkley Forest District.
- We do not consider that a preservation of the narrow viewshed of the river is sufficient to maintain its wilderness character. Wilderness experience is affected by the proximity of development and access. Additional areas adjacent to the viewshed should be protected, with access control and partial cutting systems applied to buffer the protected area, as was agreed to in the Babine LRUP.
- Quite aside from and in addition to the wilderness issue, the areas west of Lee and Mulwain Creeks should be protected in their entirety due to the high terrain hazard, erodible soils and evidence of natural slope failure in these units (MoF File #12600-25, Vol. 2, 01/01/91 to present).

This letter also recommended that, due to the impasse, these issues be elevated through the inter-ministry protocol on dispute resolution.

Figure 2.1) A view of the Zymoetz River from a slump initiated by Kleanza Creek Road in TFL #1. If forestry practices such as this continue, Class I angling water attributes associated with access control, water quality and pristine wilderness fishing experience will be lost at other locations along the Zymoetz.

Following a meeting between MoF representatives Larry Pedersen (Regional Manager of the Prince Rupert Forest Region) and Guenter Stahl and BCE representatives Dick Anderson (BCE's Regional Director) and Allan Edie, it was agreed by both ministries that the inter-agency process of dispute resolution was no longer necessary. In a letter to Dick Anderson dated March 30th, 1993, L. Pedersen summarized his understanding of the meeting's outcome:

- Although the concerns expressed by your staff were being pursued through the MoF/MoE protocol agreement, we now mutually agree that there is no further need to use this approach for the time being.
- The District will be asking your Ministry to jointly sign the current plan as agreed to in the non-contentious areas east of Lee and Mulwain Creeks.
- The more contentious area covered by the larger planning boundary, (primarily the areas west of Lee and Mulwain Creeks), will be studied more intensively before further discussions take place regarding the development potential of the area.
- After the more advanced soil stability mapping of the area is complete, our Ministries agree to jointly review, interpret and plan using the information[1]. At that time the "risk" of development will be addressed along with the other objectives associated with managing the Class I fishery resource.

It was also pointed out by Mr. Pedersen in this letter that "in the absence of definitive guidelines the Ministry of Forests is guided by our legislation to plan for the integration of the various resource uses and options available for this area." In Mr Pedersen's words: "I find it unfortunate that there are not more clear management objectives associated with the Class I river designation" (MoF File #12600-25, Vol. 2, 01/01/91 to present).

Based on the points made by both Ministries in these letters, interagency agreement depends first on obtaining and analysing detailed terrain maps of the area, and second on the provision of clear management objectives for the Class I angling water. To date BCE has provided no clear management objectives in association with Class I angling water designations despite the implications to land use management suggested by this designation. The issue of preserving a portion of the Upper Zymoetz River catchment as a wilderness area addressed by Allan Edie's letter is the responsibility of the Bulkley and Kalum South Land and Resource Management Planning processes. Regarding the second point of Larry Pedersen's letter, BCE has not signed the MRMP for the non contentious areas east of Lee and Mulwain Creeks. Further, this plan did not achieve consensus among its committee members, and has never been officially approved for use. With no other resource management plan in place, the Bulkley Forest District currently continues to manage development in the spirit and intent of the MRMP, mindful of the Bulkley Valley

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[1] This point prompted the Bulkley Forest District to contract Professional Geoscientist Denny Maynard to produce detailed terrain hazard maps of the catchment area west of Serb Creek.

Community Resources Board (BVCRB) (G. Stahl, personal communication, August 1995). Once completed, the Bulkley LRMP in combination with the new Forest Practices Code will overtake the MRMP (IBID). Revisiting the MRMP and its implications to the Class I angling water designation of the Copper River is therefore an option through the LRMP planning process. Regarding the third point of Mr. Pedersen's letter, development is currently restricted west of Lee and Mulwain Creeks pending the outcome of terrain and soils evaluation. A forestry development zoning system has been developed using detailed terrain mapping (completed by D. Maynard in 1994) to provide information needed to assess the risk of development as directed by the fourth point in Mr. Pedersen's letter.

As a Special Management Zone 3 (SM3) in the current draft of the Bulkley Valley BVCRB Consensus Management Direction (CMD), "forestry and mining are allowed" in the Copper Planning Sub-Unit 12-2[1] , "but are subject to constraints that give priority to other resource values" in the area (BVCRB CMD, June 19th 1995, p.iii). In the current Kalum District Draft Land Resource Management Plan, the recommendation of the Steelhead Society to preserve the Upper Copper River 7 km above and below Red Canyon Creek[2] is acknowledged. It is further stated that: "There was consensus by the working group that an area be set aside as wilderness, although no consensus as to the size of the area." (Kalum Forest District LRMP (Draft), June 1992, p.36). However, because half of this 14 km portion of the Copper River would lie within the Bulkley Forest District, management objectives must be communicated between both districts.

Currently, forest harvesting operations within the Kalum Forest District TSA are occurring upstream of Limonite Creek along the Copper River in TFL #1. From the east, forestry operations are advancing through the Bulkley Forest District TSA towards Mulwain Creek. Increased access by logging roads into the Upper Zymoetz River

[1] The Copper Planning Sub-Unit 12-2 is a corridor which extends along the Upper Zymoetz River and McDonell Lake within the Bulkley TSA. This area is not the same as planning unit REA 5 of the MRMP.
[2] Red Canyon Creek's confluence with the Zymoetz River is on the boundary of the Bulkley TSA and TFL #1 in the Kalum TSA. The proposed wilderness area is split equally between both forest districts.

watershed is now compromising the wilderness and pristine nature of the Class I angling water within both districts. Should water quality be affected by turbidity from these ongoing logging operations, even the attributes associated with a Class II angling water could be compromised (see APPENDIX A for Class II criteria). Turbidity problems already exist in the Zymoetz River catchment from exposed banks, glacial and other natural sources (M. Geertsema, personal communication, August 1995).

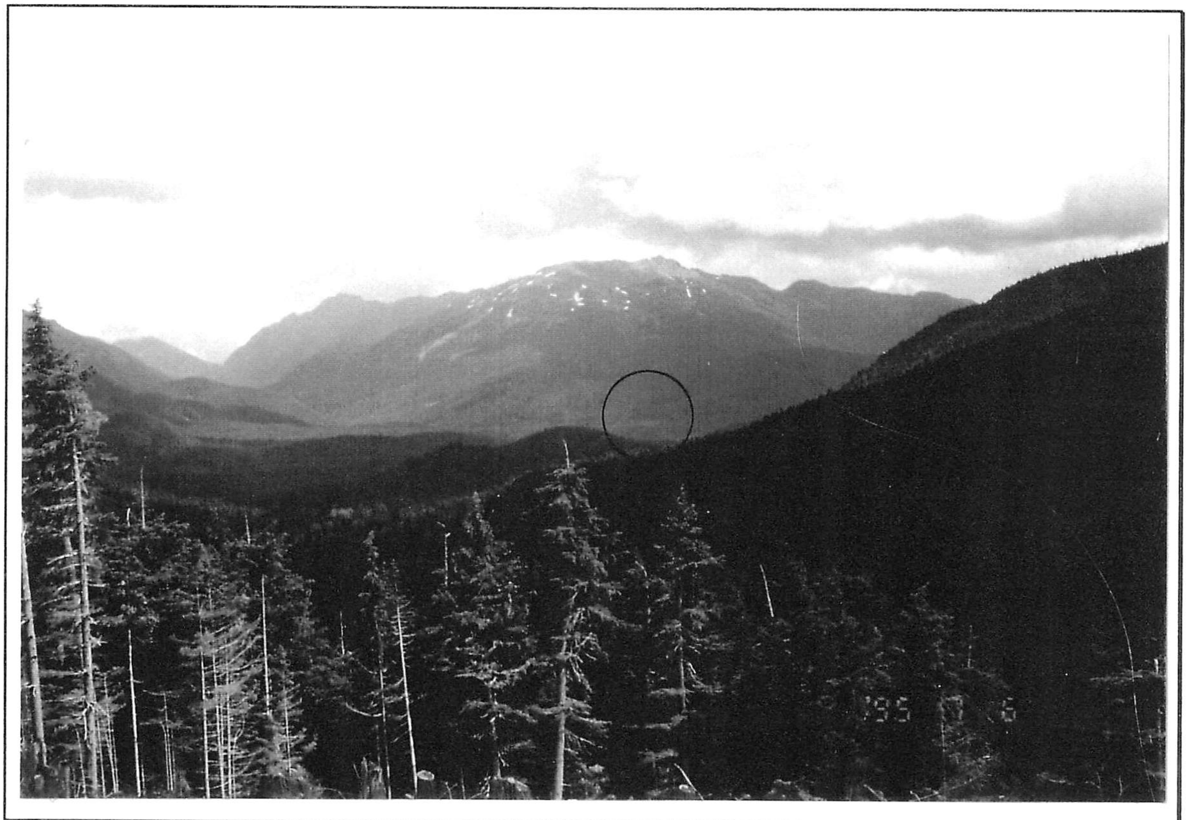

Figure 2.2) Looking across the Zymoetz River catchment from TFL #1 , a cutblock in the Bulkley District's McDonell Resource Planning Area can be seen. This photograph was taken from another cutblock at kilometre 55 of the Kleanza Creek Road. In between this advancing development is the last remaining unaltered portion of the Zymoetz River catchment.

Presently, both the Bulkley and Kalum Forest Districts are in the planning process of developing their LRMPs. The opportunity exists now for communication to occur between the CRBs of both districts regarding the management direction for the entire Upper Zymoetz River Class I angling water.

3.0 FORESTRY DEVELOPMENT ZONES WEST OF SERB CREEK

Terrain stability and surface erosion potential maps were prepared for the MRPA west of Serb Creek in 1994. When Denny Maynard and Associates Ltd. completed this mapping at 1:20,000 scale, it was apparent that the maps were complicated (D. Maynard's Report I, explaining his map work, is provided in APPENDIX C of some copies of this report). Therefore, a large scale visual interpretation of these maps is provided to facilitate planning and management of the Class I angling water attributes in the Zymoetz River catchment and to help address the issue of terrain sensitivity west of Lee and Mulwain Creeks.

The Forestry Development Zoning System is an interpretation of terrain stability and surface erosion potential mapping that groups terrain polygons sharing similar major operational concerns. By zoning mapped terrain into levels of operational (timber harvesting and road construction activity) concern, planners can assess the risk of development in the contentious area west of Lee and Mulwain Creeks. The water quality of the Zymoetz River and its tributaries, a major criteria of its Class I designation, can then be protected by planning where forestry development can safely proceed. Grouped polygons are not all the same. Specific polygon information provided by Denny Maynard on these maps must be used for more detailed planning purposes. A legend for the forestry development zoning system has been provided in Appendix B of this report. The maps themselves, because of their size, will be provided separately from this text.

3.1 Methods

In their original form, the terrain stability and surface erosion potential maps of the area west of Serb Creek are of the detail and complexity more suited to operational (road building, timber harvesting etc.) planning uses. This detail and complexity makes interpretation of these maps difficult for people who do not have a geoscience background. As a result, it was necessary to provide an interpretation of the map data so that it could be more easily used. This was done by grouping terrain polygons having similar major operational concerns. Care was taken so as not to dilute information by over-emphasizing areas of lower concern while under-emphasizing the risk to those of higher concern.

Using terrain stability and surface erosion potential maps of the area west of Serb Creek (Maynard 1994), areas of operational concern have been highlighted using an adaptation of a traffic-light land use zoning system (Eisbacher & Clague, 1984). For the specific use of outlining operational concerns to timber harvesting and road building activities, it was necessary to expand on the basic three colour scheme without changing its basic principles.

Five levels of concern, rated from very low to very high, have been created in this interpretation of terrain stability and surface erosion potential data. At the same time, the three colours of a traffic-light system have been maintained to facilitate the idea of *proceed*, *caution* and *stop*. Areas which can be conventionally logged with little risk of damage to the surrounding environment will be associated to a "green light". This stable terrain is indicated by a *green zone*. In actuality, this system will leave these polygons uncoloured because they are of very low concern. Areas of very high to extreme concern will be coloured red to represent a stop signal. These actively unstable terrain polygons will makes up the *red zone* where no forestry development (logging and road building activities) should be carried out unless field inspected and approved by a qualified terrain specialist (such as a Professional Geoscientist or Professional Engineer). Areas of caution, however, are much more complicated. In all orange zones, there is a potential for some form of logging activity be it conventional or selective in nature. However, because the potential also exists for logging to be restricted from these areas, a site inspection by a terrain specialist is recommended and in most cases required by the FPC before development proceeds. Different levels of operational concern exist in this caution zone which must be represented in a way that does not over-emphasize areas of low concern at the expense of under-emphasizing areas of high concern. Thus the orange caution light category has been divided into three separate levels of concern. *Orange 1 zones* of low level concern are represented simply by orange hatch marks. Moderate level concern is indicated by *orange 2 zones* with solid orange colouration. Greater attention is brought to orange 3 zones of high level concern by colouring red hatch marks over an orange base colour. These three orange zones where logging operations may be able to proceed with caution can not be treated as a homogenous group.

Terrain stability, surface erosion potential, and geomorphic processes contributing to mass movement potential (such as gully erosion, slumping, soil creep, rockfall etc.) were considered. Of these characteristics, the five class terrain stability data forms the basic framework of this interpretation. Terrain stability assessment gives an indication of the likelihood of landslides occurring after timber harvesting and road construction. The expected magnitude of landslides or the potential downslope damage that may be caused is site specific and therefore can not be determined from map interpretation (M. Geertsema, personal communication, August 1994). Terrain stability classes range from I to V with I being the most stable and V being the most unstable terrain. Surface erosion potential and geomorphic processes contributing to mass movement are then used to refine the level of concern within each stability class. Thus, a high (H) surface erosion potential in a terrain stability class IV polygon would be of greater concern than an H rating in a class III or less polygon. Similarly, active gully erosion in a class V area is considered more serious than in a class IV or lower. By nature, geomorphic processes contributing to mass movement potential are characteristics of the highest terrain stability classes. A polygon with a terrain stability class of V with a very high (VH) surface erosion potential and active mass movement processes[1] would therefore achieve the highest level

[1] Active mass movement processes which appear on the terrain stability and surface erosion potential maps are: active gully erosion by flowing water, snow avalanching, or landsliding (V); rapid mass movement such as debris slides and flows and rock failures (R); and slow or small scale mass movement (e.g. creep, slumps) (F). For more information see the map legends produced by Denny Maynard (1994)

of concern possible by being designated a *red zone*. The lowest end of concern would be a *green zone* class I polygon with very low (VL) surface erosion potential and no geomorphic processes which could contribute to mass movement events.

Polygons with inclusions of higher stability classes, no matter how minor, are colour coded according to the highest terrain stability class[1]. For example, a polygon with a composite terrain stability rating of III//IV will be treated as the higher, more unstable, class IV rating. Thus even though the majority of the polygon area contains class III terrain, the inclusion of the more unstable class IV terrain warrants that the appropriate precautions for the higher stability class be taken. This way they are treated with the highest level of concern necessary in the planning stages and approached with the required amount of caution. Because it can not be determined from the map alone where these higher ratings are within the polygon, it must be verified by field inspection prior to forestry operations. Terrain stability and surface erosion potential data produced by Denny Maynard and Associates is provided with a high level of confidence (Maynard 1994, p.8). (An explanation of criteria used by Denny Maynard to evaluate these qualities is provided in Appendix C)

A cautious, but optimistic approach has been taken in this interpretation. Although knowledge and experience is constantly increasing in the Bulkley Forest District regarding forestry operations in steep and sensitive terrain, a cautious approach is still warranted. With optimism, it is assumed that any forestry operations proceeding into this sensitive area will follow a high standard under the new Forest Practices Code (FPC)[2] and where necessary, address any oversights that may be found in the code. Forestry practices should make preservation of Class I angling water attributes of the Zymoetz River a primary concern and thus let this objective dictate operational standards.

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[1] These composite units often include gullies that are not mappable (M. Geertsema, personal communication, August 1995).

[2] The Forest Practices Code (FPC), also known as "the code" came into place on June 15th, 1995.

3.2 Forestry development zones (five levels of concern for terrain evaluation)

The five levels of concern represented by the forestry development zoning system are not meant to replace the terrain stability and erosion potential maps produced by Denny Maynard. The stoplight colour coding system is an interpretation of the map data to be used as a visual strategic and operational planning tool. On an operational scale, this adapted traffic-light zoning system can be used as only a guide. More specific operational direction must be gained from the original map data produced by D. Maynard or preferably from detailed site evaluations by a qualified terrain specialist.

3.2.1 Green zone (very low concern): uncoloured polygons

Polygons which have been left uncoloured represent "green traffic-light" areas of very low concern to logging and road building operations. These polygons contain no evidence of current or past geomorphic processes which could contribute to mass movement. Surface erosion potential is, at most, low (L) and terrain stability class rating are II or less. Minor erosion of fines can be expected from disturbed soils and ditch lines in areas with a low surface erosion potential. Management is necessary to ensure that water is not channelled onto more sensitive sites. (FPC Mapping and Assessing Terrain Stability Guidebook 1995, p.14 and Schwab 1993, p.16). Because terrain stability classes are II and below, significant stability problems are not expected following timber harvesting or road construction (FPC Mapping and Assessing Terrain Stability Guidebook 1995, p.10 and Schwab 1993, p.13). Periodic inspections of logged and roaded terrain and immediate revegetation of disturbed sites in these zones should be carried out to correct minor erosion problems which may occur (see Figure 3.1) (D. Wilford, personal communication, August 1995).

Figure 3.1) The terrain above is considered to be of very low concern to logging and road building operations. With a low (L) surface erosion potential and terrain stability classes II (interpreted using terrain stability and surface erosion potential map 93L.081 (Maynard 1994)), this terrain is considered to be a *green zone* where development may safely proceed. As seen above, slight problems of erosion from disturbed soils are to be expected in these zones. Periodic inspections of green zones and appropriate erosion control measures (such as grass seeding) may therefore be needed (D. Wilford, personal communication, August 1995). This photograph was taken from the McDonell Main Road approximately 2 km south of the Moore Creek crossing.

3.2.2 Orange (caution) zones: all polygons with orange colouring

The next level of concern to logging and road building operations is that of caution, or an "orange traffic-light". In this sensitive terrain, development must proceed with due caution and take all necessary precautions to ensure that practices are environmentally sound. In most cases, a field inspection by a qualified terrain specialist is necessary before hand. As terrain becomes more complex, the level of caution increases.

With the added complexity of the map area, it becomes more difficult to group polygons where caution is required into only one level of concern. To do so would oversimplify the terrain and draw attention from areas of greater concern. For this reason three levels of concern are used to represent the varying degrees of caution. These levels of concern, in increasing order, are: orange 1 zones (low concern); orange 2 zones (moderate concern); and orange 3 zones (high concern).

3.2.2.1 Orange 1 zone (low concern): orange hatch marked polygons

The first, and lowest *level of caution* is indicated by orange hatch marks. It contains higher risk class II and III terrain where site management is a concern. Polygons with a terrain stability rating of II combined with a surface erosion potential of M form the base level of concern. Although Class II terrain is considered generally stable, the inclusion of moderate surface erosion potential in these polygons increases the level of concern. Water management is critical, complete road deactivation must be planned for, and all disturbed sites must be grass seeded (FPC Mapping and Assessing Terrain Stability Guidebook 1995, pp.10 & 14 and Schwab 1993, pp.13 & 16).

The highest terrain stability rating in orange 1 zones is class III. Their inclusion is dependant on having no active geomorphic processes which could contribute to mass movement. Minor stability problems and slumping is expected along road cuts for one to two years following construction. Semi-permanent deactivation of roads is required in class III terrain when roads are no longer used regularly or maintained (FPC Mapping and Assessing Terrain Stability Guidebook 1995, p.10 and Schwab 1993, p.13).

Although site inspection by a terrain specialist is not required in orange 1 zones, it may prove necessary in certain instances. As the complexity of class III terrain increases to include high surface erosion potential and evidence of inactive small scale gully erosion and landsliding, on site assessment may be needed prior to logging or road building. Class III terrain with high (H) surface erosion potential and inactive gully erosion (VI) form the upper margin of this category. Polygons with high surface erosion potential can expect major problems with water channelled onto or over them and require complete road deactivation and immediate revegetation where disturbed (FPC Mapping and Assessing Terrain Stability Guidebook 1995, p.14 and Schwab 1993, p.16) (Figure 3.2). It can be expected that areas where water can easily be channelled, such as inactive gullies, will be at the highest risk in this category. Selective logging and special road building techniques may be necessary (Maynard 1994, p.26).

Figure 3.2) Terrain above has been interpreted to have a terrain stability class III rating with a high (H) surface erosion potential. This is an orange 1 zone of low concern where forestry operations must proceed with caution. Minor stability problems and slumping can be expected along the road cuts and water management is required. Highly erodable soils may be a major concern if water is channelled onto or over this location. The photograph was taken a few metres from the Moore Creek crossing facing north. Terrain was interpreted using terrain stability and surface erosion potential map 93L.081 (Maynard 1994).

3.2.2.2 Orange 2 zone (moderate concern): solid orange polygons

Terrain stability class III polygons with active gully erosion by flowing water, snow avalanching or landsliding (V) form the lower limit of the second level of concern. Avalanching is not a major concern in the area, but can initiate debris torrents[1] . Forest harvesting activities operating near avalanche prone slopes must be careful not to initiate these events (Maynard 1994, pp.24-27). In particular, gullied slopes are cause for concern. Two potential hazards in gullied terrain are debris flows and debris floods[2]. Debris floods are a danger to stream water quality due to their ability to transport large amounts of sediment. Debris flows are potentially very destructive to timber and streams because they can transport large volumes of material at great speeds (FPC Gully Assessment Procedure Guidebook 1995, p.2). With a high capacity to transport sediment along their channels, active gullies have important implications to forestry operations. Surface erosion, slope failure, and transport of mass wastage material to lowlands is of concern. Active gullies connected to downslope valley-bottom streams are of greatest concern due to their ability to transport sediment (Maynard 1994, p. 24). The FPC states that field inspections by terrain specialists are "usually not required" (FPC Mapping and Assessing Terrain Stability Guidebook 1995, p.10), in class III terrain. However, class III terrain with active gully erosion and/or small scale mass movements is recognized as the exception to this rule. Consequently, it is included in orange 2 zones with moderate concern class IV terrain[3]. In all class IV terrain, a field inspection by a qualified terrain specialist is required before any development takes place (FPC Mapping and Assessing Terrain Stability Guidebook 1995, p.10). Therefore, for the area west of Serb Creek, site specific assessment by a qualified terrain specialist is recommended as being necessary before any logging or road operations commence in orange 2 zones.

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[1] Debris torrents are not common in the B.C. Interior (Wilford, personal communication, August 1995).
[2] Debris floods occur down larger streams or rivers. (Schwab, personal communication, July 1995)
[3] Denny Maynard (P.Geo) agreed with this assessment in an August 1995 personal communication.

Terrain stability class IV polygons are included in this category provided that no geomorphic processes contributing to mass movement potential exist. Because of the increasing complexity of class IV terrain, Denny Maynard further subdivided it into class IV and IVc polygons (Maynard 1994, p.30). This was to separate operational concerns associated with clearcutting (IVc) from those associated with road building (IV). Specialization to this degree is beyond the scope of this text. As such, class IV and IVc polygons and their associated forestry operations guidelines will be treated collectively as class IV terrain.

Figure 3.3) This recent, road initiated, small scale rockfall event was found on the McDonell Main Road approximately 150 metres west of the Irvine Creek crossing. As an *orange 2 zone* (of moderate concern), problems of instability can be expected following road building or clearcutting. This terrain is of stability class IV with a moderate (M) surface erosion potential (Maynard 1994, map 93L.081).

Forming the upper margin of orange 2 zones is class IV terrain having an H surface erosion potential and inactive gullies or remnants of old erosive processes. Also included in orange 2 zones are terrain stability class IV terrain with no active or inactive geomorphic processes and low surface erosion potential. Problems of instability associated with road building and clearcutting should be expected in all orange 2 zones (Figure 3.3 on previous page). However, logging practices deemed appropriate by a terrain specialist can proceed in orange 2 polygons if they can maintain control of any sediment erosion or terrain instability which occurs as a result.

3.2.2.3 Orange 3 zone (high concern): orange polygons with red hatch marks

As suggested by the red hatch marks over these orange polygons, orange 3 zones are sensitive areas of high concern. Exclusive to this group are terrain stability class IV polygons that contain active geomorphic processes. These processes can include slow or small scale mass movement such as creep or slump (F), or active gully erosion by flowing water, snow avalanching or landsliding (V). The possibility exists that on site evaluation could recommend deferring logging or protection-forest status in terrain of class IV stability (Maynard 1994, pp.43-44). Containing higher concern class IV terrain, it is much more likely that development will need to be restricted in orange 3 zones than in lower concern class IV terrain found in orange 2 zones. Although evidence of active instability exists in these class IV polygons, they have not been assigned a terrain stability class rating of V. Therefore, appropriate harvesting and road building practices are a possibility if approved by a qualified terrain specialist (Figure 3.4). Should logging or road building proceed, strict adherence not only to the FPC, but also to Denny Maynard's recommendations for class IV and IVc terrain should be followed (see Appendix C).

Figure 3.4) The irregular topography seen in the photograph above is *orange 3 zoned* terrain of high concern to logging and road operations. The terrain is of stability class IV with a high (H) surface erosion potential and evidence of active gully erosion by water and/or active landsliding (interpreted from: Maynard 1994, map 93L.081). The photograph is of the north-west side of an unnamed creek on the McDonell Main Road, 700 metres south-east from the proposed Johnson creek crossing.

3.2.3 Red zone (very high concern): red polygons

All polygons coloured red indicate a class V terrain stability rating. By definition, class V terrain west of Serb Creek is very sensitive with significant evidence of various active mass movement processes and/or surface disturbance (Maynard 1994, pp.47-48). This terrain is characteristically steep and can be prone to active or recurrent landslides even before any development occurs (Figure 3.5). A high to extreme potential exists in these areas for continued or accelerated mass movement during and following conventional logging operations. In his 1994 report on the area, Denny Maynard has recommended that "logging activity (road building and clearcutting) should normally be precluded from this unit" (p.44). Planners should, therefore, assume that no development can be carried out in red zones unless it has been proven otherwise by a qualified terrain specialist (Figure 3.6).

Figure 3.5) In the picture above, rapid erosion occurs naturally less than a kilometre from where Mulwain Creek enters the Zymoetz River. Rated by Denny Maynard as terrain stability class V with very high (VH) surface erosion potential (1994, Map 93L.071), the actively unstable terrain is considered a *red zone* to forestry development. No road construction or timber harvesting of any kind should take place in these actively unstable red zones unless approved by a qualified terrain specialist after careful field evaluation.

Figure 3.6) The photo above was taken at the Irvine Creek crossing on the McDonell Main Road. The bridge was built over a narrow *red zoned* corridor of the creek after approval by a Professional Engineer. According to map 93L.081 (Maynard 1994), the bridge crosses class V terrain with a H surface erosion potential and active gully erosion and/or landsliding. Care must be taken to ensure that erosion does not occur on the exposed cutbank and flow into the creek along the ditch. Grass seeding of the slope should be carried out for this purpose. Continued inspection and maintenance will be required for as long as the bridge exists.

Figure 3.7a above & 3.7 b below) Red zoned terrain at this unnamed creek crossing at kilometre 3.7 on the South Copper Mainline was interpreted to be of stability class V with a very high (VH) surface erosion potential. Active rockfall and gully erosion by water and/or landsliding is also present (Maynard 1994, map 93L.072). At the time of this photograph, proper water management and erosion control precautions had not been taken at this location. As a result, runoff was eroding the soil foundation of the bridge and other disturbed areas, transporting it into the creek. (L. Vanderstar, personal communication, May 1995)

4.0 FORESTRY PRACTICES IN THE UPPER ZYMOETZ RIVER CATCHMENT

To date, the application of inappropriate forest management practices has had a significant effect on post logging landslides and sediment erosion throughout the province of British Columbia. The Forest Practices Code Mapping and Assessing Terrain Stability Guidebook (April 1995, p. 11, 26 and 34) provides this data (Table 4.1 below) representing the percentage of landslides greater than 0.05 ha occurring in each of the terrain stability classes after harvesting or road construction:

Terrain stability class	Likelihood of landslide initiation	Percentage of polygons with one or more landslides following timber harvesting or road construction
I	Negligible	0%
II	Very low	0-5%
III	Low	6-30%
IV	Moderate	31-70%
V	High	71-100%

Table 4.1) Relationship between terrain stability class and likelihood of landslides 5 to 15 years after harvesting or side cast road construction practices on the B.C. Coast. This data may not apply to other climatic regions or longer time periods.

The guidebook suggests that the potential for landslides can be reduced significantly through the use of appropriate forest management practices and road building methods.

In general, areas of concern (orange 1 to 3 zones and red zones) outlined in the Forestry Development Zones of section 3.0 are slopes of greater than 50% gradient. Through time, forested slopes develop a static equilibrium that can easily be disturbed by road construction and logging activities. The undercutting of hill slopes, increase of surface weight, alteration of surface and subsurface drainage, and reduction of short term anchoring and reinforcing effects of tree roots are important consequences of road construction and logging which have a great influence on slope stability (MoF Land Management Handbook Number 18 1994, p.8). Failures and surface erosion associated with logging or road construction practices can occur long after the timber has been removed from an area. An increase in the frequency of landsliding events generally occurs from 3 to 10 years following forest removal. This time period coincides with the time it takes for roots of smaller diameter (20 mm or less) to undergo advanced deterioration (Sidle et al. 1985, p.65). However, the effects of timber harvesting can continue to influence the stability of hill slopes for much longer than ten years. If not decommissioned, road systems especially require long term commitments to their upkeep if erosion and slumping problems are to be managed. Clearcuts and roads approved in orange (proceed with caution) and red (unsafe to proceed) zones will need to be monitored and maintained for as long as is necessary to protect water quality in the Upper Zymoetz River catchment.

With the Forest Practices Code (FPC) now in place (as of June 15th, 1995), much of the operational direction needed will be provided on a province wide basis. On a regional and more so on a district level, the FPC may not be specific enough to fully cover the uniqueness of certain terrain. Although the Bulkley Forest District is becoming more experienced at managing forestry development in steep sensitive terrain (terrain of stability class III or greater), a cautious approach with such operations is still necessary. Strategic and operational planning and management direction should remain flexible in order to incorporate new procedures developed to address oversights discovered in the FPC. Some recommendations specific to the McDonell Resource Planning Area west of Serb Creek are provided by Denny Maynard in Appendix C.

An example of one oversight in the FPC can be found at Willow Creek on the north-east edge of cutblock 93L.083-014. Currently, clearcut logging is permitted to the edge of any ravine or slope which neighbours the cutblock. However, in this instance, the practice of logging to the break in slope may be unsuited to the terrain of the McDonell Resource Planning Area (Figure 4.1a & 4.1b).

Figure 4.1a) Clearcutting on the north-east side of cutblock 93L.083-014 has caused hydrologic changes in subsurface water flow and exposed once sheltered trees to the effects of the wind. Compounding this problem, the clearcut extends to the break in slope where a steep ravine descends to Willow Creek. As a result, a landslide has occurred forming a small gully in the ravine and transporting sediment and forest debris into the creek. Although this site was logged before the FPC came into place, current practices under the code still allow logging to the break.

Figure 4.1b right) This picture was taken from Willow Creek looking south-west to cutblock 93L.083-014. An increase in subsurface flow and/or possible windfall may have initiated the landslide which made this gully. At the time this picture was taken, groundwater continued to flow to where it surfaced at the top of this slope. This small new stream continues the erosion process in the gully carrying sediment into Willow Creek. Although this site was logged before the FPC came into place, current practices under the code still allow logging to the break.

5.0 CONCLUSIONS

Class I angling water attributes, conflicting resource values, and outstanding inter-agency issues affecting the Upper Zymoetz River catchment have been discussed. Addressing the issue of terrain and soil sensitivity in the area west of Mulwain and Lee Creeks, a zoning system for timber harvesting and road construction has been developed using terrain stability and surface erosion potential maps produced by Denny Maynard, M.Sc., P.Geo in 1994. This zoning system has been applied to the entire map area, extending west from Serb Creek in the McDonell Resource Planning Area of the Bulkley Forest District. The purpose of the forestry development zoning system is to guide operational and strategic planning in the map area and in doing so, help ensure that water quality in the Zymoetz River catchment is managed and it's Class I angling water designation protected. Thus any environmentally sound forestry operations that do not compromise this goal (and any others set out as planning and management directions) are viable. New practices that can help to achieve this goal and allow multiple resource use in the Upper Zymoetz River catchment should be encouraged.

Conclusions regarding future development in the Upper Zymoetz River catchment and the management of the Class I fishery are left to the Land Resource Management Planning processes of both the Bulkley and Kalum Forest Districts. Similarly, the proposed preservation of a wilderness area in the Zymoetz catchment is an issue that must be resolved by the LRMP planning process along with the Interagency Planning Team. Communication between the Community Resources Boards of both districts along with recommendations from BCE regarding clear Class I angling water management objectives should greatly assist the resolution of outstanding issues and any future planning in the Upper Zymoetz River catchment area. Until this time, Class I angling water guidance is provided by T.W. Chamberlin's 1990 discussion paper entitled "Land Use Implications of Class I and II Classification of Angling Waters" (see APPENDIX A).

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APPENDIX A

Land Use Implications of Class I and II Classification of Angling Waters

LAND USE IMPLICATIONS OF CLASS I AND II CLASSIFICATION OF ANGLING WATERS

A Discussion Paper
T.W. Chamberlin
April 20, 1990

INTRODUCTION:

Recent legislation (Wildlife Amendment Act, 1989) has enabled the designation of Class I and II angling use on them. This legislation is in support of a policy recognizing the extremely high sports fishing values of these waters, including not only the existence of special fish, but also a highly desirable fishing experience.

In the case of Class I water, this experience contains an additional element of "wilderness" or "pristine" value which is difficult to quantify but far too easy to compromise through forestry or land development activity. The Initial Policy Discussion Paper (December, 1988) and its Update (August 1989) focused on the regulatory aspects of the policy with respect to fisherman, but did not deal specifically with implications to other resources.

This discussion paper attempts to describe more explicitly the land use implications of these classifications, especially with respect to the forest industry. Some parallels exist with the Coastal Fish/Forestry Guidelines which deal only with habitat concerns, and readers are encouraged to consult them as well.

In this discussion, "classification" is defined in the context of the list of waters in the regulations pertaining to the amended Wildlife Act.

DEFINITIONS OF CLASS I AND II WATER:

Class I:

The Initial Policy Paper describes Class I waters as "containing extremely valuable wilderness fishing opportunities where both guided and non-guided use (including use of B.C. residents) should be controlled". It states that they "require comprehensive plans and considerable control. Commercial activity would be carefully integrated to preserve the natural character of the river. Intensive interagency planning is probably needed." (emphasis added)

Fishing on Class I water is thus characterized as an experience where high quality fishing is found in combination with unblemished water quality, an unmodified visual landscape and an abundant diversity of natural flora and fauna.

This combination is probably limited to ten or so waters throughout British Columbia. Each of these, however, has the potential of generating literally millions of dollars of benefits to British Columbians each year.

Class II:

Class II waters are described as containing "high natural values", often in attractive natural settings, where Ministry of Environment regulations will focus on managing guided (and Perhaps non-resident) activity, but where the number of resident anglers will not be restricted and will be allowed to grow over time.

Integrated habitat management and interagency planning will be required to preserve the high natural values of Class II waters, but the objective of maintaining an unmodified landscape experience may not always be met.

Benefits generated from Class II waters are also high, and in the aggregate may exceed those of Class I. In 1990, about 30 waters have been designated Class II. Others will be added in subsequent years as angling demand increases.

Unclassified Water:

Many waters and extremely high fishery values need not be classified yet because the growth of fishing pressure does not warrant their regulation at some future time, the considerations discussed below will certainly apply.

The Recreational Fisheries Branch will identify the potential classification of waters on a 5 to 20 year planning horizon as resource permit. Lakes and rivers will be included in the designations.

LAND USE AND RESOURCE INTERACTIONS:

Sustaining the values described above requires considerably more than merely ensuring the existence of fish. The three major areas of concern which interact with other land uses are access, the recreational environment and fishability. These will be discussed separately with respect to Class I and II waters.

ACCESS

Class I:

Class I water is often difficult to access. We view this limitation as a desirable characteristic of a wilderness fishing experience and seek to maintain it. As a rule of thumb, vehicles and roads should be totally restricted within a riverine corridor. The corridor's width will vary according to specific watershed characteristics, but should in most cases be no less than 1 km in width.

Access outside the riverine corridor will be managed through a Coordinated Access Management Plan to limit industrial traffic to specified times and locations, and to direct recreational traffic to appropriate parking or camping locations.

Boat launch or takeout points on Class I water should also be limited. Rivers with "multi-day" float opportunities should be preserved by restricting boat access points to the upper and lower ends of "wilderness" reaches.

The access limitation for Class I water contributes to at least three elements of its wilderness character: persistent noise from traffic and industrial machinery is minimized; crowding from anglers or other recreationalists is limited; and the sense of accomplishment from being on the water is maximized.

Access development in the vicinity of Class I water will require coordination between agencies, a long-term (proactive) time perspective, public input and the designation of maintenance and enforcement responsibility for gates, barriers and trespass.

Class II:

In contrast to Class I water, Class II water may be accessed at numerous locations. Indeed, in order to distribute the density of angling throughout attractive Class II water, a purposeful access plan to enhance access opportunities may be pursued. At the same time, however, sensitive location of industrial roads and operations should attempt to minimize intrusive noise, dust and visual blight.

Because the objectives of Class II water place no restrictions on resident angling opportunities, considerable public input should be anticipated during the access planning process.

The RECREATION ENVIRONMENT

Class I:

The wilderness recreation environment typically encompasses scenic values, wildlife experiences, solitude and quiet. Access limitations contribute to some of these. The maintenance of scenic values and wildlife require additional focused planning and inventory programs specific to the characteristics of the landscape.

Viewing analysis, for which the Ministry of Forests has developed excellent methodologies, help define the limits of riverine corridors required to preserve river based viewscapes.

Evaluations of wildlife populations, habitat and wildlife viewing opportunities must consider the full range of animal migration patterns, and often require multi-season or multi-year time frame. Road access contributes significant impacts to both viewscapes and wildlife populations, and must be considered with them.

These considerations suggest that planning processed in the vicinity of Class I water will require a minimum of a two year framework to deal with the recreational environment.

Class II:

Class II water requires less emphasis on the recreational landscape, but similar values should be maintained when possible. Streambank Management Zones (SMZs) which are designed to maintain fish habitat through specific harvesting practices may also contribute to the recreational environment. Additional measures such as visual buffers, haul timing restrictions and slash burning controls may also be considered where high densities of use develop, or on weekends and holiday periods.

FISHABILITY

Class I and Class II:

Fishability is a term describing those factors which enable fisherman to successfully catch fish. In addition to the presence of fish, the water must not be too filled with debris for casting or boating and, most importantly, must be clear enough for fish to see a lure or fly. When the turbidity of the water column exceeds this standard, the river is "out", and the fishing is over.

Turbidity is caused by suspended sediment which may be introduced by natural events such as landslides, storms, glacial melt, but is often accelerated or initiated by logging and other land uses which result in disturbed soil. In essentially all non-glaciated, undisturbed watersheds, natural turbidity is very low during the mid to late summer fishing season. This is especially true in lake headed streams, which is why they often produce high value fisheries.

The amount of sedimentation required to result in a deleterious effect on fish habitat has been extensively researched, and measures to control it are well documented (see Coastal Fish/Forestry Guidelines). However, turbidity sufficient to restrict the fishability of a stream can be caused by much smaller amounts and much finer particle sizes. Certainly, any harvesting or landuse practise which exposes erodible mineral soil represents a potentially serious problem for stream fishability.

Both Class I and Class II waters are equally affected by turbidity. In addition, because of the downstream transport of sediment, all upstream tributaries of Class I and Class II waters may be sources for fine sediments which may impact water many kilometres downstream.

Planning and management measures to prevent turbidity problems are well documented, and include soil and terrain analysis, drainage control, appropriate construction techniques, seasonal limitations on operations and the aggressive revegetation of disturbed soils. In the water sheds of all Class I and most Class II waters, the rehabilitation of disturbed sites is a very high priority, and should be addressed with the same urgency as are toxic chemical spills.

SUMMARY:

Class I and II water classifications introduce the explicit recognition of recreational fishery values beyond the mere presence of special fish stocks. Class I values, based on the wilderness aspects of the fishing experience, require more intensive access planning, purposeful management of viewscapes and the management of wildlife viewing opportunities as well as populations. Both Class I and II waters require more attention to water turbidity than would be required for habitat maintenance alone.

Current planning processes are probably sufficient to meet these objectives. However, the staff and resources to ensure adequate lead time, public input, multi-agency involvement, and full watershed coverage are often not available. Both the Ministry of Environment and the Ministry of Forests must cooperate fully with other interested parties to achieve these objectives.

APPENDIX B

Forestry Development Zones Map Legend and Base Criteria

FORESTRY DEVELOPMENT ZONES MAP LEGEND AND BASE CRITERIA

(adapted traffic-light development zoning system)

Green Zone (very low concern): Safe to proceed

Terrain is considered stable. No significant erosion or stability problems are expected following road construction or logging. Field inspection by a terrain specialist is not required. Terrain is rated as being no greater than terrain stability class II with a surface erosion potential of L or less.

Orange Zones (caution): Forestry operations must be prepared to stop

Orange 1 Zone (low concern) Erosion and stability problems are expected. Water and soil management becomes critical in disturbed areas. These problems will increase in seriousness from this level and up. Field inspection by a terrain specialist may be necessary, but is not required. The base level of concern is class II terrain with M surface erosion potential. The upper margin of concern consists of terrain stability III polygons with an H surface erosion potential and inactive gullies (V^I).

Orange 2 Zone (moderate concern) Field inspection by a qualified terrain specialist is recommended as being necessary before any forestry operations can proceed in terrain from this level and up. Class III terrain with active gully erosion (V) forms the base level of concern. Class IV terrain with and H surface erosion potential and V^I forms the upper margin.

Orange 3 Zone (high concern) Terrain is considered actively unstable from this level and up. Appropriate logging and/or road building operations may proceed if field evaluation by a qualified terrain specialist allows. This zone contains class IV terrain with at least one active geomorphic process contributing to mass movement potential (V, F, and R)

Red Zone (very high concern): Unsafe to proceed

No development should be planned in this actively unstable terrain. Special cases may allow appropriate logging and/or road building operations after careful field evaluation by a qualified terrain specialist. All terrain in red zones is class V and considered actively unstable.

APPENDIX C

Terrain Classification, Terrain Stability, Surface Erosion Potential, & Sediment Transfer Capability of Upper Zymoetz River Watershed

VOLUME I: REPORT

TERRAIN CLASSIFICATION, TERRAIN STABILITY, SURFACE EROSION POTENTIAL, AND SEDIMENT TRANSFER CAPABILITY OF UPPER ZYMOETZ RIVER WATERSHED

PREPARED FOR:

B.C. Ministry of Forests
Bulkley Forest District
Smithers, B.C.

PREPARED BY:

Denny Maynard, M.Sc., P.Geo
DENNY MAYNARD & ASSOCIATES LTD.
North Vancouver, B.C.

JANUARY, 1994

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PROFESSIONAL
PROVINCE OF
D. E. MAYNARD
BRITISH COLUMBIA
GEOSCIENTIST

JANUARY, 1994

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VOLUME II: MAPS

Three map themes are portrayed on each of the following 1:20,000 TRIM base maps: 93L 71, 72, 81, 82 and 103I 80, 90, 100.

The map themes are:

- Terrain Classification
- Terrain Stability and Surface Erosion Potential
- Sediment Transfer Capability

ACKNOWLEDGEMENTS

An efficient and productive field program contributed significantly to the success of this project. A large measure of credit for this is due to Marten Geertsema of the Bulkley Forest District who assisted in all the field work and organized much of the field logistics. His enthusiasm in the field and in evening sessions examining aerial photographs was greatly appreciated. Irene Weiland, contract geologist with the Prince Rupert Forest Region, also participated in part of the field program and her expertise was a valuable addition. The very capable flying of Tom Brooks of Canadian Helicopters Ltd. (Smithers, B.C.) also greatly assisted the field work by providing access to all requested sites.

1.0 INTRODUCTION

A program of mapping terrain, terrain stability, surface erosion potential, and sediment transfer capability in the upper Zymoetz River watershed was requested by the Bulkley Forest District, B.C. Ministry of Forests. This report discusses the methods and results of this program which consists of a 1:20,000-level analysis of the terrain and an assessment of the potential effects of conventional forest harvesting on terrain stability and surface erosion. In addition, the capability of surface drainages to transport sediment from the slopes to the main creeks and river is subjectively evaluated.

Data and interpretations are presented at a level which are suitable for helping to plan forestry development in the watershed, but are not usually detailed enough to allow site-specific, operational recommendations and decisions.

The project was initiated in May, 1993 with the field work carried out in two trips during mid-late June and mid-late July. Final interpretation of the aerial photographs and preparation of the maps and report were done late in the year and completed in January, 1994. Paper copies of all maps are enclosed in an accompanying bound cover (Volume II: Maps).

2.0 SURVEY OBJECTIVES

The objectives of the survey were the following:

1. To map, at a reliability scale of 1:20,000, terrain (surficial materials, landforms, and geomorphic processes) in the forested areas of upper Zymoetz River watershed.

2. To produce a derivative map of terrain stability and surface erosion potential which indicates an expected response of terrain in the study area to conventional forestry operations (road construction and clearcut harvesting).

3. To produce a derivative map of sediment transfer capability of all the various segments of surface drainage channels in the watershed.

4. To prepare a report describing survey methods and reliability, physical environment of the study area, surficial geology and materials, slope processes and hazards, and criteria for classifying terrain stability, surface erosion potential, and sediment transfer capability.

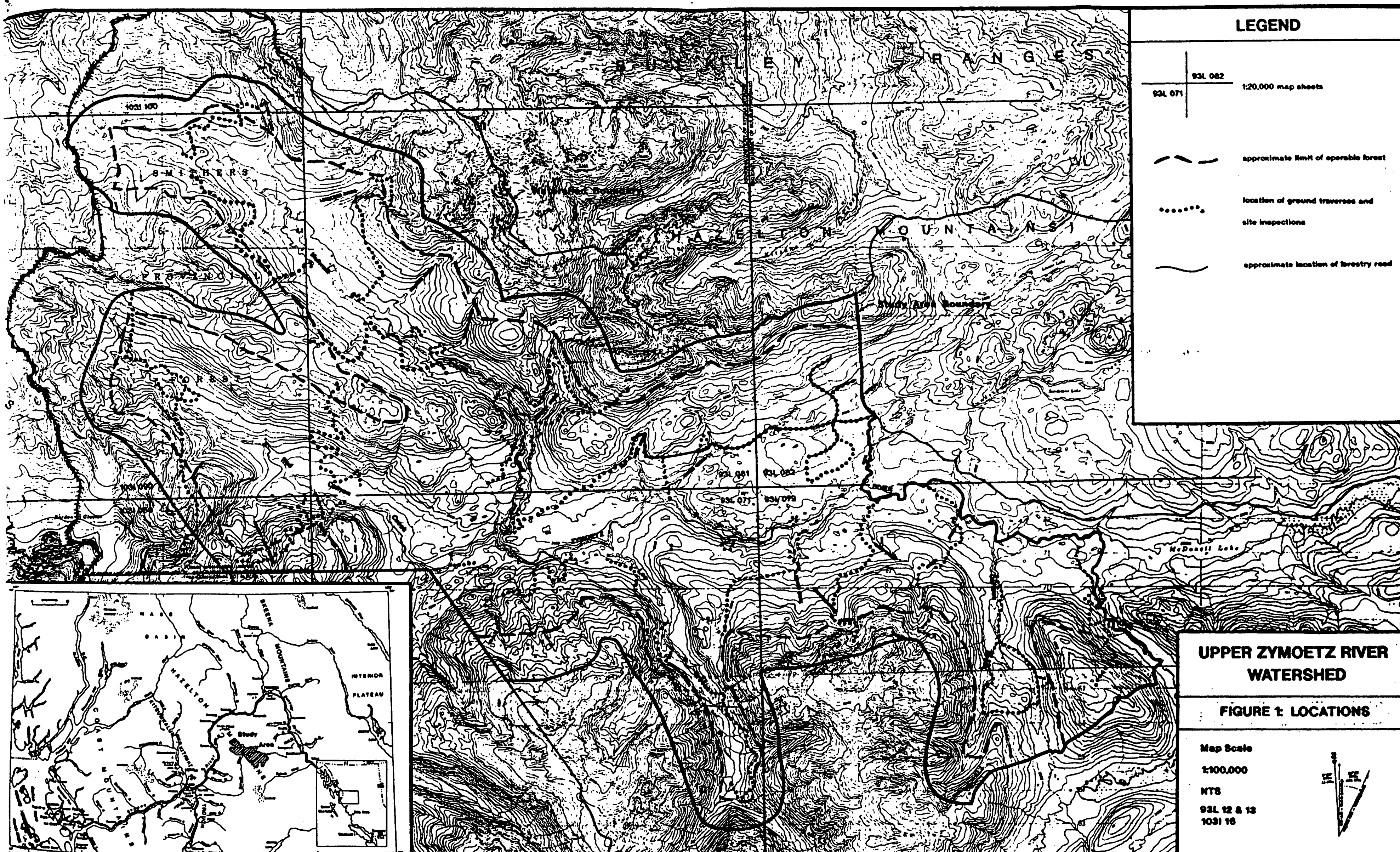
3.0 SURVEY AREA

Upper Zymoetz River occupies a broad, westerly draining valley which dissects part of the mountainous area between the central Interior Plateau and coast of British Columbia. The main river rises in a wetland area bounded by Dennis and Aldrich lakes, south of Hudson Bay Mountain about 15 km west of Smithers, B.C. The study area includes most of the main valley drainage basin west of the tributaries of Serb Creek and Coal Creek and most of the south-easterly flowing tributary valleys of Red Canyon and Mulwain creeks (figure 1). The study boundary intersects Zymoetz River at its confluence with Red Canyon Creek; downstream the Zymoetz flows about 35 km south and then another 40 km westerly to Skeena River about 8 km northeast of Terrace, B.C.

The study area encompasses an estimated 30,000 ha, of which about 20,000 ha are considered as operable forest land; the remaining mapped area is mostly inoperable forest with some lower sub alpine fringes. A midpoint in the study area is 48 km due west of Smithers. Main valley tributaries to Zymoetz River include Serb, Caribou, and Lee creeks which enter from the south and Red Canyon and Mulwain creeks which enter from the west and northwest respectively. Numerous other tributaries are incised into small valleys and isolated canyons and ravines; most of these are not formally named but for reference those with local names are identified on figure 1. The range of elevation within the map area is illustrated by some selected spot heights: Zymoetz River-Red Canyon Creek confluence - 630 m; benched lands flanking Zymoetz River - about 900 m; valley floors of upper Mulwain and Red Canyon creeks - about 1100m ; average lower limit of the alpine - 1400 m. Mount Sir Robert (2371 m), located southwest of Red Canyon Valley, is one of the highest points in the immediate region.

Regional bedrock is dominated by sedimentary and volcanic rocks of early Jurassic - Cretaceous age with small intrusions of late Cretaceous - early Tertiary granitic rocks (Hutchison et al 1979; Tipper et al, 1979). Most of the study area falls within two of the major biogeoclimatic zones of Krajina (1973). Sub-Boreal Spruce dominates to the east with Coastal Western Hemlock occurring west of lower Mulwain Creek; at higher elevations and in areas affected by cold-air flow, zones of Mountain Hemlock and Englemann Spruce - Subalpine Fir exist. Mean annual precipitation in the map area is estimated to be about 100 - 150 cm (Farley, 1979) with higher values expected in the mountainous areas to the south and west. The main soil types are of the Brunisolic and Podzolic orders with common, but minor, inclusions of Regosols and Gleysols (Runka, 1972). The major soil-forming surficial deposits are glacial till, glaciofluvial sediment, colluvium, alluvium, and organics.

The most efficient access to the study area is by helicopter from Smithers; flying time is about 20 minutes to Serb Creek and about 40 minutes to the upper end of either Red Canyon or Mulwain Creek. A recently built forestry road provides access to the subdued bench-lands north of Zymoetz River. Driving time is about one hour from Smithers to Coal Creek. New construction has extended this road west of More Creek as of autumn, 1993.


LEGEND
93L 062
93L 071
1:20,000 map sheets
approximate limit of operable forest
location of ground traverses and site inspections
approximate location of forestry road
BULKLEY RANGES
HAZELTON MOUNTAINS
SMITHERS
PROVINCIAL
FOREST
Watershed Boundary
Study Area Boundary
93L 081
93L 082
93L 071
93L 072
McDonell Lake
UPPER ZYMOETZ RIVER
WATERSHED
FIGURE 1: LOCATIONS
Map Scale
1:100,000
NTS
93L 12 & 13
103I 16
INTERIOR
PLATEAU
HAZELTON
Study
Area

4.0 SURVEY METHODS AND RELIABILITY

The work program involved inventorying existing features, conditions, and processes of the landscape by field observations and aerial photographic analysis, and assessing these to make interpretations relating to the stability and erodibility of slopes following conventional logging. Terrain mapping was done according to the Terrain Classification System for British Columbia (Revised Edition), (B.C. Ministry of Environment, 1988). Additional data on slope gradient and soil drainage were noted according to the Canadian System of Soil Classification (C.S.S.C., 1978).

Terrain units were stereoscopically delimited on 1977, 1:20,000, black-and-white aerial photographs. The final photo typing incorporated the field data with photo and contour map analysis. A Third-Order Photogrammetric Stereo Plotter (C.P.1) was used to transfer the terrain polygons from the aerial photographs to screened, 1:20,000 TRIM base maps. The study area encompasses parts of seven map sheets - 93L 71, 72, 81, 82 and 103 I 80, 90, 100 (figure 1).

The Terrain Classification Maps portray a mosaic of polygons which subdivide the land surface according to origin and texture of surficial materials, landforms (surface expressions), and presence of modern geomorphic processes which modify the landscape. In addition, information is provided on slope gradients and soil drainage, and "on-site symbols" are used to indicate specific landscape features such as landslides.

The preparation of the Terrain Stability and Erosion Potential Maps involved assessing each terrain unit according to its estimated stability and erosion potential following conventional logging. This type of classification indicates the expected response of the landscape to clearcut forest harvesting and road development. Terrain stability criteria, originally established from research by personnel of MacMillan Bloedel Ltd. and B.C. Ministry of Forests, are modified to adapt to conditions in the study area; these are explained in appendix I. Further modifications are applied to classifying gullies and gullied units (Maynard, under revision). A rating of surface erosion potential is also included on the stability maps. This rating is a qualitative assessment of the potential for generating sediment during and after logging, mainly by road construction. An explanation of the criteria used for rating erosion potential is given in appendix II. Stability and erosion potential units are derived directly from the individual terrain units and are plotted on separate TRIM base maps (screened contours).

The Sediment Transfer Capability Maps classify sediment transfer characteristics within each tributary and main stem channel segment and then estimate potential for the transfer of sediment between different areas within the watershed. The classification is based on Hogan and Wilford (1989) and has been modified and adapted to conditions observed in the upper Zymoetz drainage. The modifications have been discussed with Dan Hogan, Research Fluvial Geomorphologist, B.C. Ministry of Forests. Hazard rating is determined by a combination of two components - sediment delivery potential and sediment through-put potential. Rating symbols are attached to each designated channel reach for all surface drainages identified on the TRIM base maps.

Field work was carried out in two trips, June 20-July 2 and July 18-30, 1993. The equivalent of 30 days were spent doing ground checks during mostly favourable weather. On two days weather conditions precluded helicopter flying so ground checking concentrated along and near the road between Irving and Coal creeks. On all other days, a helicopter was used for drop-offs and pickups. Most of these were in support of day-long traverses although for two days the helicopter was used full-time to visit a number of isolated sites and permit short ground visits. The ground traverses and sites were selected to intersect representative terrain types and representative areas of potential instability as well as being representatively distributed throughout the map area. Traverse and site locations are identified on figure 1. At the end of most days, a short helicopter reconnaissance (15-20 minutes) was done in the vicinity of that days transect. In this way all ground in the map area received a thorough aerial inspection. In particular, special attention was paid to important features such as landslide scars, gullies, and deeply-incised creek canyons, as well as occasional, isolated exposures of surficial materials, from the slow, low-flying helicopter.

The reliability of the terrain mapping is considered good. Ground access was more than adequate to characterize terrain conditions on most of the lower slopes in the potentially operable forest. Priority was given to field checking those lower-slope areas and valley walls (e.g. lower Mulwain Canyon) which appeared topographically and geologically more complicated. Large areas of more homogeneous terrain and mid to upper forested slopes featuring mainly straightforward terrain conditions were readily characterized by fewer ground checks and aerial observations. The quality and scale of the aerial photographs was optimal for accurate, 1:20,000 - level, interpretation of terrain features and processes; map polygons are expected to reliably describe on-ground conditions.

The assessment of terrain stability and erosion potential is presented with a high degree of confidence. The writer has carried out numerous, logging-related terrain studies throughout the province, albeit mainly on the coast. However, experience with other projects in the Hazelton Mountains provided valuable background data as to the distribution and characteristics of surficial materials in similar physiographic settings to that of the upper Zymoetz Valley (Pedology Consultants, 1983 and Maynard, 1987b and 1990a). The ratings for terrain stability and erosion potential are largely based on experience and documentation from wetter coastal areas (Howes, 1987, Rollerson et al, 1986, and Rollerson, 1992) but, where applicable, have been modified to account for the different physiographic and climatic conditions of the Intermontane mountains.

Characterizing sediment transfer capability of the various creek and river reaches is somewhat more subjective. Currently there is not a lot of documentation in support of the classification system (Hogan and Wilford, 1989) although it has been successfully applied in a few terrain mapping projects in the Prince Rupert Forest Region. Representative reaches of all different channel types were visited throughout the map area. Sediment delivery and through-put characteristics have been evaluated based on these field observations and previous experience (Hogan, personal communication). The main limitation to the accuracy of these ratings is for the smaller streams where their features are not easily discernible on the aerial photos; for these smaller drainages not field checked, the ratings are extrapolated from streams in a similar landform position.

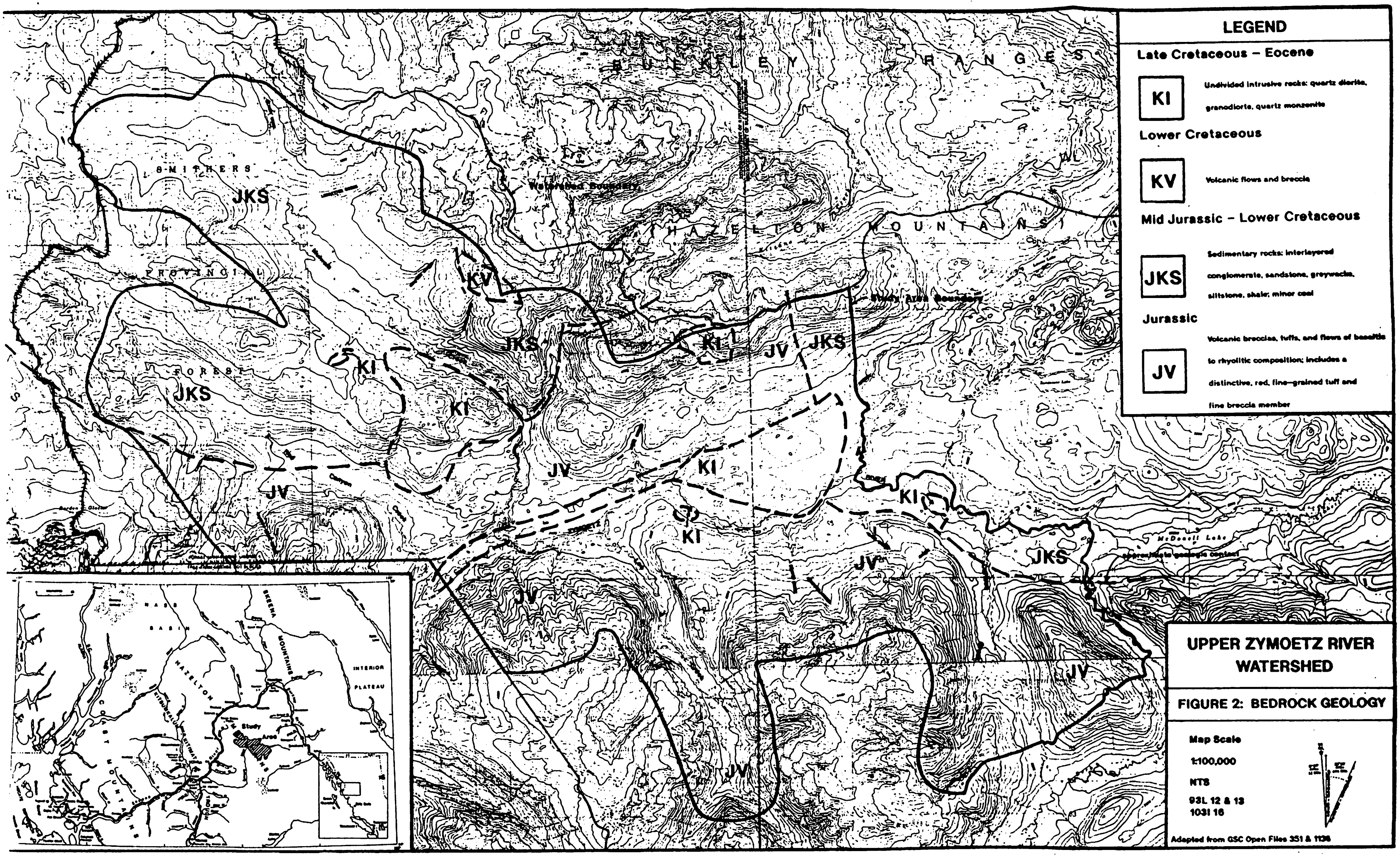
Accuracy of all the map plotting is excellent. Transfer of the original terrain polygon boundaries from the aerial photographs was done with sophisticated equipment onto accurate TRIM base maps. Detailed contour and planimetric data which reliably represent actual slope configurations and gradients and positions of drainage channels greatly facilitated the accurate plotting of map polygons and delineation of stream reaches.

5.0 GENERAL GEOLOGY AND PHYSIOGRAPHY

Zymoetz River dissects the Bulkley Ranges of the Hazelton Mountains (Clague, 1984), occupying a relatively wide valley bordered by gentle to steep slopes; floor elevations of the main stem and its larger tributary valleys range from 600 to 1000 m. Mountain ridges and peaks located around the study area are usually broad and rounded with elevations of 1600 to 2400 m. Valley glaciers and small ice fields occur in the highest mountains bordering the map area. Borden Glacier and an adjacent cirque ice field flow northwesterly from Mount Sir Robert; smaller areas of active ice also occur on the ridge between Caribou and Lee creeks and in the peaks north of Johnson and Newton creeks.

The presence of many ice-free cirques in the high mountain areas suggests that the area has been heavily glaciated in the past. In fact, Pleistocence ice has probably completely overridden most of the Bulkley Ranges a number of times. Glaciers moving along major valleys caused oversteepening of mountain sideslopes and contributed to the present-day U-shaped valley profiles; rounded summits are the result of ice moving across the mountain ridges. Glacial and post-glacial deposits mantle the mid to lower, gentle to moderate slopes and infill the broader sections of valley floor. Steeper, mid to upper slopes are mainly bedrock and colluvial complexes; coarse colluvium (talus) is common on slopes below major rock cliffs. In places, small rockslides, rockfalls, debris slides, and snow avalanches originate on upper slopes. Steep, deeply-incised creek canyons and ravines are also common sites of mass movement activity.

Bedrock geology is summarized on figure 2. (Tipper, 1976 and Woodsworth, et al, 1985). Lower Jurassic volcanic rocks underlie most of the main Zymoetz Valley and the southern side of lower Red Canyon Creek. These rocks are mainly fine-grained tuffs, flows, and breccias which are highly fractured in places (photo 1). Many of the gullies and canyons are entrenched along these fracture zones (photo 2). Fractured volcanic bedrock is also a significant source of instability and surface erosion. The tuffs are particularly susceptible


LEGEND
Late Cretaceous – Eocene
KI
Undivided intrusive rocks: quartz diorite, granodiorite, quartz monzonite
Lower Cretaceous
KV
Volcanic flows and breccia
Mid Jurassic – Lower Cretaceous
JKS
Sedimentary rocks: interlayered conglomerate, sandstone, greywacke, siltstone, shale; minor coal
Jurassic
JV
Volcanic breccias, tuffs, and flows of basaltic to rhyolitic composition; includes a distinctive, red, fine-grained tuff and fine breccia member
UPPER ZYMOETZ RIVER WATERSHED
FIGURE 2: BEDROCK GEOLOGY
Map Scale
1:100,000
NTS
93L 12 & 13
103I 16
Adapted from GSC Open Files 351 & 1136
BULKLEY RANGES
HAZELTON MOUNTAINS
SMITHERS
PROVINCIAL
FOREST
Watershed Boundary
Study Area Boundary
approximate geologic contact
McDonell Lake
SKEENA
MOUNTAINS
INTERIOR
PLATEAU
HAZELTON
NASS
BASIN
COAST MOUNTAINS
Study Area

to erosion; creeks draining areas where highly-weathered, red-stained rock predominates become laden with red-brown, fine sediment even in the smaller rainstorms. Sedimentary bedrock underlies most of the rest of the map area. Upper Red Canyon Creek, the ridge between Red Canyon and Mulwain valleys, and most of Mulwain Valley west from Johnson Creek are mapped as assemblages of mid Jurassic to lower Cretaceous conglomerate (photo 3), sandstone, greywacke, siltstone, and shale with minor coal. Sedimentary rocks also crop out at the eastern edge of the map area with exposures common along Coal Creek, Zymoetz River (photo 4), and lower Caribou Creek. Fracturing is much less intense in the sedimentary bedrock and this is reflected in the lower number of deeply-entrenched gullies and canyons and sites of rock instability in these areas.

Small intrusions of late Cretaceous-Eocene granitic rock are mapped in the upper Zymoetz watershed, noteably on the ridge west of lower Mulwain canyon and in a band along the north side of Zymoetz River. While some granitic rock was noted in these areas (as well as in a few other isolated areas) it does not appear to be as extensive as portrayed on figure 2.

The dominantly fine-grained volcanic and sedimentary bedrock greatly influence the textures of the derivative glacial and residual surficial materials. Matrix textures are dominantly silty in most colluvial and surface till deposits. In areas of coarser, clastic sedimentary rock sandy matrix textures in colluvium may prevail. Clay-rich tills also occur. These were mainly noted at depth in thick deposits although they also occurred near the surface in places in Mulwain Valley.

6.0 SURFICIAL GEOLOGY AND CHARACTERISTICS OF MATERIALS

Although major valleys around the study area became established in early or middle Tertiary time during uplift of the Coast and Hazelton mountains, it was the recurrent glacial erosion and deposition of the Pleistocene Epoch which modified the area to its present-day form (Clague, 1984). Little is known of early glacial events because the sedimentary record has been largely covered or removed. However, the sediments and landforms generated during the last major (Fraser) glaciation and during post-glacial time are well preserved in the study area.

At the beginning of the Fraser Glaciation, ice advanced out of high mountain areas, initially flowing along the major, pre-existing valleys and coalescing into a southerly flow from the upper Zymoetz area. The buildup of ice was probably accompanied by aggradation of outwash and preglacial lake deposits that formed in front of advancing valley glaciers. Most of these materials were eroded by overriding ice, but in places they remain preserved beneath thick accumulations of later sediments. They are usually only exposed where post-glacial erosion has incised deeply into the landscape.

At the glacial maximum most ridges around the study area were buried by mainly westerly flowing ice. Some higher peaks projected above the ice surface as nunataks. In places, bedrock and pre-existing surficial sediments were being scoured and removed and, in other places, glacial till was being deposited beneath the ice sheet.

Deglaciation probably commenced relatively quickly and continued through a complex interaction of frontal retreat and downwasting. Uplands and mountain ridges emerged first, dividing the ice sheet into a series of valley tongues that decayed in response to local conditions (Clague, 1984). There is no evidence of local still-stands or readvances of late-stage mountain glaciers (e.g. in the form of terminal moraines) within the map area although these may have occurred higher in the cirque valleys, closer to the ice sources.

Deglacial sediments are extensive throughout the map area, mainly as a thin surface mantle of ablation till which melted out of inactive, decaying ice. In addition, meltwater flow from the receding and stagnating glaciers eroded and transported valley fill as well as surficial sediments and bedrock fragments from the slopes, redepositing them mainly in temporary channels formed alongside the ice. It is also probable that small, temporary lakes formed where fine sediments (sand to clay) accumulated. Glaciofluvial sands and gravels are preserved in a few places as remnant terraces and kames, usually bordering present-day drainages which were also areas of meltwater flow. No significant deposits of glaciolacustrine sediments are identified. The dominance of ablation till over the meltwater-derived materials suggests that upper Zymoetz Watershed was mostly covered by ice stagnating in-situ with meltwater flow concentrated in some marginal areas that became ice free. Evidence of early deglacial erosion can be seen across some mid-elevation (1100-1400m) ridges where meltwater was channelled between ice-filled valleys. A distinctive meltwater channel is deeply eroded into the ridge between Silcote and upper Mulwain creeks; another example is bedrock rift, partially infilled by an elongate lake, between upper Gass Creek and Caribou Valley. As tributary valley glaciers further retreated and the ice infilling Zymoetz Valley downwasted on the slopes, the central valley floor must have become free of ice and the ancestral Zymoetz River began downcutting. Concurrent deposition of gravels and sands as lateral terraces occurred in places alongside this major meltwater channel.

A reasonable estimate of the timing of Fraser Glaciation events in the study area can be extrapolated from dates suggested for the nearby Bulkley Valley (Clague, 1984). Ice extent was probably at a maximum abut 14,500 - 15,000 years ago with deglaciation commencing soon after and the floors of major valleys becoming ice free between 11,000 and 9300 years ago. Stagnating glacier ice probably remained in the higher-elevation valleys of upper Zymoetz Watershed for a slightly longer time.

Fluvial and slope erosion and deposition continued in post-glacial time, particularly in the early stages where easily eroded material was readily available on oversteepened, poorly vegetated slopes. Gullies became incised in underlying bedrock and debris was transported downslope to be deposited as colluvial and fluvial fans and cones on lower slopes and as valley-floor fans and floodplains. As slopes gradually stabilized, valley-floor aggradation decreased and rivers and streams accelerated their downcutting, forming fluvial terraces along many channel reaches. Earlier fluvial deposits became deeply incised and remain as relict features at various elevations above present-day base levels. Active floodplain and fan aggradation continues in the present, but at decreased levels to that of early post-glacial time.

Colluvial processes also continue in present day at levels markedly lower than the erosion which probably rapidly modified slopes in the late deglacial-early post-glacial period. Bedrock weathering produced the most common post-glacial sediments; discontinuous to continuous mantles of colluvium occur on sloping rock and in-situ veneers of disintegrated rock occurs on subdued bedrock terrain. Colluvial materials also include surficial and bedrock debris deposited by landslides and snow avalanches at the base of slopes as fans and aprons.

Organic materials are also relatively common post-glacial sediments, having gradually accumulated in enclosed, shallow depressions and on poorly-drained, gentle slopes, particularly in valley-floor positions.

The distribution of surficial materials and their various textures, landforms, and modifying geomorphic processes are shown on the Terrain Classification Maps. The main surficial materials and their common physical properties which occur in upper Zymoetz Watershed are as follows:

<u>Colluvium</u>

Materials which are the products of mass wastage and have reached their present position by direct, gravity-induced movement. Colluvial deposits are common in the study area and occur in a variety of landforms and with a range of textures.

Variable weathering of the different rock types greatly influences the character of the main colluvial deposits - bedrock-derived mantles of varying thickness (usually in the range of 0.3 - 1.5 m) which may be present on moderate to hummocky to steep slopes. These mainly accumulate by slow downslope creep. Colluvium derived from fine-grained sedimentary and volcanic rocks usually has a silt-dominated matrix supporting angular rock fragments (photo 1). However, in one locality (a tributary valley to Red Canyon Creek) the colluvium had highly weathered in a seepage zone to almost a pure clay with no coarse fragments. A coarser colluvial matrix (mainly sand) with larger clasts is expected where dominant bedrock includes coarse, clastic sedimentary facies (sandstone, conglomerate) or granitics.

Colluvium which forms as the result of mass movement processes tends to be coarser-textured material than the slope mantle deposits. Talus, consisting of rubble and block-sized material, is derived from the ravelling and failure of bedrock cliffs and steep rocky slopes (photo 5). Landslide and snow avalanche debris derived from bedrock slopes are usually more poorly sorted than talus deposits and may include finer matrix material as well.

Colluvial deposits occur throughout the map area, from the valley floors to high ridge crests. They are most common on upper slopes and along deeply-incised canyons and gullies. Rock outcrops occur on many of the steeper sites. Colluvium mantles bedrock slopes on gradients as low as 30% but is more usual on 60-90% gradients. Most moderately to steeply sloping deposits are well to rapidly drained, but seepage and imperfectly drained sites may occur where slope gradients abruptly decrease.

Other common colluvial landforms are the lower and toe-slope fans, cones, and aprons which have accumulated at the base of active slopes and mass movement sites (gullies and landslide and snow avalanche tracks). Characteristics of these deposits are dependant on their source and on the state of activity of the depositional processes. Coarse, angular, loose material is probably indicative of more recent or recurrent activity from bedrock slopes; a mature, well-developed soil with finer-textured matrix supporting angular rubble suggests accumulation occurred slowly over time or as the result of much older upslope bedrock instability. In contrast, colluvium derived from upslope failure of surficial material will have textural characteristics reflective of such deposits. For example, landslides in till will produce diamicton debris whereas poorly-sorted gravel will accumulate below failures in glaciofluvial deposits.

Weathered Bedrock

Material which has weathered in-situ from underlying bedrock, usually on gently sloping or rolling terrain. Bedrock structure and texture remains largely intact with a high proportion of residual fines accumulating. Deposits are usually less than .5 m thick but, in places, deeper weathering may occur on less competent rock. The broad, undulating ridge tops in mid-slope and upper-slope positions are the main areas of occurrence of weathered rock, although discontinuous, weathered veneers were noted wherever bedrock is at the surface. Fine-grained volcanic tuffs and sedimentary shales and siltstones are most susceptible to in-situ, surface weathering.

Fluvial

These materials are transported and deposited by streams and rivers. The sediments occur as channel, floodplain, terrace, and fan deposits. Drainage of fluvial materials is dependent on their texture and position of underlying water table or impervious layer. Fluvial sediments in the study area are widespread along all the main valley floors. Active channels consist mainly of fine to bouldery gravel with remaining floodplain flats which are subject to overbank inundation capped by fine sands and silts. Use of floodplains is often restricted by the potential flood hazard and fluctuating water table.

Fluvial fans also occur frequently along the main valleys. Main landforms include: small fans at the mouths of gullies or steeper channels, typically coarse gravelly to rubbly showing varying evidence of periodic flooding, channel shifting, and sediment deposition; larger, lower-gradient fans at the mouths of larger tributaries or low-gradient channels, overbank sands cap gravels with varying evidence of fluvial erosion and deposition; and mostly inactive, lower-slope, coalescing deposits and raised fans which are gravelly at depth and often capped by finer sands, present-day streams are incised into the older fluvial sediments, in places through to underlying bedrock or glacial till. In addition, terrace deposits occur sporadically along main channels where downcutting has left remnants of older fluvial sediments raised at various elevations above current base levels (photo 6). Terraces are normally of limited width between the floodplain and valley wall and may consist entirely of granular material or may be only thin deposits capping bedrock or till.

Fluvial deposits which may provide suitable aggregate sources include certain areas of larger fans and the thicker raised fan and terrace deposits, particularly those which are raised significantly above the seasonal water table and potential flood level. Fan material is usually very permeable but subsurface drainage may be restricted by high water tables near active channels. Also, fans may be subject to periodic flooding and channel shifting. Usually smaller active fans and active areas of larger fans are unsuitable as potential sources of aggregate.

<u>Glaciofluvial</u>

Materials that have been deposited by glacial meltwater either directly in front of, or in contact with, glacier ice. These can typically range in texture and structure but usually consist of interbedded gravels and sands; however, some ice-contact deposits may display abrupt textural changes, coarse poorly-sorted gravel, and/or interlayers or lenses of flow till or glaciolacustrine sediments. Well-sorted granular deposits are usually well to rapidly drained but subsurface flow may be impeded where inclusions of impermeable material occur.

Glaciofluvial landforms in the study area consist mainly of kames, kame terraces, and ice-contact fans, most of which have been modified to some degree by post-glacial erosion. Remnant terraces occur at varying levels along sections of all the main tributary valleys. These include older deposits in lower-mid slope positions, such as along Serb and Lee creeks, where extensive gully erosion has left ridges of gravel capping till-mantled slopes. Later-stage terraces are also prominent where they border present-day streams (photo 7). Some consist of thick sands and gravels such as in upper Red Canyon Valley but, more commonly, the gravels mantle till at the terrace surfaces such as along parts of lower Mulwain canyon and in mid Lee Creek valley. A large glaciofluvial complex, featuring thick hummocks and ridges of sand and gravel surrounding kettle holes and old channels, represents a remnant ice-contact deposit which built into upper Mulwain Valley from meltwater diverted through the large channel eroded into the northern ridge.

In the main Zymoetz Valley, glaciofluvial deposits are most common on the subdued uplands bordering the south side of the river. Much of this sediment was derived from meltwater erosion which initiated the formation of the numerous, deeply-incised stream ravines which exist on the south valley slope. Deposits include both ice-contact kames and kame terraces and outwash fans, terraces, and blankets. In many cases, outwash deposits are structurally and texturally similar to fluvial deposits.

Glaciofluvial material which was deposited in front of advancing ice is observed in a few localities where deep erosion has cut through the surface till. A noteable section is near the mouth of Mulwain Creek where a thick sequence of coarse, poorly-sorted gravels capped by fine-textured till is exposed down to creek level (photo 8). Presumably, advance outwash deposits are preserved elsewhere, particularly near the confluences of the major drainages, but remain covered by surface till.

Deposits of post-glacial glaciofluvial sediment often provide excellent sources of aggregate; thick, dry, well-sorted outwash with favourable topography is most suitable. However, common characteristics which may reduce aggregate potential include highly variable textures and structures, till at shallow depth, and proximity of steep slopes to creek and river channels.

Lacustrine (Glaciolacustrine)

Sediments deposited in bodies of standing fresh water, mainly by settling from suspension and turbidity flows. Where much of the sediment was apparently introduced into the lakes by meltwater streams or directly from glacier ice, then a glacial origin is assumed. The sediments are mostly fine textured (silt with some clay and fine sand) and finely laminated, although they may include minor coarse sand and gravel or scattered drop-stones. They have very low permeability and are highly erodible.

No significant post-glacial lake deposits have been identified in the map area suggesting that any meltwater ponding which may have occurred was very short-lived and/or restricted to small, isolated sites. However, it is expected that many of the depressional organic deposits on the subdued uplands are developed on lacustrine muds which infilled small lakes and ponds in post-glacial time.

Evidence of at least one pre-glacial lake can be seen along lower Lee Creek where a thick sequence of till overlies varved glaciolacustrine silts which are exposed at creek level. It may also be presumed that advance glaciolacustrine deposits are deeply buried along with advance outwash in the vicinity of the main valley confluences.

Moraine (Glacial Till)

Material transported and deposited directly by glacier ice. Typically it is a dense, compact, impervious sediment consisting of poorly-sorted mixtures of sand, mud, and rock fragments. Deposits are usually massive or crudely stratified, although lenses of silt, sand, and gravel may occasionally occur. Moraine most commonly is found as lower and mid-slope mantles although gentler, upper-elevation slopes and ridge crests may also be covered with a veneer of till. In general, till rarely occurs on uniform sideslopes exceeding 70%, but thin isolated deposits likely can be found in association with mid-slope colluvial-bedrock complexes. In areas where steep colluvial units lie upslope of morainal deposits, the upper boundary of the morainal landform may be overrun by rubbly silty colluvium. Surface weathering in till often creates a looser-structured, more permeable soil which is well to moderately-well drained.

Morainal deposits in the upper Zymoetz Watershed are ubiquitous; two main groups, related to the Fraser Glaciation, are subdivided on the basis of their genesis and physical properties:

1. silt to clay-rich lodgement tills which are characteristically massive and very compact. These were deposited at the base of active, overriding ice which left a mantle of varying thickness plastered onto the landscape. Erosion of the dominantly fine-grained sedimentary and volcanic bedrock of the region provided the fine constituent material which dominates these tills. Deposits range in thickness from less than a metre (photo 9) to many tens of metres. In general, regular valley slopes are mainly covered by .5 - 5 m of till; exceptionally thick deposits probably mostly occur where ancestral valleys were infilled (e.g. lower Mulwain Creek, lower Lee Creek) (photo 10). In many places, the tills appear more clay-rich with depth (e.g. the large Lee Creek slide-exposure). Silty surface textures seem to dominate although clay tills were also noted in many surface exposures, particularly in upper Mulwain and Red Canyon valleys (photo 11-13).

2. sandy to silty ablation tills which are characteristically crudely stratified to massive, have a significant sand component to their matrix, are less compact, and commonly contain a higher proportion of coarse fragments (photo 14). These deposits occur at the surface as discontinuous mantles with average thicknesses ranging from .5 - 3 m. They mainly formed from melt-out of

stagnating and ablating ice; localized meltwater-winnowing removed some fines, producing localized sorting in the tills and isolated pockets of stratified, granular sediment in close association. These ablation mantles are found at all landscape positions but are thickest and most continuous on the subdued bench-lands flanking Zymoetz River (photo 15). They usually overlie the finer-textured basal till but, in places, directly cover bedrock.

The characteristics and extent of morainal deposits in the study area are very significant for forestry operations. On sloping ground the tills drain reasonably well but on subdued to depressional areas and in seepage accumulation sites poor drainage is common. Erosion potential is high in these materials; evidence of long-term gully erosion can be seen on most slopes in excess of 40% which are mantled by thick till. In addition, active erosion and mass movement (ranging from rapid flow slides to slow-moving slumps) are common processes where thick till deposits have been undercut by post-glacial stream action.

Organic

Material resulting from vegetative growth, decay, and accumulation in and around closed depressions and on gentle slopes where the rate of accumulation exceeds that of decay. They usually consist of unstratified peat which is water absorbent and very poorly drained. A high water table is common.

Organic deposits are widespread in the study area, infilling isolated depressions on subdued terrain within Zymoetz and Red Canyon valleys and mantling much of the wet valley floor bordering upper Mulwain Creek (photo 16). Deposits vary in thickness but may reach several metres in the larger depressions. Plateau depressions are mainly controlled by till and bedrock landforms and may be partially filled with underlying lacustrine silts. In upper Mulwain Valley the organics mainly mantle thick, gently sloping, fine-textured moraine, although the occasional deposit overlies floodplain gravels.

Bedrock

Bedrock units are mapped where rock outcrops occur at the surface or are mantled by less than 10 cm of surficial material. Specific rock types are not indicated on the terrain maps; a general distribution of bedrock is shown on figure 2. Rock outcrops occur mainly on the upper, steep valley sides (photos 5 and 17) and along sections of all the deeply-incised creek canyons and stream ravines. Most upper slopes also have discontinuous colluvial mantles around isolated bedrock cliffs. Many of the creeks and gullies are incised into near-vertical canyons (photos 2 and 3). Bedrock topography is also prominent in some plateau areas where rock ridges and hummocks are only thinly mantled by till, colluvium, or weathered rock and outcrops are common.

Softer, finer-grained rocks (tuffs, siltstone, shale) and highly fractured sequences of more competent facies (flows, sandstone) weather and break quite readily. These are more easily worked by heavy machinery but are also more susceptible to erosion. Natural failures and gully-wall ravelling (photos 2, 18, and 19) are more common in the softer rocks and, when disturbed, they will tend to break down to fine sediment. Massive volcanic flows and breccias, sedimentary sandstones and conglomerates, and igneous granitics are, in varying degrees, much harder and more competent rock types. Blasting will usually be required for excavations and the shot rock will be mainly solid fragments. However, layers and inclusions of softer, more friable rock can be expected in most volcanic and sedimentary sequences.

7.0 GEOMORPHIC PROCESSES

Processes of weathering, mass movement, erosion, and deposition modify surface materials and landforms. Process modifiers are attached to the terrain symbols on the Terrain Classification Maps where geomorphic processes have significantly modified a landscape unit. Geomorphic processes identified on the maps include: snow avalanching, gullying, mass movement, periglacial processes, meltwater channelling, and kettling. The latter two are processes which were active during deglaciation (erosion by flowing meltwater and the formation of depressions by the melting of ice blocks incorporated in surficial deposits), but which have been inactive since then. The other processes are presently active or have been active some time during postglacial time.

Periglacial processes are non-glacial phenomena of cold climates; they include frost-related processes commonly occurring in alpine and subalpine areas. The occurrence of these has little or no effect on forestry operations. The more important processes are those which affect many areas of steeply sloping valley sides, from rock-dominated upper slopes to lower scarps bordering floodplains. These slope-modifying processes usually involve complex interactions of such factors as climate, bedrock geology, topography, and characteristics and stratigraphy of unconsolidated materials. They are described as follows:

Snow Avalanching

Avalanching is the rapid downslope movement of snow and ice, as well as incorporated rock, surficial material, and vegetative debris, by flowing and sliding. Avalanche slopes occur in the upper ends of the tributary valleys and on most upper ridge slopes. All initiate in alpine or subalpine areas but only occasionally reach the valley floors of the upper valleys (photo 20). Snow avalanching is not a concern on most of the forested slopes bordering the major valleys of Zymoetz River and Red Canyon and Mulwain creeks.

Winter and early spring logging should avoid avalanche areas because of the high safety hazard. In some cases, logging may increase avalanche activity. Harvesting higher elevation forests on steep upper slopes could create conditions conducive to avalanche initiation and, hence, damage to downslope timber. Also, logging of timbered slopes immediately adjacent to avalanche areas could, in extreme snow conditions, result in some areal extension of avalanche runout. Permanent roads crossing avalanche tracks will usually require upgrading each spring.

Gullying

The development of individual and subparallel, steep-sided, narrow ravines is the result of the modification of sloping terrain by fluvial erosion and mass movement. Gullying of slopes is a common landscape feature in the study area and has important implications regarding surface erosion, slope failure, and the transportation of mass wastage material to lowland areas. Most active gullies have a high capability for transporting fine sediment along their channels. Steep-gradient gullies may also have the capability of mobilizing introduced coarse debris into a torrent flow and transporting it a considerable distance.

Deep, steep-sided ravines are considered as sensitive sites because of the possible adverse effects forestry operations may have on gully-wall and channel stability. Roads built through these gullies usually require extensive, deep cuts which, unless care is taken, can adversely alter surface and subsurface slope drainage and constrict the natural channels. Poorly planned yarding can cause extensive disturbance on gully sideslopes and along channels, lending to increased erosion and instability.

The most significant gullies and gully systems in the map area are those that are directly linked by an active channel to a valley-bottom creek or river. All of these must be considered as potential sources of sediment. Three types of gully form are recognized: short, steep-gradient gullies incised into scarps or canyons directly bordering a floodplain; steep-sided, steep-gradient gullies incised into uniform bedrock slopes which extend from upper slopes to the valley floor (photo 20); and deep, steep canyons confining low to moderate-gradient channels which are incised in benched terrain, partly in thick surficial sediments and partly in bedrock (photo 2). The first two types of gully form have high potential for transport of mass movement debris direct to the valley floor and thus have the most significant potential sedimentation impact. Forestry operations should be severely restricted around all these gully types.

Lower and mid slopes dissected by small individual gullies with low channel gradients and long run-out zones or by numerous, subparallel inactive gullies are essentially disconnected from any valley-floor creek and thus are considered to have low to very low sedimentation potential. Nevertheless, constraints to conventional forestry operations (e.g. special road-building techniques and yarding prescriptions) may be required in such areas to minimize site disturbance and soil degradation.

<u>Mass Movement</u>

Mass Movement is the downslope transfer of earth materials under the influence of gravity. Rapid mass movement types include debris slides, flows, and torrents and small rockslides-rockfalls. They occur throughout the study area but are restricted to a few critical terrain types. Evidence of slow or small-scale mass movement events such as small slump blocks, tension cracks, and accelerated creep (tilted trees) is used to indicate sites of potential landsliding. These mainly occur in bedrock headscarps, in old landslide deposits which may still be active, in very wet surficial deposits, and along high, steep scarps of thick surficial materials bordering main creeks.

Small rockslides-rockfalls are relatively common on upper slopes where steep rock cliffs or rocky gully sidewalls and headwalls dominate (photos 17 and 20). Coarse-textured colluvial deposits (talus) usually accumulate below these areas (photos 5 and 17). These types of failures are usually of limited concern for forest harvesting because they occur in mostly inaccessible areas with low timber values. The main effects such failures may have on forestry operations are the hazards they pose to downslope runout zones and the surface disturbance they may cause in these zones.

Slope instability in the potentially operable forest mainly occurs along scarps and canyon walls bordering deeply incised creeks and gullies. Failures on open slopes are rare and usually involve isolated seepage which saturates the soil mantle triggering the instability. Slides originating on freely-drained slopes will be drier and not travel long distances. Wetter slides or flows tend to travel farther with greater downslope impacts because of their fluidity. Flows can initiate in saturated colluvium but are more likely to occur on seepage slopes underlain by fine-textured glacial till.

Failures along creek and gully scarps will have a direct, immediate effect on sediment loading of the fluvial system. Three main types of instability occur on these canyon walls: slump-flows in thick sequences of surficial deposits (photos 7, 11, and 12); dry ravelling and surface sliding of surficial material being undercut by lateral creek erosion (photos 8, 10, and 13); and ravelling and surface sloughing of fine-textured colluvium and weathered fine-grained bedrock (photos 2, 3, 4, 18, and 19). Logging and road building should avoid these areas to prevent causing any increase to the natural instability.

Debris torrents are channelized debris flows which can travel long distances down steep-gradient gullies. These can also have a significant impact on the introduction of debris into valley-floor streams. In most cases, torrents are likely initiated by rockfalls, debris slides, or snow avalanches introducing a slug of debris into steep channels. Debris-charged flows then move rapidly along the channel, often scouring it to bedrock before depositing debris in low-gradient (less than 10%) run-out zones. In the study area only a few torrent gullies are recognized, mainly in upper Lee Creek valley (photo 20) with an occasional site in upper Red Canyon Valley and upper Ledbetter Valley. The main torrent gullies tributary to Lee Creek are separated from the active floodplain by wide run-out zones across extensive valley-floor fans (photo 21). Thus, the potential for direct mass movement deposition into Lee Creek from a debris torrent is low to moderate. Forestry concerns in these areas are two-fold: logging and roads should be prohibited from sidewalls and headwalls of torrent-prone gullies to prevent any disturbance which may initiate or add to the magnitude of a debris flow, and all road crossings of channels emanating from a torrent-prone gully must account for the potential hazard posed by scouring and/or debris deposition by being securely located, designed, and constructed.

Slow or small-scale mass movement features are indicative of areas which may be susceptible to more destructive landsliding. The largest of these potential failures are associated with tension cracks and large semi-detached bedrock fragments on ridge crests between Ledbetter and Newton creeks and on north and west facing cliffs east of Bloody Mary Creek. Forestry operations will have no impact on these inaccessible sites but downslope risk posed by such bedrock instability is very difficult to quantify or predict. Evidence of active movement (slump terracettes, tilted trees) was observed in an old landslide deposit below one of these bedrock headwalls (moderately steep slope on the south side of Red Canyon Creek) (photo 22). Slopes below the Ledbetter-Newton ridge display similar characteristics on the aerial photos and may also be subject to recent movement. Forestry operations should be precluded from these old slide areas where definitive indicators of recent movement can be verified in the field.

Slumping, surface sloughing, and rapid soil creep also provide evidence that deposits of surficial material are potentially unstable. These are unlikely to be determined by aerial photographic interpretation and must be verified in the field. Sites which are commonly identified in the study area occur on shallowly incised creek and gully banks, on sideslopes of inactive gullies, and on very wet morainal slopes, often bordering a stream. The most dramatic evidence for potential failure in thick surficial deposits was observed along the scarps bordering lower Mulwain Creek canyon. Fresh scarps, cracks, slump blocks, tilted trees, and excessive seepage all suggest very high instability potential (photo 23). Logging and road development should be precluded from most of these sensitive areas (particularly the latter example) and should only be considered where mitigative measures can prevent or minimize an increase in soil erosion and mass movement.

8.0 TERRAIN STABILITY AND SURFACE EROSION POTENTIAL

Individual terrain units have been assessed according to their estimated stability and erosion potential following logging. This classification, indicating the expected response of the landscape to clearcut forest harvesting and road development, is shown on the Terrain Stability and Erosion Potential Maps. Explanations of the terrain stability and erosion potential classifications and the criteria used in determining them are detailed in appendices I and II.

Terrain stability rankings provide a relative assessment of mass movement potential but give no indication of expected landslide frequency, magnitude, or impact. Ratings are intended to "flag" potential problem areas; actual decisions on logging or road construction should be based on careful field evaluation by appropriate terrain or forest engineering personnel. Problems of instability are expected to be most severe in classes IV, IVc, and V. There is a high potential for landslides within class V units during and following road construction and following conventional clearcutting. Class IV units have a lower potential for clearcut failures but road-associated problems are probable if special construction and maintenance techniques are not considered. The potential for road-associated landslides is lower in class IVc units but clearcut failures are more probable because of slope wetness, soil texture, or extensive, small-scale surface disturbance.

Usually there are only minor to no instability problems expected on classes I, II, and III units following logging. However, it should be noted that within class III terrain, small areas may occur which are potentially unstable; in effect these are inclusions of class IV or IVc ground which are too small to identify during reconnaissance mapping. Similarly, inclusions of stable ground may occur within class IV, IVc, and V units. In a few locations some terrain stability polygons are given composite ratings in order to highlight complex inclusions of sensitive terrain which are cartographically difficult to delimit on their own at the scale of mapping. Composite ratings are only used for two main terrain types: narrow, incised, inactive gullies in a uniform slope (e.g. III//IVc) and narrow terrace scarps bounding a level or subdued surface (e.g. I//III or II//IV).

Gullied terrain and individual gullies are rated by a dual component (Maynard, under revision). Sideslope stability potential is rated by the same 5-class system as open-slope stability. The other component estimates the capability of the gully channel(s) to transport mass movement debris through the gully system. Ratings are given as high, moderate, or low. This assessment has important implications regarding gully channel and bank erosion and downstream sedimentation. An example of the stability rating applied to a gully unit is IV-M.

Ratings of surface erosion are a qualitative assessment of the likelihood of sediment generation during and after logging development. Areas of major concern are roads, recent landslides, sensitive landforms, and sites excessively disturbed by yarding or site preparation; usually surface erosion is not a major concern in most clearcut areas. The surface erosion ratings are not intended in any way to restrict logging; rather, they should be used to "red flag" potential problem areas so that appropriate preventive or remedial action can be planned. Erosion potential is rated by a 5-class system ranging from very low to very high.

Areas which could be most severely affected by logging development are those stability class V units which are rated as having high or very high surface erosion potential. These include all the deeply incised, steep-sided gullies and canyons where colluvial and bedrock banks are actively sloughing or thicker surficial deposits are actively failing and the scarp and lower-valley surficial landforms where surface failures, slumping, and gullying are common. All the major creeks and rivers and most of the main tributaries are bordered by such areas for parts of their length (photos 2-4, 6-8, 10-13, 18, 19, 23, and 24). These slopes are very significant because they are mainly surrounded by productive, accessible forest but are highly sensitive to disturbance because of their close proximity to the main drainages of the watershed.

Erosion and mass movement activity in these ares will have a direct sedimentation impact on the drainage system. All streams have the capability of transporting the finer fraction of sediment; only the steep-gradient gullies have the potential to move mass movement debris long distances. These areas should remain in protection forest to prevent increasing the sediment yield to the streams. The old fire which destroyed the bench-land forest on the south side of Zymoetz River, west of Serb Creek provides evidence of the destabilizing effect of removing trees from the canyon walls; slide and erosion activity along lower Gass Creek is much more intensive in the burnt area than along forested canyon reaches (photo 24).

Other highly sensitive class V - High erosion potential areas which are much less obvious include old landslide deposits on moderate to moderately steep slopes which display signs of slow, active movement. Slump-earthflows in clay-rich till along mid-Mulwain Creek and an old rockslide deposit on the south side of Red Canyon Creek (photo 22) may reactivate if disturbed and should be left as protection forest; similar-looking rockslides are also mapped on the ridge between upper Ledbetter and Newton creeks.

Mid to upper, steep colluvial-bedrock open slopes and bedrock-dominated scarps which are subject to recurrent failures or show significant evidence of old landsliding or potentially unstable features, such as tension cracks, are also rated as stability class V (photo 17). Erosion potential of these is mainly low to moderate but may be high where significant, finer-textured colluvial deposits are incorporated. Many of these areas are considered inoperable, either because of inaccessibility, poor timber, or both. Logging should normally be precluded from these class V slopes, but some selective development in and around sensitive sites may be considered where the slopes are disconnected from all streams and thus sedimentation potential is negligible.

All open colluvial-bedrock slopes over 70% which show no evidence of mass movement are rated stability class IV; erosion potential is usually low to moderate depending on thickness and texture of the colluvium. These are scattered throughout the map area but also occur mainly on mid to upper valley slopes. Despite their apparent surficial stability, class IV ratings are applied because of their steepness and the potential for road-sidecast failure. Careful harvesting with full-suspension systems usually does not lead to significant instability problems on such slopes; however, road construction should be minimized. If roads are necessary then special construction conditions (e.g. full-bench cuts and endhauling) should apply. Isolated debris failures may be expected in such areas so proximity to streams and sedimentation potential must be considered in the development plans.

Harvesting-related instability is of more concern in class IV and IVc gullied and scarp units. These are common in the operable forest along certain reaches of most main creeks and streams in the watershed. Erosion potential for these areas is usually rated moderate to high. Any disturbance from logging or road building which exposes excessive mineral soil and alters runoff patterns may lead to increased erosion and/or cause mass movement. These areas should normally be avoided for any logging development where there is a high potential for stream sedimentation. Where impacts on a nearby stream are considered minimal or development of a selective site is necessary (e.g. road crossing of a gully), then operations may be considered provided that they are well planned and properly designed and supervised. Special conditions, such as no wet-weather operations, may be required for some areas.

Most of the operable forest in the watershed is on stability class II and III ground. Where erosion potential is low to moderate, as for most well drained colluvial, glaciofluvial, and fluvial slopes less than 70% and morainal slopes less than 60%, there are few constraints to logging operations. Again, the most sensitive sites occur adjacent to creeks and streams, particularly where gullying or seepage contributes to a rating of high erosion potential. Any logging development in areas rated stability class III with high erosion potential or where minor inclusions of class IV or IVc are indicated must be carefully considered. Prudent layout of roads, landings, and block boundaries is important as is a yarding plan which minimizes disturbance of the sensitive sites such as seepage slopes and gullies. The potential for stream sedimentation is an important factor when assessing development plans in the more erodible terrain. Special conditions, such as avoidance of extreme wet periods may be required on yarding and road building in these areas.

Although stability and erosion concerns are minimal in class I terrain, logging development is often precluded by such factors as high water table and poor timber values in and around large organic deposits and depressional wetlands and by fisheries and wildlife concerns and flood hazard along floodplains and valley-floor streams.

9.0 SEDIMENT TRANSFER CAPABILITY

All main stem and tributary channels have been assessed as to their sediment transfer capability according to the method described by Hogan and Wilford (1989). Ratings are derived by combining an assessment of the potential for sediment delivery to a channel segment and the potential for sediment to be transported through that particular reach of the channel.

The Sediment Transfer Capability Maps show a rating symbol for each distinguishable stream, creek, and river channel segment. Most of the smaller channels are marked on the TRIM base maps. A few additional streams which were identified during the field reconnaissance or by aerial photo interpretation have been added. Some steep-gradient channels shown on the base maps are avalanche or landslide tracks and, in fact, have little or no surface flow; these are not rated in this system. The rating symbol consists of three components, each of which has five classes:

1. sediment delivery potential is rated by classes I to V and is based on:
   - surface erosion potential and terrain stability of adjacent and nearby slopes
   - distance and landscape characteristics between an existing or potential sediment source and the stream
   - presence and stability of a floodplain
   - stream-bank stability
2. sediment through-put potential is rated by classes 1 to 5 and is based on:
   - channel gradient
   - stream flow volume
   - presence of lakes or wetlands
   - width of valley flat in relation to channel width
3. sediment transfer capability is rated by classes very low to very high and reflects a linkage between the amount of sediment input into a channel segment and the ability of that channel reach to transport the sediment.

An explanation of the rating system and of the criteria used to define the various rating classes are presented in appendix III.

The upper Zymoetz Watershed features a number of main-stem and valley-tributary channels which are low gradient and have no significant barriers to fish migration. Anadromous fish have been identified in Zymoetz River above the Serb Creek confluence, in Coal Creek, and in Mulwain Creek up to its confluence with Cruise Creek. Good habitat with no apparent limitations to fish use also exists in Serb, Caribou and Lee creeks, in lower to mid Red Canyon Creek, and in upper Mulwain Creek; however, there is little information about these streams other than some limited evidence of resident fish. The lower reaches of some of the smaller tributaries such as Irving, More, Johnson, and Silcote creeks may also provide suitable fish habitat.

All these main stem and main tributary channels have at least a moderate potential for sediment through-put; that is, all fine sediment (fine sand, silt, and clay) readily moves through these systems. Coarse sediment (coarse sand to gravel) is also transported through many of the reaches, albeit in slower, more episodic fashion. Along all the main channels are segments of either tightly confined reaches where there are no gravel bars and all sediment is transported (very high through-put) or confined reaches with minor, coarse gravel bars and perhaps a narrow valley flat where all fine and medium textured (coarse sand-fine gravel) sediment is transported (high through-put) alternating with broad channel-floodplain reaches with extensive gravel bars where fines move readily through the system but coarse sediment is temporarily stored (moderate through-put) (photos 25 and 26).

The implication of this through-put assessment is that any sediment entering the main channels will eventually move into and along Zymoetz River. In particular, fine sediment can be expected to be transported almost immediately upon entering the creek or river. Thus, areas of particular concern along the main channels are where the potential for sediment delivery to the system is high to very high. Most of these occur in confined canyon sections; it is only at the upper ends of the tributary valleys (e.g. Lee, Caribou, and Johnson creeks) where main valley sideslopes directly border the channels (photo 20). Canyons are eroded into a combination of thick surficial deposits and bedrock and both the fine-textured till with associated drift materials and the fine-grained weathered rock may contribute fine sediment directly to the channels (photos 2-4, 6, 8, 10-13, 18, and 19). Field observations during a rainstorm (July 29, 1993) showed that considerable surface erosion of fines occurs on canyon walls and river banks where undercutting or slope failure exposes bare material (photos 27 and 28).

The smaller tributary streams and creeks are also potential sources of sediment which can be transported to the main channels. There are very few depositional stream reaches which will act as sediment "sinks" located between valley-slope channels and main, valley-floor channels. Wetlands in upper Mulwain Creek (photo 16) and wide fans and aprons in upper Mulwain and upper Lee valleys (photo 21) create some sites where most sediment will deposit, but most of the tributary streams will transport at least the fine sediment to the valley bottom. Flow regime of these smaller creeks is obviously instrumental in determining size and volume of sediment which is transported. Many of these channels are incised and tightly confined throughout their length and most of the reaches are rated as having high to very high through-put potential (photo 29). Occasional widening in their valley flat and channels across narrow fans may be rated as moderate through-put potential where coarse sediment is deposited for short to long-term storage (photo 30).

The implication for these smaller systems is that fine sediment can be expected to fairly readily move from a source area to a main valley-floor channel; higher flows will episodically transport temporarily stored deposits of fine to coarse material. Again, field observations provided evidence of this transport capability. During dry weather (June 27, 1993) with low stream flow, snow melt in the headwater bowl of Gass Creek incorporated considerable fine sediment into the runoff and the creek ran dirty brown throughout its length as a confined channel. Deposition of the silt was gradual along the 1 km gravel fan reach (rated as moderate through-put) and the water was clear at the Zymoetz confluence; however, any rainstorm which increased the base flow of this creek would reactivate movement of this sediment. In the rainstorm of July 29, Red Canyon Creek was very dirty (photo 31) as the result of high, fine-sediment transport from Bloody Mary Creek. Movement of this material originated in confined channel reaches with high and very high through-put ratings (photo 28) but continued along long stretches of broad channel rated as moderate through-put.

Most of these smaller streams are incised into gentle to moderately steep open slopes where sediment delivery mostly occurs from the confining canyon walls or from tributary gullies; only in headwater bowls or upper valleys are bordering slopes a potential sediment source. Similar to the main channel canyons, disturbed and failing fine tills and weathered rock on the creek banks create high to very high potential for sediment delivery. Thus, all the creek reaches rated as moderate to very high for both through-put and sediment delivery potential must be considered as sensitive areas and any forestry development in and around such sites should evaluate the extent and proximity of the potential sources of sediment to the creek channel.

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APPENDIX I
TERRAIN STABILITY CLASSIFICATION AND CRITERIA

APPENDIX I

TERRAIN STABILITY CLASSIFICATION

Terrain units are qualitatively assessed according to their estimated stability following conventional logging. This type of classification indicates the expected response of the landscape to clearcut forest harvesting and road development. Terrain factors which are considered important in assessing this estimated stability are surficial material genesis and texture, slope gradient, soil drainage, geomorphic processes, landscape position, and bedrock properties. Based on the relative importance of each of these factors, individual terrain units are assigned to an appropriate stability class. Following is a description of expected stability and logging implications for each stability class:

Stability Class I

- No significant problems of instability expected.

Stability Class II

- No significant problems of instability expected; low probability of minor inclusions of sensitive terrain.
- Normal road construction and logging practices should not significantly affect terrain stability.
- Minor road-cut slumps and bank sloughing may occur leading to periodic maintenance of ditches; regular road inspection should occur.

Stability Class III

- Minor problems of instability expected; minor inclusions of sensitive terrain are possible but no natural slope failures occur.
- Minor stability and erosion problems should be expected, particularly with road construction on regular slopes greater than 50% and on wet or gullied slopes with

gradients as low as 35%; regular road maintenance and inspection and repair of ditches and culverts required.

- Road planning should include an engineering review in potentially sensitive areas and provision for seasonal and/or semi-permanent deactivation when road-use is suspended or not regularly required.

- Clearcutting should not significantly reduce terrain stability; there is a low likelihood of post-logging failure, although small debris slides and slumps may be expected on wet or gullied slopes.

Stability Class IV

- Problems of instability are expected; marginally stable steep slopes and sensitive terrain. Natural landslides are rare but terrain conditions are either similar to nearby unstable slopes or show evidence of small-scale instability and/or excessive steepness.

- Moderate to high potential for road-associated landslides. On-site geotechnical evaluation is required. Avoid locating roads but, where they are necessary, special construction techniques and on-site supervision are required. Critical terrain includes uniform slopes in excess of 65%, excessively wet slopes, and deeply-incised gullies. Regular road maintenance and inspection and repair of ditches and culverts required, particularly during all wet periods. When road use is discontinued carry out permanent deactivation and resloping of road prism.

- The potential for significant landsliding following clearcutting ranges from moderately low to high. Harvesting with full-suspension systems is required. Sensitive terrain includes seepage and disturbed slopes, shallow, steep colluvial slopes, and high gully and creek banks. Detailed geotechnical evaluation may recommend deferring logging from highly sensitive areas.

Stability Class IVc

- Problems of instability are possible; moderately steep slopes with no natural landslides but considered highly sensitive because of drainage conditions, material texture, gullying, and/or significant surface disturbance. Detailed geotechnical evaluation is recommended.

- The potential for road-associated landslides is low to moderate (similar to class III) because of lower slope gradients; road drainage problems may occur on seepage slopes. Regular road maintenance and inspection and repair of ditches and culverts required. Road planning should include an engineering review and provision for seasonal and/or semi-permanent deactivation when road use is suspended or not regularly required.

- Landslide potential following clearcutting is moderate to high. Harvesting with full-suspension systems is required. Special logging prescriptions or protection-forest status may be recommended.

Stability Class V

- Significant problems of instability are expected; active or recurrent landslides initiate within mostly steep terrain. Also included are very sensitive terrain types such as steep-sided gullies and very wet slopes where small-scale mass movement and/or surface disturbance is significant.

- High to extreme potential for continued or accelerated mass movement in parts of the unit during and following road construction and following conventional clearcutting. Logging activity (road building and clearcutting) should normally be precluded from this unit.

- On-site geotechnical evaluation may determine that locating specially constructed roads or careful logging of selective sites is feasible in some areas. Any such activity requires thorough planning, engineering, and supervising at all stages of operation through to complete deactivation and site rehabilitation.

TERRAIN STABILITY CLASS CRITERIA

Criteria for determining the various terrain stability classes have been developed from experience and research in numerous studies of predicting post-logging stability potential. Relevant published works include Howes (1987), Rollerson (1992), and Rollerson et al (1986). The writer has extensive experience in carrying out terrain stability studies in mountainous areas of British Columbia; particularly relevant are criteria used in an area of similar physiography and geology (Maynard, 1987b and 1990a).

Following are the main terrain types and criteria assigned to each stability class:

Stability Class I

- Valley-floor and depressional floodplains, wetlands, and organics.
- Fluvial and glaciofluvial terrace surfaces set back from high scarps.
- Lower slope fluvial and colluvial fans - well-drained slopes less than 25%.
- Other lower slope and enclosed depressional units less than 20% regardless of drainage.

Stability Class II

- Well drained morainal and glaciofluvial slopes mainly between 20-50%.
- Well drained toe slopes between 20-50% with minor seepage and/or wet depressions; may include morainal or glaciofluvial landforms and/or colluvial-fluvial cone-apron complexes.
- Uniform, well-drained colluvial slopes less than 55%; irregular slopes may contain localized steeper segments where small bedrock outcrops occur.
- Morainal-colluvial complexes with minor bedrock outcrops; well to moderately well drained with isolated rock-controlled slope segments up to 60%.
- Wet toe slopes or mid-slope seepage sites, usually moraine or fine-textured colluvium, with gradients mainly less than 40%; fine slope wash or organic veneers may occur as minor components.
- Benched or plateau areas with thin moraine, weathered rock, and small organics mantling bedrock; slopes range from 5-50% with variable drainage.
- Rock controlled ridge crests in alpine-subalpine; thin colluvium and weathered rock on well to rapidly drained 10-60% slopes; periglacial processes may occur.
- Any subdued or gently sloping areas located immediately above steeper slopes.

Stability Class III

- Well-drained morainal and glaciofluvial slopes mainly between 45-70%.
- Gullied and moderately drained morainal slopes mainly between 35-60%; slightly

steeper gradients are tolerable where gullies are inactive or drainage is better.

- Wet till slopes less than 50%; organic veneers or fine slope wash may occur.
- Well-drained morainal-colluvial complexes with minor bedrock on slopes of 55-70%
- Thick colluvium on uniform, well-drained slopes between 50-70%; minor gullying may occur.
- Irregular slopes with near-surface bedrock; dominantly colluvium with lesser till veneers; slopes may range from 40-75% and drainage is well to rapid; small bedrock gullies and outcrops may occur.
- Confined streams and gullies where bank sideslopes are less than 5 m high and 65% gradient and channel gradient is low to moderate.

Stability Class IV

- Well-drained morainal slopes ranging from 60-75% and averaging greater than 65%; little evidence of small-scale instability.
- Glaciofluvial and fluvial scarps in excess of 65%; well to rapidly drained.
- All bedrock-controlled slopes in excess of 70% where there is no evidence of recent instability; small gullies incised in bedrock may occur along with isolated seepage sites or small-scale disturbances. Evidence of old landsliding may occur provided that most of the unit appears stable. Surficial material is mainly colluvium with minor, well-drained morainal veneers.
- Very steep, stable bedrock slopes; 80-130% are common gradients; coarse colluvial veneers are subordinate components.
- Deeply-incised, steep-sided, bedrock-controlled creek gullies and canyons with no active or recurrent mass movement; minor seepage, creep, and small sloughs may occur in isolated sites in colluvial veneers; channel gradients are low to high.
- Gully banks and creek scarps greater than 5 m in height with slopes exceeding 65%; eroded into surficial deposits, often through to bedrock. Minor seepage and surface sloughing but no significant evidence of active mass movement.
- Old rockslide debris, coarse-textured on slopes of 40-70%; minor slumping suggests the potential for some reactivation of the slope debris.

landslides.

- Deeply-incised, steep-sided, steep-gradient gullies and gully complexes which show evidence of recent or recurrent debris failures and/or torrents.

- Mantle of old landslide debris; silt matrix and slopes of 45-75%. Evidence of active, slow mass movement is widespread in the form of slump terracettes and tilted trees.

- Incised, steep-sided gullies where there is widespread evidence of small-scale instability on the sideslopes or headwalls creating a high potential for debris torrent initiation.

- Deep, steep-sided creek gullies and canyons eroded through surficial materials into fractured bedrock; evidence of instability may include crumbling bedrock, colluvial sloughing, and slump-flows of unconsolidated deposits; channel gradients are low to moderate.

APPENDIX II
SURFACE EROSION POTENTIAL CLASSES AND CRITERIA

APPENDIX II

RATING SURFACE EROSION POTENTIAL

This rating is a highly qualitative assessment of the potential for sediment generation during and after logging development. Usually surface erosion is not a major concern in clearcut areas, except for roads, recent landslide tracks, sensitive landforms, and sites extensively disturbed by yarding or site preparation. Terrain units have been subjectively assessed according to their estimated erodibility in a manner similar to that done for determining slope stability. Many of the same terrain factors (surficial material genesis and texture, slope gradient, soil drainage, geomorphic processes, landscape position, and thickness of deposit) are considered when determining both erodibility and stability.

The surface erosion ratings are not intended in any way to restrict logging; rather, they should be used to "red-flag" potential problem areas so that appropriate preventive or remedial action can be planned.

No definitive studies have been carried out on logging-related surface erosion on the B.C. coast. Previous attempts to qualitatively rate surface erosion potential have been undertaken as part of terrain stability assessments in other north coast areas (e.g. Rollerson, 1986 and Maynard, 1987 a and b, 1990 a and b). The following assumptions form the basis of rating surface erosion potential:

- Fine-textured sediments (clay to fine sand) will have a higher potential for sediment generation than medium-textured materials. Coarse-textured, rubbly materials will have a relatively low potential for sediment production.
- As slopes steepen, a higher energy erosional environment exists.
- On steep slopes more surface area is exposed during road construction than on gentle slopes.
- Thicker deposits have a higher potential for total sediment yield.

- Gullied deposits have undergone erosion in the past and, thus, are considered more susceptible to future erosion.

- Slopes with a high potential for post-logging failure are ranked higher than areas of lower stability class; more sediment is available for erosion if sites are excessively disturbed or exposed by landsliding.

SURFACE EROSION POTENTIAL CLASSES

VL - Very Low Potential

- Flat or gently sloping terrain; organic soils and floodplains.

- Minor bank and channel erosion caused by disturbance of streams.

L - Low Potential

- Gentle slopes and steeper but short slopes.

- Minor erosion of fines from ditch lines and disturbed soils may be expected; water should not be channelized onto sensitive sites.

M - Moderate Potential

- Moderately steep slopes and long slopes; finer-textured, erodible soils.

- Water management is very important; erosion of ditches and across disturbed sites is expected.

- Plan preventive remedial actions for disturbed areas; grass seeding and road deactivation should be done.

H - High Potential

- Moderately steep slopes and highly erodible soil textures or steep slopes with coarser-textured materials.

- Major problems can be expected where water is channelized onto or over these areas.

- Mitigative planning must be thorough to permit road development; disturbed sites must be immediately revegetated and all surface water controlled.

VH - Very High Potential

- Steep slopes and erodible soil textures; evidence of gully erosion and/or active surface erosion.
- Severe surface and gully erosion problems exist which may preclude any logging development.
- Protection forest is usually recommended.

CRITERIA FOR RATING SURFACE EROSION POTENTIAL

Very Low

- Valley-floor and depressional floodplains, wetlands, organics, and fans; slopes less than 15%.
- Coarse, bouldery fans sloping to 25%.
- Depressional morainal terrain, impeded drainage and slopes less than 10%.

Low

- Fluvial and glaciofluvial deposits with slopes mainly less than 40%; includes fan deposits with fine-textured surface capping on slopes as low as 10%.
- Coarse, well-drained colluvial-fluvial fan-cone-aprons on slopes up to 55%.
- Thick, well-drained moraine on slopes of 20-35%.
- Thin, well-drained moraine on slopes mainly less than 55%.
- Depressional morainal terrain with wetland complexes and small channels; slope up to 25%.
- Thick, coarse-textured, well-drained colluvium on slopes up to 70%.

- Thin, fine-textured, well-drained colluvium on slopes up to 70%.

- Colluvial-bedrock complexes with average slopes exceeding 70%; colluvial veneers are coarse textured.

- Coarse deposits of old landslide debris; stable, coarse material.

- Rock dominated, steep to very steep slopes; some coarse, rapidly drained colluvium; may be subject to bedrock instability.

- Complexes of thin moraine, colluvium or weathered rock, and minor organics on bedrock-controlled hummocks and ridges; slopes mainly between 20-70%.

Moderate

- Fluvial and glaciofluvial granular sediments on slopes of 35-70%; includes granular mantles over till where drainage is well to rapid.

- Gullied glaciofluvial slopes mainly between 25-50%.

- Thick, well-drained moraine on slopes of 35-60%; where inactive gullies and/or minor seepage occurs slopes are between 30-50%.

- Thin mantles of well-drained till on slopes between 50-70%; includes units where small gullies are incised through to bedrock and complexes with thin, fine-textured colluvium.

- Wet moraine or fine-textured colluvium with gradients mainly less than 50%; fine slope wash or organic veneers may occur as minor components.

- Very wet toe slopes and seepage sites; fine colluvial slope wash and/or organics cap till on slopes 10-30%.

- Thick, well-drained colluvial deposits with fine-textured matrix on slopes of 55-70%; minor gullying may occur. Where silty textures dominate or seepage is common slopes only up to 55%.

- Gullied colluvial slopes with gradients 50-75% where thick colluvium is coarse textured or the colluvial mantle is thin.

- Colluvial-bedrock complexes with slopes greater than 70%; includes thin silt-matrix colluvium and coarse colluvial veneers which are gullied or failing.

- Incised, steep-sided creek gullies and canyons with no active or recurrent mass movements; channel gradients are low to moderate; till and/or glaciofluvial gravels are at scarp edge but banks are mainly rock and colluvium.

<u>High</u>

- Glaciofluvial and fluvial scarps in excess of 65%; gullied scarps have slopes of 45-75%. Includes actively failing or eroding granular terrace deposits.

- Thick, well-drained moraine on slopes in excess of 60%; where slopes are gullied or subject to seepage or small-scale disturbance gradients are as low as 45%.

- Thin mantles of well-drained till on slopes in excess of 65%; includes units where small gullies are incised through to bedrock and complexes with thin, fine-textured colluvium.

- Disturbed, poorly-drained, slump-earthflow in clay-rich till; slopes are less than 50% with ponded water, tilted trees, and probable on-going slow movement.

- Open-slope colluvial-bedrock complexes, usually exceeding 70% which show evidence of natural failures and/or gullying; thin colluvium has a finer matrix.

- Mantle of old landslide debris, slopes of 45-75% with a significant silt component to the matrix and showing considerable evidence of slow mass movement.

- Accumulation of silt-clay slope wash on 20-55% wet slopes; thin organics cap the surface in places and small channels drain the surface.

- Deeply-incised, steep-sided, bedrock-controlled gullies where failure potential of the sideslopes is high; may be prone to debris torrents.

- Deep, steep-sided creek gullies and canyons eroded through surficial materials into fractured bedrock; evidence of instability includes crumbling bedrock, colluvial sloughing, and slump-flows of unconsolidated deposits; channel gradients are low to moderate.

<u>Very High</u>

- Thick morainal and morainal-glaciofluvial complex slopes which are heavily gullied and contain active failures or show evidence of intense, small-scale mass movement features; slope range from 60-80%.

- High scarps of thick glacial till with recurrent failures or evidence of significant, deep-seated slumping; slopes usually average in excess of 60%.

- Steep terrace scarps which exhibit complex stratigraphy (usually till and glaciofluvial sediments) and are actively failing or show evidence of long-term, small-scale movement; slopes usually exceed 65%.

APPENDIX III
SEDIMENT TRANSFER CAPABILITY RATINGS AND CRITERIA

APPENDIX III

SEDIMENT TRANSFER CAPABILITY

This classification system provides a qualitative link between upland erosion and potential impacts of downstream sedimentation. It does not provide any estimate of quantities of sediment transported; that depends on complex interactions of precipitation, soil moisture, and streamflow conditions at the time of sediment production.

Interpretations and descriptions presented in the following tables are mainly derived from Hogan and Wilford (1989). Modifications have been made according to field and aerial photographic observations by the writer and some informed discussion (D. Hogan, personal communication).

Table III-1 Sediment Transfer Capability Matrix

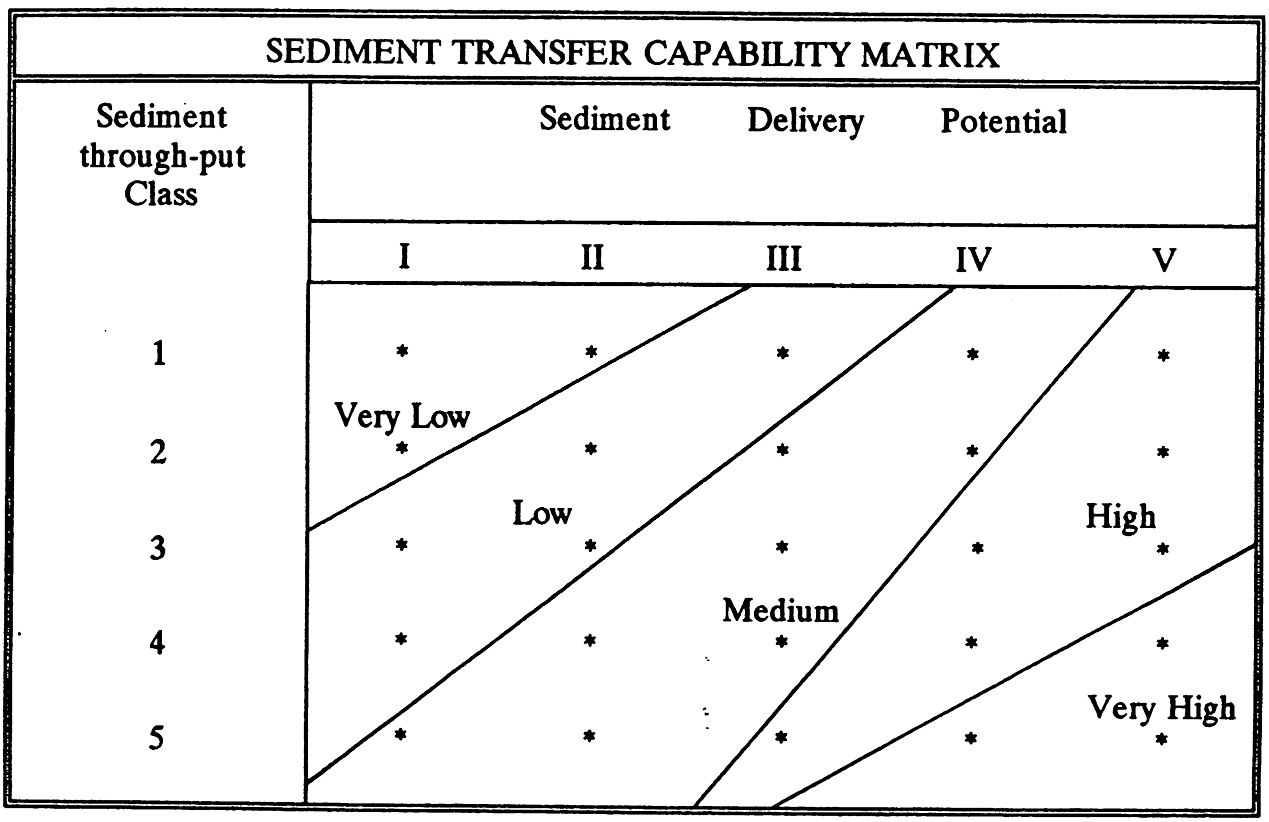

Table III-2 Sediment Delivery Potential Ratings

Class	Description
I	Very low levels and very low potential for sediment delivery to the stream reach. Bordered mainly by stability classes I-II with VL -L erosion potential so that the channel is disconnected from any significant sediment sources. Incised streams have a wide valley flat and stable stream banks.
II	Low levels and low potential for sediment delivery to the stream reach. Bordered mainly by stability classes II-III with M-L surface erosion potential. Sediment delivery from terrain units is minor; most of the channel is disconnected from sediment sources. Stream banks are stable.
III	Medium levels and moderate potential for sediment delivery to the stream reach. Bordered mainly by stability classes III-IV with H-M surface erosion potential. Active sediment sources and disturbances are present but do not directly border the stream channel; however, they may be partially connected via other steeper gradient channels. Incised channels have a narrow floodplain and mainly stable banks.
IV	High levels and high potential for sediment delivery to the stream reach. Bordered mainly by stability classes IV-V with H surface erosion potential. Active sediment sources occur, some of which directly border the channel. Other steeper-gradient channels also connect the stream to upslope sediment sources. Incised channels have a narrow valley flat in places; stream banks show signs of some instability.
V	Very high levels and very high potential for sediment delivery to the stream reach. Bordered dominantly by stability class V with H-VH surface erosion potential. Active sediment sources are major in extent and directly connected to the stream. Stream banks are unstable in many places.

Table III-3 Sediment Through-put Potential Ratings

Class	Description
1	Very low level of sediment transported through the channel reach. Applies to near-level, semi-confined channels and unconfined channels through wetlands where flow volumes are very low. Small streams in wetland depressions on upland plateaus and small floodplain tributaries. A depositional channel reach with very minor amounts of fine sediment (fine sand, silt, clay) transported out of the reach.
2	Low level of sediment transported through the channel reach. Only used for small streams with low flow volumes; confined channels up to 3% and unconfined channels up to 7%. Occur mainly on subdued plateau surfaces, low-gradient toe-slopes, and fans. A depositional channel reach with some fine sediment transported out of the reach. Very little movement of coarse sediment (coarse sand to fine gravel).
3	Moderate potential for sediment through-put. Minimum class rating for the main river and tributary creeks. On large flow systems channel gradients are 1-7% and feature wide channels with extensive in-channel and lateral gravel bars. All fines move readily through the system; coarse sediment moves episodically with temporary storage but eventually is transported through. Smaller, low-flow creeks have channel gradients of 7-15% and occur on gentle lower and mid slopes, including fans emanating from high-transport drainages. Channels are usually stable; fine sediment moves through the system with peak flows whereas coarse material undergoes short to long-term storage behind obstructions or in valley-flat widening.

4	High potential for sediment through-put. Channels are confined within valley walls or high terrace scarps so there is only a very narrow or no valley flat. Gradients are 2-5% on main, high-flow systems. All fines and coarse sand and fine gravel move through the system. Small, coarse gravel bars may occur in a few places. Small, low-flow streams are usually steeply confined with channel gradients of 10-25%. Very low flow or seasonally active channels may be slightly steeper. All fines move readily through the system; coarse sand and fine gravel move with higher flows. Coarse gravel moves episodically.
5	Very high potential for sediment through-put. Channels are tightly confined; there are no gravel bars or valley flat. On the main, high-flow systems channel gradients are steeper than 5%. All sediment is transported through the system. Small, low-flow streams are very-steeply confined with minimum channel gradients of 20-30% depending on flow volumes. All sediment is transported through the reach but movement in very low volume systems may be episodic depending on the fluctuation of water flow.

APPENDIX IV

PHOTOGRAPHS

APPENDIX IV

LIST OF PHOTOGRAPHS

1. Highly fractured volcanic tuff with a thin silty, rubbly colluvial mantle on a gullied and failing slope adjacent to a southern tributary to Red Canyon Creek. Stability Class V, erosion potential rating H.

2. Near confluence of Beatty and Tufford Creeks, deep canyon eroded into volcanic bedrock, glacial till mantles the upland surface. Stability class V, erosion potential rating VH, sediment transfer capability of this channel reach is VH (V sediment delivery potential and 5 sediment through-put potential).

3. Approximately 40 m of conglomerate exposed on the south bank of Mulwain Creek, south of the confluence with Newton Creek. Stability Class V, erosion potential rating H.

4. Horizontally bedded siltstones and shales on the south bank of Zymoetz River west of Caribou Creek. Ravelling scarp is rated stability class V, erosion potential H.

5. View of the east slope of upper Lee Creek valley. Coarse talus (stability class III, erosion potential L) accumulates below crumbling bedrock cliffs (stability class V, erosion potential L).

6. High gravel terrace on the south bank of Zymoetz River, south of Coal Creek confluence. The eroding scarp has a stability rating of V and erosion potential rating of H.

7. Thin mantle of glaciofluvial gravel caps a morainal scarp bordering upper Caribou Creek. Small slump-flows are significant criteria used to rate the unit as stability class V, erosion potential VH.

8. Bank failure on the east side of lower Mulwain canyon. Lateral undercutting causes instability and erosion of a thick sequence of advance glaciofluvial gravels and overlying till; this scarp segment is rated stability class V, erosion potential VH.

9. Sandstone bedrock is exposed in a small creek eroded through a veneer of glacial till on moderate mid slopes east of Mulwain Creek, between Ledbetter and Newton creeks. Stability class II, erosion potential L.

10. About 30 m high slide scar on the west bank of lower Lee Creek canyon. Thick sequence of glacial till overlies 7-10 m of pre-glacial stratified sediments; bedrock is

exposed at creek level. Stability class V, erosion potential VH.

11. Thick, clay-rich till at the canyon edge of an east-flowing tributary to mid-Mulwain Valley. Stability class V, erosion potential VH.

12. Clay-rich till in 10 m high banks of a north-flowing tributary to Ledbetter Creek. Stability class V, erosion potential VH; sediment transfer capability is VH (V sediment delivery potential and 5 sediment through-put potential).

13. Silty clay till on east bank of upper Red Canyon Creek. Stability class V, erosion potential H. Sediment delivery potential is rated V and through-put rating is 5 contributing to a VH sediment transfer capability.

14. Silty sandy blanket of ablation till on upland plateau west of Coal Creek. Most of this area is rated stability class II, erosion potential L.

15. Westerly aerial view of bench lands north of Zymoetz River; subdued morainal and wetland landscape. Mainly stability classes I and II and erosion potential VL and L.

16. Extensive organic deposits cover the valley floor of upper Mulwain Creek. Mainly stability classes I and II and erosion potential VL and L.

17. Bedrock cliffs and actively ravelling talus on sideslopes bordering a north-flowing tributary to Red Canyon Creek. Area of bedrock instability is rated stability class V, erosion potential L.

18. Bedrock-colluvial failure on sideslope of tributary canyon south of Zymoetz River, east of Red Canyon Creek confluence. Weathering of fine-grained volcanics produces fine sediment contributing to an erosion potential rating of H, stability class V.

19. Bedrock scarp along lower Lee Creek canyon. Weathering of fine-grained volcanics produces fine sediment contributing to an erosion potential rating of H, stability class V.

20. Major snow avalanche track in large gully system which extends from the ridge crest to valley floor on the west side of upper Lee Creek. Bedrock headwall and sidewall instability creates a high debris torrent potential in this steep gradient gully. Rated as stability class V with an erosion potential of H; sediment transfer capability is VH (V sediment delivery potential and 5 through-put potential).

21. View north along upper Lee Creek valley. Extensive fan development, on the east side in particular, provides a wide run-out zone which acts as a buffer between slope processes and valley-floor fluvial activity.

22. Tilted trees on slump terraces suggest slow movement is on-going in an old landslide deposit which blankets the south slope of mid Red Canyon Creek valley. Stability class V, erosion potential H.

23. Slump-terracettes in thick till at the scarp edge of Mulwain canyon, west bank south of Johnson Creek confluence. Indicates a very high potential for failure; stability class V, erosion potential VH.

24. View of lower Gass Creek. Erosion and instability along the till-colluvial sideslopes is highly accelerated in the once deforested area (by fire) compared to the mature forest.

25. Caribou Creek canyon. Sediment delivery potential is rated V but through-put potential is 5 in tightly-confined canyon and 3 where valley-flat broadens and gravel bar deposits. Sediment transfer capability ratings are VH and H respectively.

26. Reach of Serb Creek where through-put potential is rated 4, only coarse gravel remains. Sediment delivery potential of this reach is V to produce a sediment transfer rating of VH.

27. Bank failure in lower Mulwain canyon (see photo 8). Surface erosion during a summer rainstorm instantly muddies the creek. Sediment delivery potential is V.

28. Surface erosion during summer rainstorm of fine-textured colluvial banks bordering Bloody Mary Creek. Example of sediment delivery potential of V contributing to a sediment transfer rating of VH for this channel reach.

29. Example of a small tributary on the south side of Zymoetz River where a confined channel has a through-put potential rating of V.

30. Example of a small tributary on the south side of Zymoetz River where a broadening of the valley flat leads to temporary gravel deposition; through-put rating of this reach is 3.

31. Lower Red Canyon Creek which has been muddied by transport of fine sediment from tributary streams (noteably Bloody Mary Creek) during a summer rainstorm.

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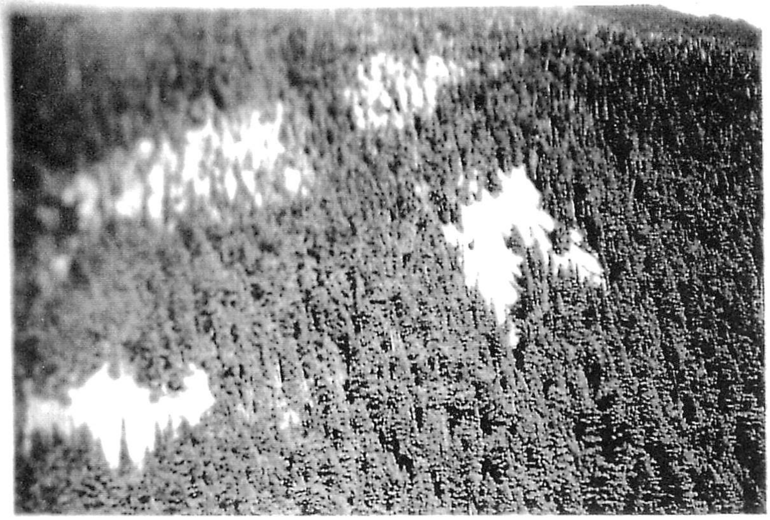
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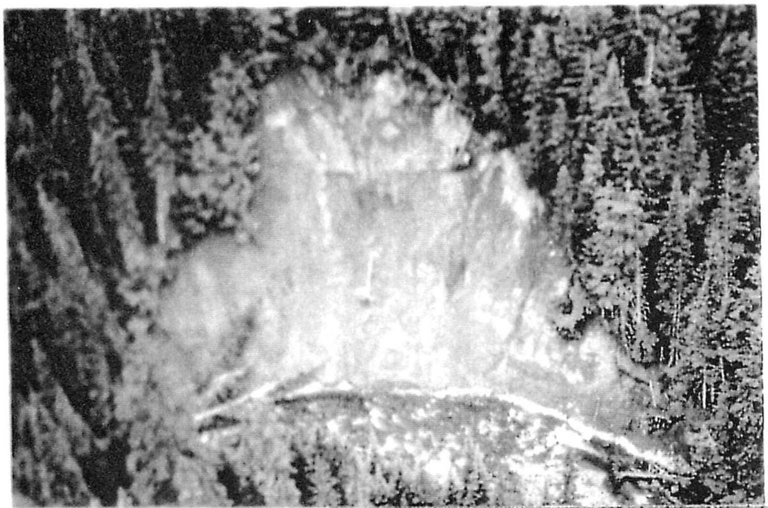

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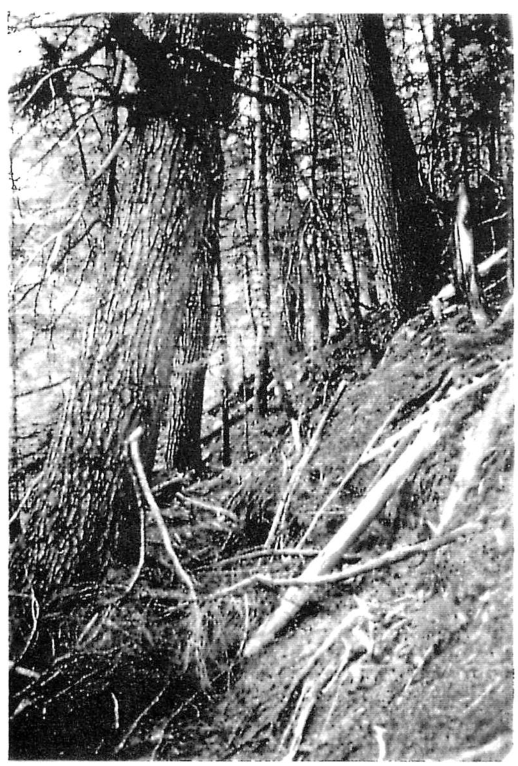

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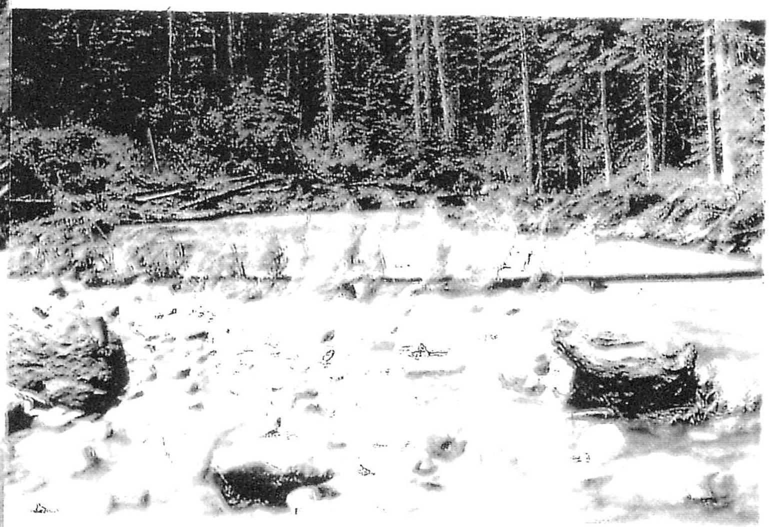

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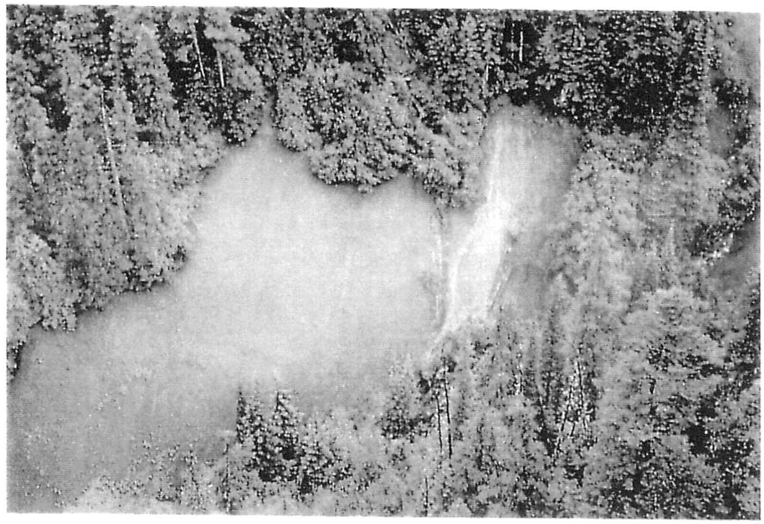

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