DETAILED TERRAIN STABILITY MAPPING OF THE UPPER NORTH THOMPSON RIVER AREA



Completed for:

Tolko Industries Limited
and
Clearwater Forest District
Small Business Forestry Enterprise Program

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1.0 INTRODUCTION

The objective of this project was to prepare 1:20,000 scale maps of terrain and terrain stability for the Upper North Thompson River study area. The study area is located approximately 35 kilometres (km) south-west of Valemount in east-central British Columbia within the Clearwater Forest District (Figure 1). The study area extends upstream from the confluence of an unnamed creek entering the North Thompson River from the south, approximately 2 km upstream from the confluence of Lebher Creek and the North Thompson River. The study boundary reflects the operational limits in this portion of the North Thompson River valley and is located within Terrain Resource Inventory Map (TRIM) sheets 83D.052, 053, 062 and 063.

Detailed terrain mapping at terrain survey intensity level (TSIL) C and interpretations for terrain stability were carried out in accordance with the Resource Inventory Committee Guidelines and Standards for Terrain Mapping in British Columbia (1996a). Terrain mapping consisted of aerial photographic interpretation of 1:15,000 scale (approximately) colour aerial photographs followed by field reconnaissance. The study area was divided into polygons of homogenous terrain (surficial materials, texture, surface expression and geomorphological processes), slope and drainage. A rating for terrain stability was assigned to each of the terrain polygons.

This report accompanies a terrain map, at 1:20,000, completed as per the guidelines set forth in the Mapping and Assessing Terrain Stability (MATS) Guidebook (Ministry of Forests 1995). It provides a general overview of the physiography of the study area, descriptions of the terrain mapping methodology and mapping reliability, information about surficial materials and geomorphological processes, and criteria used for determining terrain stability interpretations. A summary of the implications and recommendations for forestry planning and management that arise out of this terrain analysis are discussed in Section 8.0.

1.1 Report Limitations

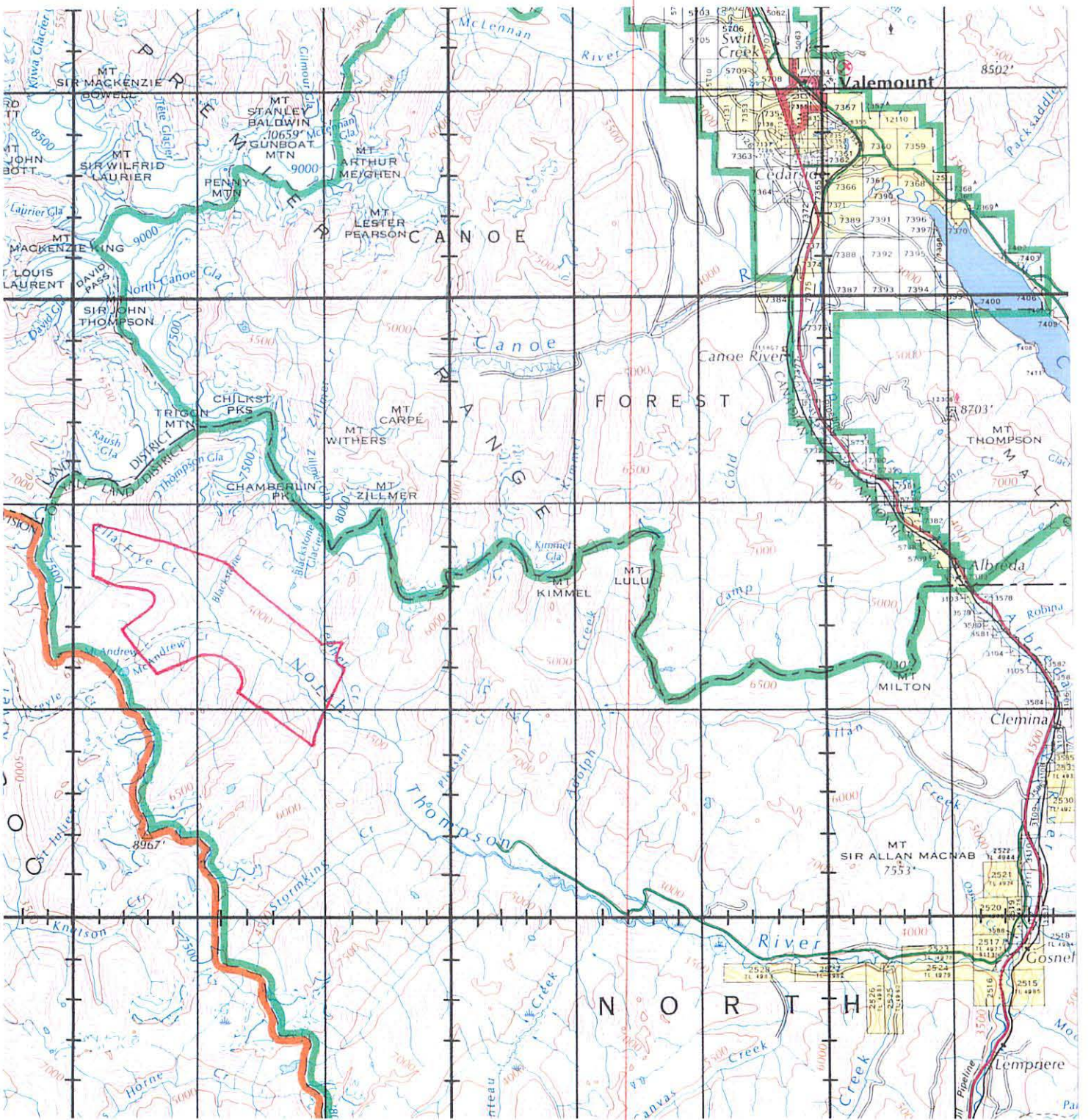
The information presented in this report and on the accompanying map is intended for forest development purposes only. The terrain stability rating is not considered appropriate for other land use applications. Identification and classification of terrain polygons has been completed using the standards methods employed by professional terrain mappers throughout British Columbia. The reliability of this mapping is consistent with other TSIL C studies that largely rely on aerial photographic interpretation supplemented by field observations. Interpretations of terrain stability are highly subjective because they are based primarily on aerial photographic interpretation. Accordingly, exactness of the boundaries and descriptions of the units shown on the accompanying map cannot be guaranteed. Subsequent, more detailed assessments should be undertaken for forest operational planning where required under the Forest Practices Code.

2.0 PHYSICAL SETTING

2.1 Physiography

The Upper North Thompson River study area is located in the Cariboo Mountains of the Columbia Mountains physiographic region (Holland 1976). The Cariboo Mountains comprise a number of north-westward trending ranges composed of sedimentary and metamorphosed sedimentary rocks of Proterozoic and Lower Cambrian age. Elevations above 2600 metres above sea level (m asl) are common and the highest peak in the area is Mount Sir Wilfrid Laurier which reaches an elevation of 3505 m asl. The mountains were intensely glaciated, with peaks above 2500 m asl projecting through the Pleistocene ice-cap as nunataks which were subjected to intense frost action and cirque glaciation. Below 2500 m asl there are rounded summits and ridges which indicate ice cover, although later cirque glaciation was intense and has produced

FIGURE 1: LOCATION OF UPPER NORTH THOMPSON RIVER STUDY AREA (SCALE 1:250,000)
Study area outlined in red.



many sharp peaks and ridges. The intensely glaciated North Thompson River valley exhibits the typical U-shaped profile, with smaller tributary hanging valleys (Plate 1). The North Thompson River drops from an elevation of 1300 m asl in the north of the map area to 1010 m asl in the south-east. Broad, flat floodplains with braided or irregular sinuous channels dominate the valley floor, although sections of the river are confined to steep and narrow bedrock canyons.

2.2 Bedrock Geology

The bedrock geology of the Upper North Thompson River study area has been mapped by the Geological Survey of Canada (Campbell 1968) and is also covered by an unpublished Ph.D thesis by Pell (1984) and later by a compilation map (Murphy 1990). Pell's (1984) work is the most comprehensive and is significantly represented on Murphy's (1990) compilation map (Figure 2). Campbell (1968) mapped the valley bottom as Quaternary sediments (Figure 2; Qs, yellow) and the rest of the study area as Proterozoic Kaza Group metasediments (gritty feldspathic quartzite, phyllite, quartz-mica schist, garnet, staurolite and kyanite-quartz-mica schist, biotitic and/or hornblendic quartzo-feldspathic gneiss, with minor marble, amphibolite and pegmatite with staurolite-kyanite schist). Pell (1984) redefined the Kaza Group as Upper Proterozoic, Windermere Supergroup and subdivided the Kaza Group in the study area into three units: the Lower Kaza Group (Figure 2; Pkl, light green), the Lower Kaza Group Carbonate Unit (Figure 2; Pklc, light blue) and the Middle Kaza Group (Figure 2; Pkm, dark green). The Lower Kaza Group is defined as a pelitic schist (locally containing kyanite, staurolite, garnet, biotite and muscovite) with minor psammite, orthoamphibolite, marble and calc-silicate rock. The Lower Kaza Group Carbonate Unit has cycles of quartzofeldspathic grit or metasandstone, phyllite or schist culminating in a brown marble up to 5 m thick. The Middle Kaza Group consists of quartzofeldspathic metasandstone, grit, conglomerate, green-grey silty slate, phyllite and schist.

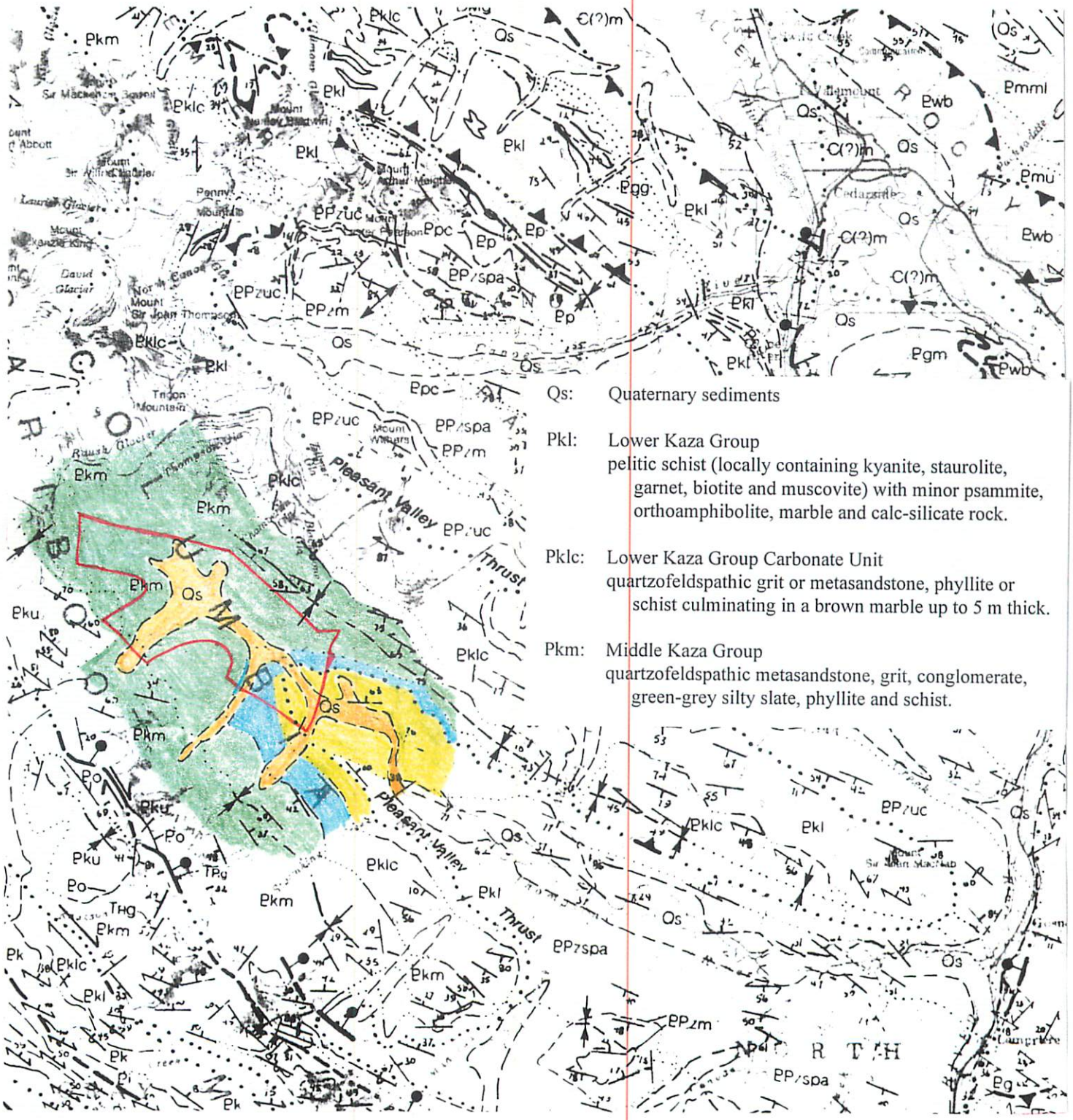
2.3 Quaternary Geology

No surficial geology or terrain mapping has previously been completed in the Upper North Thompson River study area. The distribution of surficial materials and the landforms that characterise the study area have largely been produced through bedrock weathering and the actions of glacial, glaciofluvial, fluvial and slope processes in the Quaternary Period (1.64 million years ago to present). During the Quaternary, local glaciers repeatedly modified the landscape, eroding and enlarging the main valleys. There is stratigraphic evidence of only four major glaciations in southern British Columbia in the Quaternary (Fulton *et al.* 1992), although there may have been as many as twenty glacial cycles.

The last glacial period, known as the Fraser Glaciation in British Columbia, was responsible for shaping much of the landscape as we know it today. The Fraser Glaciation occurred during the period of approximately 25,000 to 10,000 years before present and resulted in the land surface being covered by a large ice sheet at least 1000 metres thick. Ice initially accumulated in the high elevation cirques and icefields of the Monashee, Selkirk and Cariboo Mountains. Glaciers spread from these sources through the main trunk valleys, such as the Upper North Thompson River valley. As these valley glaciers thickened, ice began to cover the highlands, and eventually only the highest peaks (in excess of 2500 m asl around the study area) were not inundated by ice (Holland 1976). Deglaciation occurred by in situ ablation and stagnation on the plateaus where ice was thinnest (Clague 1989). Glacial ice continued to move through the main feeder valleys, but the rate of retreat through melting exceeded the rate of replenishment.

During expansion of the glaciers, the active ice eroded bedrock and previously deposited sediment at its base. This debris was transported near the base of the ice and deposited as dense lodgement and basal tills along the floor and sides of the North Thompson River valley. When the glacier stopped moving and started melting, ablation tills were deposited as ice melted out

FIGURE 2: BEDROCK GEOLOGY MAP OF THE UPPER NORTH THOMPSON RIVER STUDY AREA.
Study area outlined in red. From Murphy 1990.



under the accumulated debris on the ice. Post-glacially derived glaciofluvial (glacial river) sediments were deposited along the front and side margins of the ice. The majority of the glaciofluvial sediment is located on the valley floor where the meltwaters deposited a thick sequence of coarse-grained outwash sediments. Higher elevation terraces and kames of washed sand and gravel formed sporadically where glacial meltwater flowed along the sides of the retreating ice. A typical profile of the slopes, immediately post-glacially, would be bedrock covered by a blanket of till, which thins with increasing elevation, overlain by occasional glaciofluvial deposits. In the valley bottom was a thick glaciofluvial outwash deposit.

During the Holocene Epoch (10,000 years ago to the present), the landscape in the study area has been modified by colluvial and fluvial processes. Colluvial processes are gravity-induced movements of material with water or ice assisting in the movement. Fluvial processes are those associated with the transportation and deposition of sediment by flowing water. In the bottom of the North Thompson River valley the morainal sediments deposited by the glaciers are covered by post-glacial fluvial (glaciofluvial) sediments. Subsequent to ice retreat, fluvial processes have dominated the valley floor. In the 1700's, a colder period of time known as the Little Ice Age, ice once more advanced through the upper reaches of the North Thompson River valley. Fresh morainal ridges can be seen less than 600 m north of the map area boundary.

2.4 Soils

No detailed soil and landform mapping has been completed in the Upper North Thompson River study area. Soils in the study area are dominated by humo-ferric podzols from the valley floor to the alpine. In the alpine shallow regosols and thin, poorly developed podzols dominate. On the valley floor, regosols, gleysols and organic soils develop on the gravelly floodplains.

Podzolic soils in the map area typically have a gravelly sandy loam texture which is developed from coarse textured and well drained parent materials dominantly of acidic (silica rich) origin. There is abundant water which allows deep and rapid development of the soil horizons. A common profile in the study area is a black LFH, a light grey Ae horizon (leached of all but siliceous silt and sand), and a well defined Bf horizon (enriched in iron, aluminum and organic material) and a tan coloured coarse grained morainal or colluvial parent material. Occasional weak mottling was observed in wetter or less free-draining sites.

Alpine regosolic soils are generally limited to a thin A and a C horizon. Development of soil horizons in alpine regosols is hampered by cold climate and lack of surface organic cover. Valley floor regosols are defined by the lack of soil development due to shifting river channels constantly exposing older materials or depositing new sediments. Gleysolic soils are saturated with water for long periods of the year and their profiles show evidence of reducing or oxygen poor conditions. Organic soils are composed largely of organic materials and are saturated with water for prolonged periods.

2.5 Biogeoclimatic Classification

There are three biogeoclimatic zones in the Upper North Thompson River map area. They are the Interior Cedar - Hemlock very wet cool, Mica variant, cool air drainage phase (ICHvk1c), the Engelmann Spruce - Subalpine Fir, wet cold Monashee variant (ESSFwc2) and the Alpine Tundra - Engelmann Spruce - Subalpine Fir wet mild (AT-ESwcp) (Lloyd *et al.* 1990). The ICH zone is only located along the base of North Thompson River valley up to elevations of 1230 m asl. The ICH is easily recognised by the presence of western redcedar (*Thuja plicata*) and western hemlock (*Tsuga heterophylla*). The ESSF zone grades up from the ICH zone along the floor of the valley and is distinguished by the presence of white-flowered rhododendron (*Rhododendron albiflorum*) and Sitka valerian (*Valeriana sitchensis*) vegetation as well as

subalpine fir (*Abies lasiocarpa*) and Engelmann spruce (*Picea engelmannii*). The Alpine Tundra - Engelmann Spruce - Subalpine Fir zone starts between 1700 and 1850 m asl and is dominated by shrubs and herbs with some small or stunted subalpine fir (*Abies lasiocarpa*) and Engelmann spruce (*Picea engelmannii*). For the most part tree line is located between 1850 and 2000 m asl.

3.0 METHODS

3.1 Pre-typing Aerial Photographs

Terrain mapping followed the British Columbia Terrain Classification System (Howes and Kenk 1997), Guidelines and Standards to Terrain Mapping in British Columbia (Resources Inventory Committee 1996a) and the MATS Guidebook (Ministry of Forests 1995). Preliminary terrain mapping was completed by interpretation of 1:15,000 scale aerial photographs prior to field assessment. The aerial photographs used were: BCC95045: 15-23, 34-41 and 110-112 and BCC95048: 46-50 and 59-65.

Pre-typing involved placement of boundary lines around homogenous terrain, slope and drainage characteristics. Boundary lines are predominantly based on changes in slope gradient, surficial materials and landforms, and geomorphological processes. A TRIM 1:20,000 topographic map with 20 metre contour interval was used to augment line placement decisions. Solid boundary lines were placed to indicate a definite boundary (well defined, sharp slope breaks or distinct surficial geology changes); dashed lines to indicate approximate boundaries (changes that are visible over a short distance, but cannot be precisely located); and dotted lines were used to indicate assumed boundaries (changes that occur very gradually). Pre-typing of the aerial photographs identified areas of potential instability, and efforts were made to ensure field checking of these areas if they were in proposed blocks or crossed by proposed road alignments.

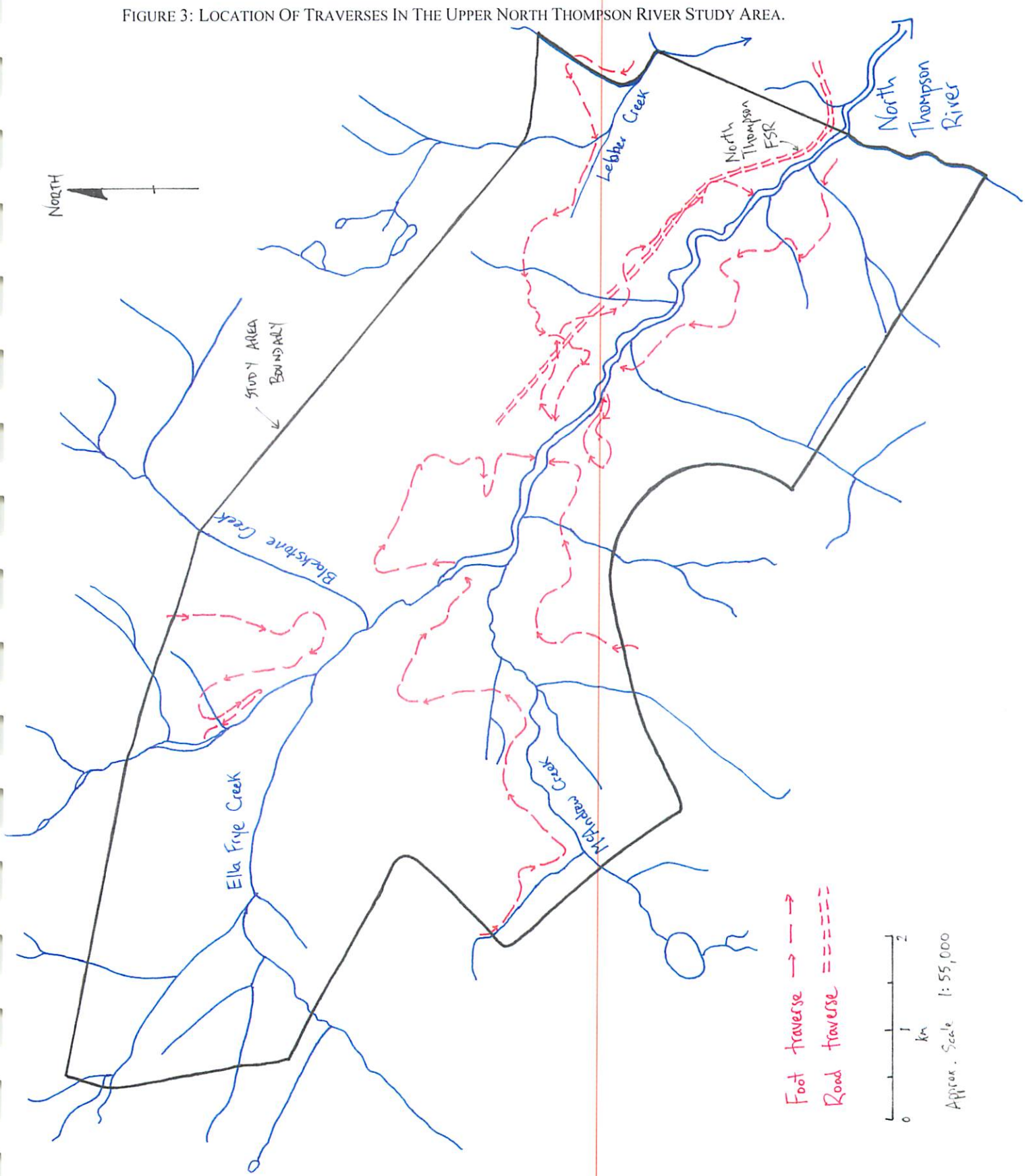
3.2 Fieldwork

Observation sites were established in June of 1996 on helicopter supported foot traverses (Figure 3) to observe a representative sample of all terrain conditions present in the map area. Road access was available via the North Thompson Forest Service Road (FSR) only to the southern edge of the map area at the time of this study. In the summer and fall of 1996 the road was extended along the north side of the North Thompson River to Blackstone Creek and one road traverse was completed in October of 1996 to approximately 2 km south of Blackstone Creek. At each observation site, the following data was typically collected: texture of surficial materials, genesis of the deposit, surface expression, geomorphological processes, soil drainage, slope steepness, aspect, description of any exposed bedrock, and indicators of slope instability. There were 133 field checks within the approximately 5225 hectare study area resulting in 2.54 checks per 100 hectares. Sixty-eight of 305 total polygons were ground checked which equals 22% polygon checks. The average polygon size in the map area was 17.1 hectares.

3.3 Editing of Aerial Photographs

Upon completion of fieldwork, terrain polygon lines on aerial photographs were added or existing ones modified. Finalized polygons were labelled using standard mapping conventions (Howes and Kenk 1997). Terrain polygons were assigned a terrain stability hazard class; the methodology for which is described in Section 7.0. Finalized mapping on aerial photographs was transferred to a topographic base map using mono-restitution by AGRA Earth and Environmental Ltd. and linked to a terrain database spreadsheet containing the polygon information (Resources Inventory Committee 1996b). The topographic map base are the 1:20,000 TRIM sheets 83D.052, 053, 062 and 063. A preliminary map was produced and reviewed for line placement and labelling. A final map was produced, showing terrain data and terrain stability classes.

FIGURE 3: LOCATION OF TRAVERSES IN THE UPPER NORTH THOMPSON RIVER STUDY AREA.



4.0 SURFICIAL MATERIALS

The surficial materials that are present in the study area are described in the following sections. Morainal and colluvial sediments are the predominant surficial materials of the Upper North Thompson mapping area. Fluvial, glaciofluvial and organic sediments and bedrock exposures were also observed.

4.1 Colluvium (C)

Colluvium is material that has reached its present position as a result of direct, gravity-induced movement; water or ice can assist in the mobilization of the material but it is not the chief transporting agent. Colluvium includes slow creep of surficial materials, unconfined surface sheet or slope wash, deposits from mass movements (rock falls, rock slides, debris slides, rock slumps and debris slumps), and sedimentation onto steep colluvial cones by gullies or avalanches.

Soil or surficial material creep occurs on all slopes, but is most noticeable on moderately steep and steep slopes. It is defined as the imperceptibly slow downslope movement of soil or rock debris and may be result from heating and cooling, wetting and drying, freezing and thawing or animal and organic interactions. Terracettes, networks of very small terraces along the slope contour, with a relatively flat top and a steeper face, are one of the more obvious indicators of creep. Rates of creep are increased when vegetation is removed and indicates that root binding is quite a significant factor on slope stability. Colluvial creep deposits are usually very similar in character to the original sediments from which they are derived. In the Upper North Thompson River study area these creep deposits are found overlying morainal and glaciofluvial sediments on moderate to steep slopes (Plate 2).

Slope or sheet wash is detachment of soil by raindrop impact and subsequent entrainment of the soil particle by runoff across the ground surface. Slope wash usually only affects the upper few centimetres of the soil profile. Vegetation cover intercepts the majority of the raindrops, decreasing impact on the soil and moderating peak flows, thereby reducing the erosion and translocation. Slope wash occurs throughout the Upper North Thompson River map area.

Mass-movements such as rock falls, slides and slumps and debris slides, slumps and flows all occur in the Upper North Thompson River map area. Rock falls (-Rb) and rock slides (-Rs) are generally clast-supported mixtures of rubble and blocks with minor amounts of interstitial sand or silt. These materials are well drained and as a result are not susceptible to surface erosion. Talus cones or aprons are developed where substantial amounts of material are deposited (Plate 3). Rock slumps (-Fm) and debris slumps (-Fu) maintain many of the attributes of the rock or surficial material. These are deep-seated slope failures that rotate as a block along a concave shaped zone of weakness; in some cases the physical properties of the resulting deposits may not differ substantially from the original material. Debris slides (-Rr) occur where the upper zone of the sedimentary profile fails and material moves downslope. The failure planes are usually very shallow in the sedimentary profile (1-4 m), commonly occurring at the weathered-unweathered interface or the sediment-rock interface. Deposits of debris slides are usually matrix supported silt, sand, gravel and rubble, and reflect the texture of the original material. If moisture conditions are right the slide mass may liquefy and become a debris flow (-Rd). Debris flow deposits are massive, unsorted deposits of all sizes of sediment that are typically matrix-supported, denser and less permeable than most of the other colluvial deposits.

Typically, alluvial cones form where the gradient of a gully or watercourse drops as it leaves a confined valley and the unconfined flow spreads out across the surface of the floodplain. Material moving through the channels are being transported by water and gravity, the relative

proportions of which causing the resulting deposits to be fluvial or colluvial. Colluvial cones are dominated by gravity driven sediments, such as debris flow, slide and snow avalanche deposits, with lesser amounts of fluvial sediment. Snow avalanches incorporate bedrock, surficial sediments and vegetation debris as they move downslope; their deposits are often similar in appearance to debris slides.

4.2 Fluvial Materials (F)

Fluvial materials have been transported and deposited by flowing water since the end of the last glaciation. Fluvial materials generally consist of moderately to well-sorted, stratified sand and/or gravel with minor amounts of silt. These deposits have a very porous structure and are highly permeable. They are usually poorly or imperfectly drained when located on the floodplains or near stream level where the water table is high. The major area of fluvial accumulation in the map area is the floodplain of the North Thompson River. At the northern end of the study area there is a gently sloped (5 to 10% gradient) actively braided floodplain of aggrading cobble gravel. Downstream from this braidplain, the river is confined in a steep and narrow bedrock canyon, below which is a very wide, very flat (0 to 5% gradient) floodplain (Plate 4). This lower floodplain extends for over 6 km downstream and is over 500 m wide at it's widest, and extends upstream into lower McAndrew Creek valley. Within the bounds of this floodplain the river has one main active irregularly sinuous channel (30 to 120 m wide). The majority of the floodplain is older fluvial sediments covered with a veneer of organics and occasional stands of timber on the drier sites.

4.3 Glaciofluvial Materials (FG)

Glaciofluvial materials exhibit evidence of having been deposited by glacial meltwater streams either directly in front of, or in contact with, glacier ice. They are generally coarse textured and have high porosity and permeability. Sorting and stratification are variable; they may occur as unsorted massive sand and gravel units or as discrete, well-sorted and well-stratified sand or gravel depending on the type of material and depositional environment.

The main occurrence of glaciofluvial sediment is under the current floodplain of the North Thompson River. In the Ella Frye Creek valley a relatively broad, gently inclined glaciofluvial terrace, which has been incised by the present river, was observed. On both sides of the North Thompson valley above the wide floodplain are glaciofluvial sand and gravel overlying till. This is the remnant of a larger kame terrace. It consists of well sorted sand with gravel and it is highly erodible, as indicated by intense gullying in some areas. A lower terrace of glaciofluvial sand and gravel, visible on the south side of the river near the east end of the study area, is less steep and has experienced much less erosion.

4.4 Morainal (Till) Materials (M)

Morainal materials or tills are those sediments deposited directly from glacial ice. Till materials in the study area generally consist of a matrix of fine materials (<2 mm) that surrounds and supports clasts (>2 mm) that vary in size and shape. Physical properties of tills are variable and based on the origin of the debris and the mode of deposition. Basal tills are the most commonly occurring sediments in the study area, ablation tills were also noted, but lodgement tills were not observed. The different types of till have not been identified on the maps as the survey intensity precluded this level of detail.

Three basic tills are commonly deposited from glaciers: lodgement, basal and ablation tills. Lodgement till is deposited by plastering of glacial debris from the sliding base of a moving glacier. These are unsorted sediments that are massive in structure. This till usually has well developed subhorizontal partings (crude platy appearance), is dense and has a matrix of sand, silt

and clay. Pebbles are dominantly oriented long axis parallel to flow direction and striations on clasts and on bedrock are parallel to flow. Lodgement tills are rarely observed on the surface, usually they are buried by other sedimentary deposits. Thin deposits of lodgement till will likely be found buried underneath the basal till layer in the Upper North Thompson River study area and will be distinguished by indistinct platy structure and their finer-grained and denser nature.

Basal till is deposited by a slow release of glacial debris from the ice that is not sliding or deforming internally. Compared to lodgement till, it is less dense, has no horizontal partings because it is not deposited by moving ice and generally has a coarser matrix. Less pressure is exerted on this till and unlithified clasts of sediment (frozen sand, silt, clay, coal etc.) may be preserved in these sediments. In the Upper North Thompson River map area the matrix of basal tills is primarily sand or silty sand and moderately to well consolidated (Plate 5). Thick basal till deposits were noted in road cuts along the newly constructed road on the north side of the valley. There were 10 to 50% clasts, small pebble to large boulder (in excess of 1 m) in size, which were angular to sub-rounded in shape and exclusively local origin.

Ablation till (also called supraglacial till) is derived from any debris upon its release from glacier ice. Re-deposition is accomplished by gravitational slope process (gravity flows) and it may take place ice-marginally, supraglacially, subglacially, subaerially or subaquatically. These are not true tills in that they have been moved since deposition and no longer are purely a product of glacial ice deposition. The matrix of ablation tills is primarily sand; ablation tills are non-cohesive due to lesser quantities of silt and less consolidated as they were deposited on the surface of the ice. There were 15 to 40% clasts, pebble to large boulder in size, which were sub-angular to sub-rounded and usually of local origin. Within the ablation tills, well sorted sand and gravel beds were noted; these may be small wispy layers or substantial pockets or lenses. Variable thicknesses of ablation till were observed in the new road cuts which reflects the changeable nature of deposition of these sediments.

4.5 Organic Materials (O)

The most obvious occurrence of organic deposits is found along the broad, open floodplain of the North Thompson River (Plates 1 and 4). Toward the western end of the study area, organic deposits were observed on low bedrock and morainal terraces above the North Thompson River and Ella Frye Creek. Occasionally, organic deposits were found on sections of lower gradient watercourses higher up the valley sides. Throughout the study area, small organic deposits are common. They frequently occur where water is ponded between bedrock irregularities or on gently sloping, poorly drained till blankets. The presence of organic materials on the valley sides is an indicator of poor drainage and, while generally not well treed, these sites are sensitive to disturbance.

4.6 Bedrock (R)

Bedrock controls the basic form of the landscape and is generally overlain by a cover of till or colluvium on the valley walls. Upper elevations of the North Thompson valley, mostly above the map area, are dominated by rock with a thin colluvial cover and morainal sediments below cirques and other glacial source areas. In the northern and western portions of the study area, Kaza group metasediments form elongate ridges with well defined bedding parallel to the main valley (elongate north-west to south-east). On the southern side of the study area the bedding is more oblique to the valley (west and west north-west to east and east south-east).

Steep bedrock cliffs and associated talus slopes are most commonly found along smaller tributary valleys where glacial erosion has over-steepened the walls. Steep sided ridges of bedrock are found on the north side of the main North Thompson River valley (Plate 6). At the north-western

end of the study area the valley narrows and bedrock escarpments are found on both sides at lower elevations. Within the map area, bedrock has been exposed in two sections along the North Thompson River; in the canyon to the west and on the north side at the eastern end.

Striations and elongate bedrock forms were noted on outcrops in the McAndrew Creek valley, and ice flow direction was measured at 048° and 053° and indicates local topographically controlled ice flow direction along McAndrew Creek valley.

5.0 SOIL DRAINAGE

Soil drainage refers to the rapidity and extent of water removal from a soil relative to additions (Luttmerding *et al.* 1990). Soil drainage is influenced by permeability, groundwater level and seepage, however these are not readily quantified in the field and are rarely used in these type of studies. Our assessment of the drainage of the soil was completed through recognition of the key diagnostic soil horizons, texture, vegetation associated with the area and the local terrain.

Six soil drainage classes were used: rapidly drained (r), well drained (w), moderately drained (m), imperfectly drained (i), poorly drained (p), and very poorly drained (v). Abbreviated definitions of the soil drainage classes are provided in Table 1. Complete definitions of the soil drainage classes are provided in Luttmerding *et al.* 1990.

TABLE 1: SOIL DRAINAGE CLASSES AND COMMON TERRAIN UNIT ASSOCIATIONS

Drainage Class	Definition	Common Terrain Unit Association
Rapidly	Water is removed rapidly from the soil in relation to supply. Excess water flows downward into underlying material. Soils are usually coarse textured and shallow.	Steeper slopes in colluvium and rock. Talus cones are the most common example. Soils are mainly regosols.
Well	Water is removed from the soil readily, but not rapidly. Excess water flows downward into underlying material or laterally as subsurface flow. Soils are intermediate in texture and thickness.	Steeper slopes in till, moderate slopes in glaciofluvial or colluvial deposits. Soils are mainly podzols or regosols.
Moderately Well	Water is removed from the soil somewhat slowly in relation to supply. Excess water is removed slowly due to low perviousness, shallow water table or lack of gradient. Soils are medium to fine textured.	Moderate slopes in till and gentle slopes in glaciofluvial, colluvial and fluvial sediments. Soils are dominantly podzols.
Imperfectly	Water is removed from the soil sufficiently slowly in relation to supply such that the soil is kept wet for a significant part of the growing season. Soils have varied physical properties, but usually show gleyed horizon.	Gentle, undulatory and nearly flat slopes in all sediments. Evidence of standing water on the ground surface but minimal openings in forest cover. Mottles may be present.
Poorly	Water is removed from the soil so slowly in relation to supply that the soil remains wet for the majority of the time the soil is not frozen. Soils have varied physical properties but usually show gleyed horizons or fall within the Gleysolic or Organic soil orders.	Gentle slopes to flat ground in all sediments. Evidence of standing water on ground surface and openings in forest cover. Shallow water table usually indicated. Organic sediments common.
Very Poorly	Water is removed from the soil so slowly that the water table remains at or on the surface for the greater part of the time that the soil is not frozen. Soils have varied physical properties and are either of the Gleysolic or Organic soil orders.	Flat ground with organic or very fine textured glaciolacustrine sediments. Open water may be present, large openings with well developed organic wetlands.

Adapted from Describing Ecosystems in the Field (Luttmerding *et al.* 1990)

6.0 GEOMORPHOLOGICAL PROCESSES

Geomorphological processes are natural mechanisms of weathering, erosion or deposition that result in the modification of the surficial materials and landforms at the earth's surface. These symbols are used to indicate a process is actively modifying the whole or portions of the polygon. Geomorphological process subclasses indicate a sub-division based on specifics of the process; polygons which include the site or zones of initiation are denoted on the maps with the use of the " (quotation) symbol.

6.1 Snow Avalanches (-A)

Snow avalanches are the rapid downslope movement of snow and ice, as well as incorporated rock, surficial material and vegetation debris, by flowing or sliding. Avalanching is common on steep slopes that experience heavy snowfalls. Avalanche tracks below treeline are strips of shrubs and immature trees that are clearly visible on aerial photographs and on the ground. Older avalanche tracks are commonly visible for many years as the regenerated trees are often of different species and age class and thus a different shade of green. Avalanches that are repetitive commonly construct cones of rocky debris on lower slopes (Plate 7). When avalanches reach a creek they are an episodic source of natural sediment. Timber harvesting on steep slopes may create initiation zones for avalanches where they previously did not exist. Lower on slopes, harvested areas may allow the avalanches to extend further downslope than they did prior to logging.

6.2 Braided Channel (-B)

There is a braided channel in the upper reaches of the North Thompson River in the map area. A braided channel is characterized by the presence of active channels with numerous unvegetated or sparsely vegetated bars. Swamps and backchannels are common on the braidplain.

6.3 Slow Mass Movement (-F)

Slow mass movements are defined as the slow downslope movement of masses of cohesive or non-cohesive surficial material and/or bedrock by creeping, flowing or sliding. It can be applied to the initiation, transportation or depositional zone of the process. In the map area slow mass movements are occurring in the form of bedrock and surficial material slumps. Slumping occurs along a concave upward failure plane resulting in the backward (upslope) rotation of the upper portion of the original surface while the whole mass moves downslope. Steep, arcuate headwalls and hummocky piles of debris are identifying features of slumping. Slump movements can be slow or rapid and may occur all at once or have episodic activity.

Bedrock Slump (-Fm)

Five large bedrock slumps were identified in the map area. The age of these slumps is unknown; they are interpreted to be post-glacial as tills are found in the headwalls and they have not been modified by glacial activity. None of the slumps show any signs of fresh activity beyond rock falls and small slides at the headwall, but slumping may be a very gradual process and their status should be monitored.

The largest bedrock slump is located on the south side of Ella Frye Creek on a north facing slope. The steep, arcuate bedrock headwall of this slump is approximately 1.5 km wide and the slumped mass covers an area 500 to 1000 m downslope from the headwall (Plate 8). Further up Ella Frye Creek a second slump was observed on the south facing slope of the valley. At the north of the map area, on the west facing side of the North Thompson River, a third slump is visible off the side of a bedrock ridge onto the narrow terrace above the channel. In the centre of the map area, on the north side of the North Thompson River, a large slump off a protruding bedrock ridge was noted. In the upper reaches of the west arm of Lebher Creek a slump is noted off a bedrock ridge, reaching down the edge of the creek canyon.

Surficial Material Slump (-Fu)

One large slump in surficial material was observed in the map area in the McAndrew Creek valley. A broad, arcuate headscarp in till with hummocky ground below was visible in the field. The size of the mass-movement and the arcuate headwall suggest a slump mechanism, but it could also be several smaller debris slides which have coalesced.

6.4 Irregular Sinuous Channel (-I)

The North Thompson River has an irregularly sinuous channel on the large floodplain in the centre of the map area (Plate 9). An irregular sinuous channel is characterized by one clearly defined main channel with irregular turns and bends; backchannels, side channels, bars and islands are present.

6.5 Surface Seepage (-L)

Abundant surface seepage, or evidence of substantial seasonal seepage, is provided by physical or vegetation indicators. This is applied when one terrain unit has much more seepage than similar terrain units or an open spring is located in the polygon.

6.6 Rapid Mass Movement (-R)

This is the rapid downslope movement by falling, rolling, sliding or flowing of dry, moist or saturated debris derived from surficial material or bedrock. It can be applied to the initiation, transportation or depositional zone of the process. In the study area rock falls, debris flows, rock slides and debris slides have been identified.

Rock falls (-Rb)

Rock fall is the descent of relatively small masses of rock by falling, bouncing or rolling. Rock falls occur as individual particles of rock or as masses, blocks or slabs of rock which become detached from the bedrock outcropping and fall downslope; particle size ranges from pebbles to blocks. Accumulation of these particles forms a moderately steeply to steeply sloped, clast-supported talus cone or apron, with a minor amount of interstitial sand or silt matrix, below the bedrock outcropping. Rock fall occurs from steep bluffs throughout the map area; it is also associated with rock slides and bedrock slumps (Plate 10).

Debris flows (-Rd)

A debris flow is the rapid movement of a mixture of different grain sizes, water and organic material. A failure may originate as a slump, slide or snow avalanche on an open slope, but with the addition of water becomes a debris flow in a confined channel. Debris flows may be a significant source of sediment to streams; they can introduce high volumes of fines which may impact downstream aquatic habitat and they can also dam the main stream and cause catastrophic flooding. Debris flows do not appear to be a major factor in the geomorphic evolution of the map area. The only existing debris flow channel observed was on the south side of the valley approximately 300 m south-east of the confluence of McAndrew Creek with the North Thompson River (Plate 11).

Forest development will increase the potential for debris flows to occur. When steep gully sidewalls are impacted by forest development they often develop into debris flows which move rapidly through the gully system. Any development of the steep sidewalls of gullies should be investigated in detail by a qualified registered professional geoscientist or engineer. Road construction across gullies will also be critical. Redirection and concentration of drainage along road ditches and into watercourses not used to large volumes of water must be avoided.

Rock slides (-Rr)

Rock slides are the result of detachment of relatively large masses of rock, usually along an existing plane of weakness, that slide downslope and may disintegrate in the process. Materials

derived from rock slides accumulate to form moderately steeply to steeply sloped, clast-supported talus cones or aprons (Plate 12). Rock slides occur as masses of rock which break up during transport into blocks, slabs or individual particles of rock (final particle size ranges from pebbles to blocks), with minor amounts of interstitial sand or silt matrix.

Debris slides (-Rs)

A debris slide is the rapid movement by sliding of a disintegrating mass of surficial material. The cause of these is commonly a plane of weakness in the surficial material which allow increased pore water pressures to develop and subsequently fail. Commonly the plane of weakness is a unweathered, denser till unit or a smooth bedrock surface. Sometimes debris slides occur where a stream undermines the bank and causes failure. Four debris slides are located in the Upper North Thompson study area, three of these are on the south and west facing slopes, one is on the north slope on the sidewall of a gully (Plate 11).

6.7 Inundation (-U)

Inundation refers to ground which is seasonally under standing water which results from a high watertable. The floodplain of the North Thompson River is composed of a thick sequence of glaciofluvial sediments overlain by a thin fluvial and organic cover, the majority of which is flooded for the most of the year.

6.8 Gully Erosion (-V)

Gully erosion is the modification of a slope by the processes of running water in combination with debris slides, debris flows and snow avalanches resulting in the formation of deep and steep ravines. Gullying is the predominant geomorphic process occurring in the project area and may used to indicate the presence of one large gully or numerous smaller, sub-parallel gullies. Active gully erosion in the map area is primarily by water, although mass-movement processes are also occurring. Development of the gullies probably occurred immediately post-glacially when there was significant amounts of surface water from melting ice and the valley was unvegetated. These conditions allow for the most active erosion; subsequently, as the amount of surface flow decreases and vegetation takes hold, the rate of gully erosion slowed. Presently the gullies are well vegetated and most factors indicate they are inactive, however they do indicate erosional action, and are susceptible to future erosion if appropriate harvesting and road building practices are not used. These gullies carry water for a large part of the year, however the key period of flow is during snowmelt runoff and spring rains.

A series of gullies developed on the higher elevation glaciofluvial kame terraces on both sides of the North Thompson River will be a critical area on which to control drainage. The sand and gravel which forms the kame terrace is uniformly graded, lacks cohesion, is loosely consolidated and highly susceptible to erosion. The underlying tills are coarse and only loosely to moderately compacted and are quite susceptible to erosion. Drainage must be controlled within the existing watercourses and not diverted on to the open slopes or ridges between the gullies. Debris slides may occur at the headwalls or on the sidewalls of the gullies where vegetation is removed and if there is sufficient water may liquefy and become debris flows. One large gully on the south side of the valley has evidence of recent debris slides on the sidewall and the subsequent debris flow in the channel. Other gullies throughout the map area indicate the presence of highly erodible sediments and act as convenient paths for debris flows.

Snow avalanching may be the leading primary erosional and depositional process in many of the upper elevation gullies and may also be an increased factor following road construction and timber harvesting in and around gullies.

7.0 TERRAIN STABILITY

Terrain polygons were classified for terrain stability based on information found in the MATS Guidebook (Ministry of Forests 1995). Terrain stability is a rating of the likelihood of a landslide initiating in a terrain polygon following timber harvesting or road construction. The factors that influence terrain stability are the physical attributes of the surficial deposits, slope steepness and morphology, and the drainage or hydrological conditions. Terrain stability classes were initially assigned to each polygon based on physical attributes, slope steepness, and presence of obvious geomorphological processes such as gullying or mass movement. Terrain stability classes range from I to V (Table 2) where I, II, and III designate areas with no or minor slope stability problems following road construction and timber harvesting. Class IV indicates a moderate likelihood of failure while Class V indicates a high likelihood of failure with the presence of active failures. Table 2 is taken from the MATS Guidebook (Ministry of Forests 1995) and outlines each of the classes in general.

Following fieldwork the terrain stability ratings were modified as required to suit local conditions. Final terrain stability ratings take into account features which are not observable on aerial photographs such as drainage, texture, and small scale mass movements.

TABLE 2: TERRAIN STABILITY CLASSIFICATION AND MANAGEMENT IMPLICATIONS

Terrain Stability Class	Interpretation	Management Implications
I	No significant stability problems exist.	None.
II	There is a very low likelihood of landslides following timber harvesting or road construction.	Minor slumping is expected along road cuts, especially for one or two years following construction.
III	Minor stability problems can develop. Timber harvesting should not significantly reduce terrain stability. There is a low likelihood of landslide initiation following timber harvesting or road construction.	Minor slumping is expected along road cuts, especially for one or two years following construction. A terrain stability field assessment by a registered professional is usually not required.
IV	Expected to contain areas with a moderate likelihood of landslide initiation following timber harvesting or road construction. Wet season construction will significantly increase the potential for road-related landslides.	A terrain stability field assessment of these areas is usually required to be made by a registered professional qualified to assess terrain stability prior to any development.
V	Expected to contain areas with a high likelihood of landslide initiation following timber harvesting or road construction. Wet season construction will significantly increase the potential for road-related landslides.	A terrain stability field assessment of these areas is usually required to be made by a registered professional qualified to assess terrain stability prior to any development.

Adapted from: MATS Guidebook (Ministry of Forests 1995)

8.0 RECOMMENDATIONS AND CONCLUSIONS

Field and aerial photograph interpretation work indicates that there are areas within the Upper North Thompson study area that have a moderate to high likelihood of landslides. These areas include the headwalls and transport zones of steep gullies, steep morainal, fluvial and colluvial slopes, areas associated with large bedrock and surficial slumps and steep bedrock bluffs with associated rock falls and slides. As timber harvesting continues the ground being developed will increasingly be on steeper and more sensitive slopes. Much of the lower elevation timber will be removed on the first pass, subsequent harvesting will focus on higher elevation sites with more difficult access or on sites where active geomorphic processes will make road construction and maintenance a challenge. Development above areas mapped as Terrain Stability Class IV or V should be as carefully planned and implemented as areas within Terrain Stability Class IV or V ; detailed terrain and hydrological assessments of such areas would be prudent.

The following discussions and recommendations are provided to aid in reducing slope instability and minimizing erosion and delivery of sediment to creeks:

- Diverted drainage is a leading cause of forest development related landsliding in the interior of British Columbia. Natural drainages have developed since glaciers retreated and are often in a finely balanced state of equilibrium. Road ditches can divert water into other drainages, thereby increasing the effective size of a catchment area. The amount of increased drainage is a combination of ground water and surface water intercepted by the road prism and redirected along ditches and through culverts. Instead of numerous small surface drainages and extensive subsurface flow, the water is directed through one culvert and then into one channel. An increase in water discharge by diversion may exceed the capacity of the natural drainage system and may result in landsliding. In general, it is recommended that existing natural drainage paths be maintained as much as possible and diversion of water be minimized.

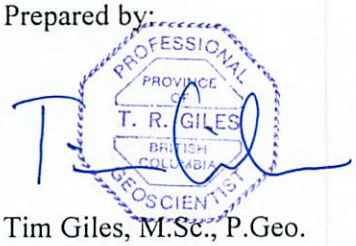
- Cut slopes in terrain with easily erodible material may require stabilization. In the Upper North Thompson study area, such materials are loose sandy glaciofluvial, loose sandy basal and ablation tills, and loose sandy colluvial sediments. Stabilization may require the use of engineering solutions such as geotextiles, gabion walls, armouring or subsurface drains, lock blocks or bio-engineering techniques. Cut slopes may have to be flattened to angles lower than industry practice, or other techniques used above and beyond conventional grass-seeding.

- Fill slopes on moderately steep or steep slopes (in general >60% gradients) should be avoided, particularly in wet or poorly drained areas. Fill slope failures may be a reflection of poor drainage in the sediments, poor drainage control of the road system, construction on unstable sediments, or use of organics within the road bed. Any road planned to cross slopes in excess of 50% must have a road location survey which includes plans, profiles and cross-sections.

- Evidence of debris flows associated with gullies was noted in one gully in the Upper North Thompson River map area. When steep gully sidewalls are impacted by forest development they may fail as small debris slide events that impact the gully channel. If sufficient conditions of slope and water are achieved, the slide translates into a flow which moves rapidly through the gully system. Any development of the steep sidewalls or headwalls of gullies should be investigated in detail by a qualified registered professional geoscientist or engineer.

Information contained within this report and on the maps and aerial photographs are based on observations of land-surface conditions and current understanding of slope processes. The maps are provided as a tool to aid in forest development planning. However, because slope stability is strongly influenced by subsurface conditions that are not apparent from surface observations or aerial photograph interpretation (e.g., characteristics of subsurface materials, subsurface hydrologic conditions), by events whose time of occurrence cannot be predicted (e.g., extreme storms, earthquakes), and by land management practices, the results and recommendations provided in this report cannot guarantee that no landslides will occur in areas affected by forestry activities. Appropriate use of terrain information and implementation of recommendations in this report, or other more detailed terrain stability field assessment reports that are done, will, however, reduce the risk of landslide and erosion.

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APPENDIX 1: LIST OF AERIAL PHOTOGRAPHS

The aerial photographs listed below were used during completion of this project. They are listed by line from north to south and within the lines from west to east.

Line Number	Flight Line	Photograph Numbers
N1	BCC95048	50-46
N2	BCC95048	59-65
N3	BCC95045	23-15
N4	BCC95045	34-41
N5	BCC95045	112-110

APPENDIX 2: ANNOTATED PHOTOGRAPHS



Plate 1: North Thompson River (flowing right to left, west to east) with hanging tributary river valley entering from the south.



Plate 2: Exposure within the shallow headscarp of a small debris slide. Colluvial deposits are derived from underlying morainal sediments, near Observation Site NT23 on south-west facing slope west of Blackstone Creek. Note the presence of poorly defined terracettes formed in the exposed sediments.

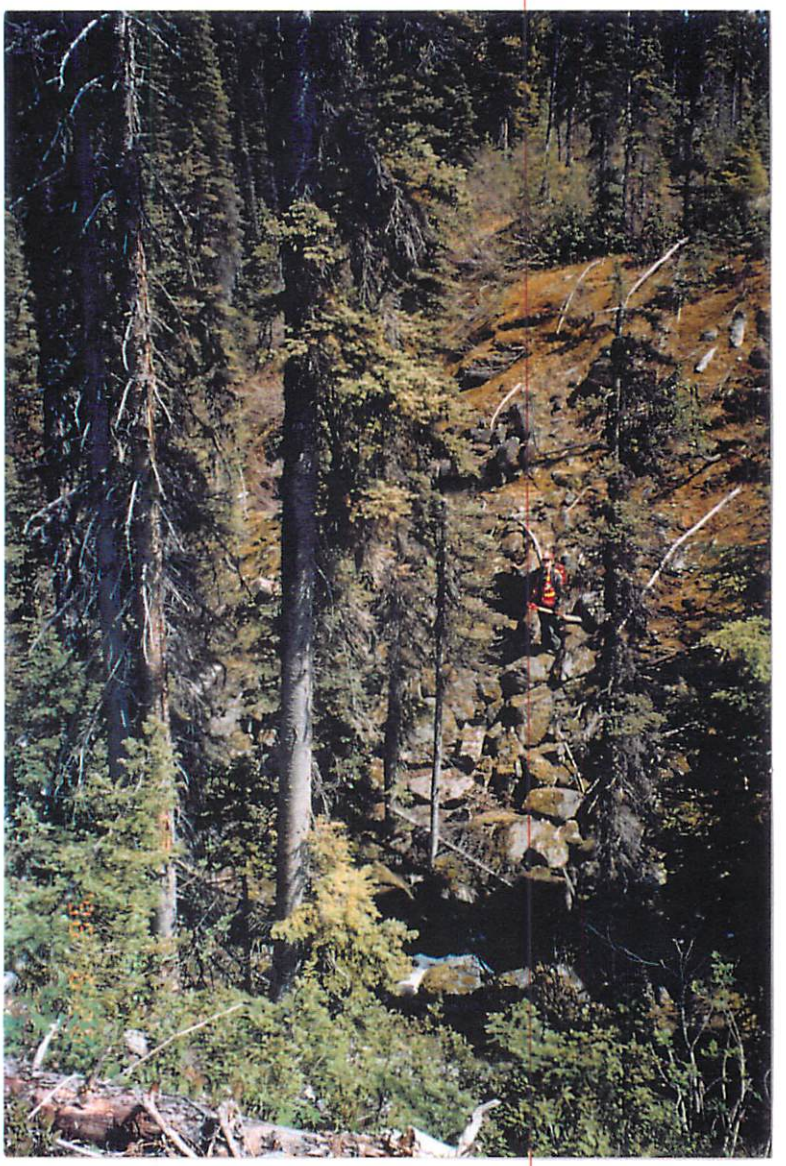


Plate 3: Rock fall or rock slide talus cone deposit near Observation Site NT 112, note the steep slope, coarse particle size and interlocking nature of these sediments. Deposit consists of angular particles, up to 2 m diameter, with a fine sand and silt matrix.

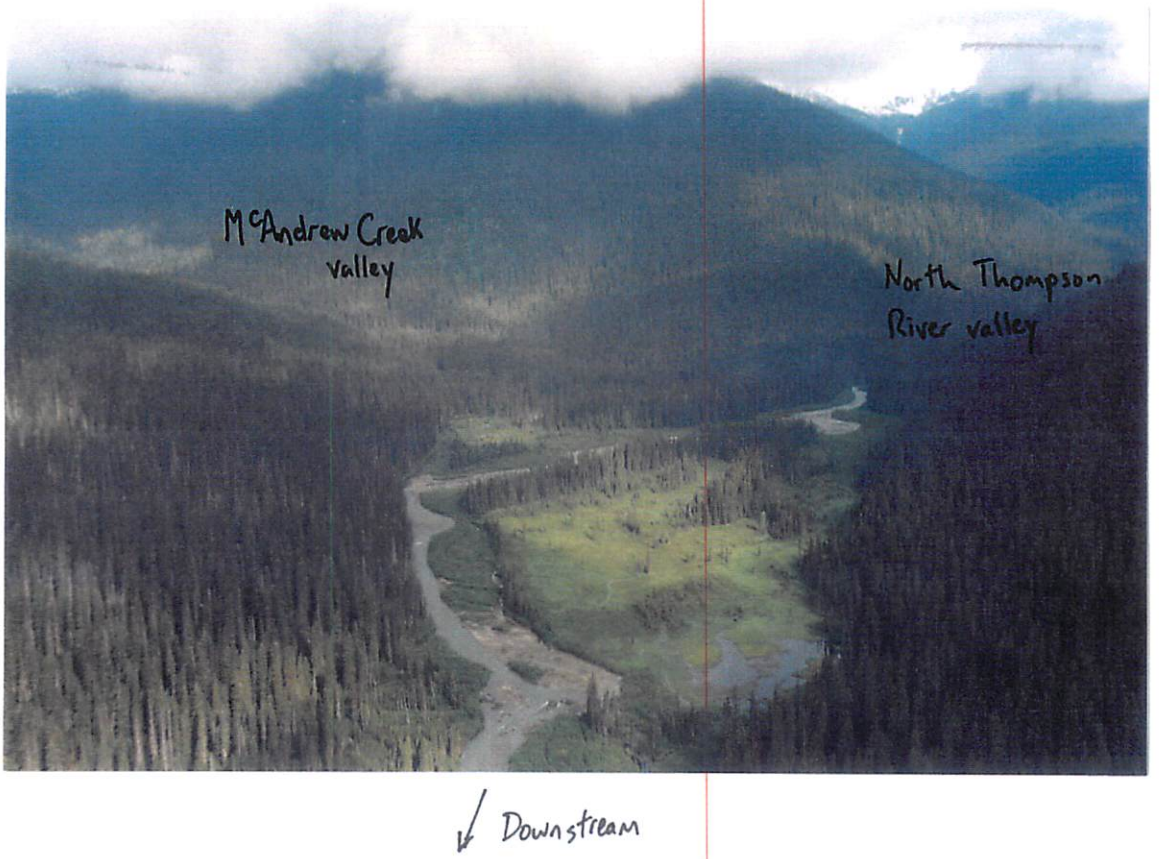


Plate 4: Active floodplain of the North Thompson River, McAndrew Creek enters through the valley to the left (south-west) while the North Thompson flows out of the canyon to the centre right (north-west). Note the irregular sinuous channel, numerous coarse gravel bars with one well developed channel and the organic plain to the sides of the valley.



Plate 5: Basal till from the McAndrew Creek valley, near Observation Site NT4. Note the massive nature of the till, note also the poorly drained nature of the soils at this time of season.

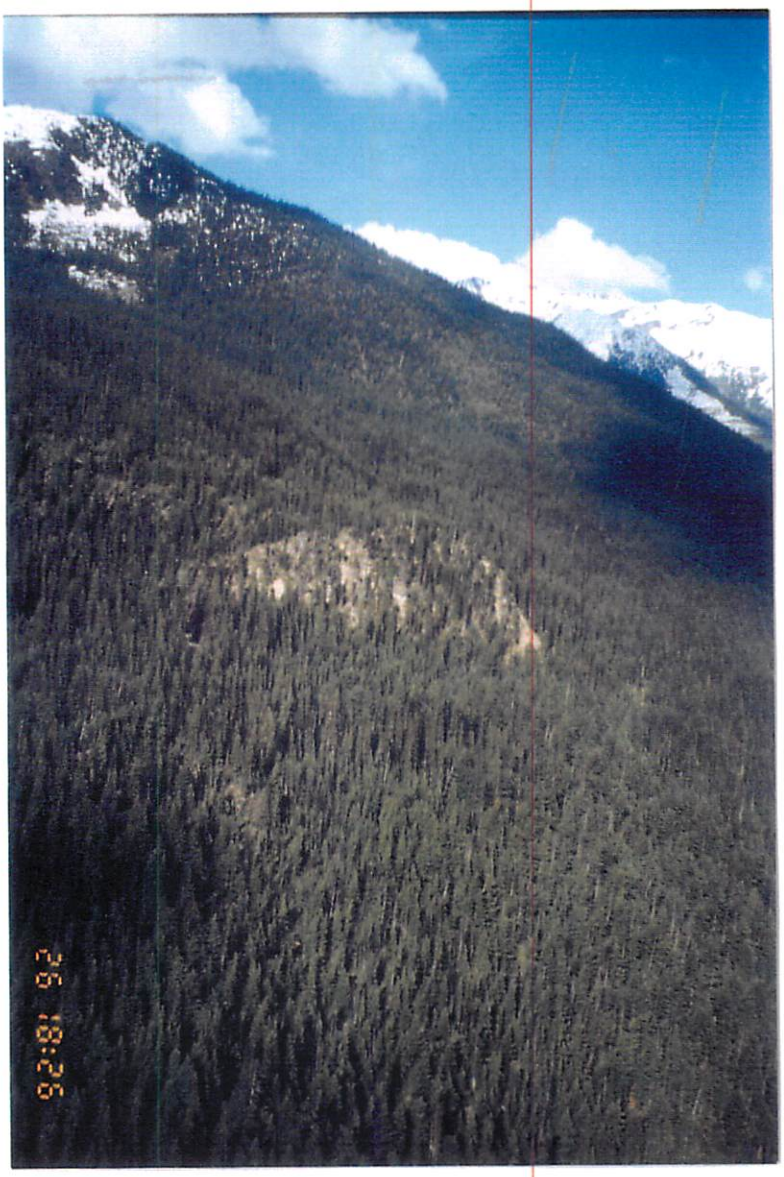


Plate 6: Steep sided bedrock ridge on the north wall of the North Thompson River valley. Rockfall and rock slides have occurred from this rock ridge and the talus cone or apron below is quite extensive downslope.



Plate 7: Snow avalanches tracks and colluvial cones on the steep north-west facing slope of Blackstone Creek valley.

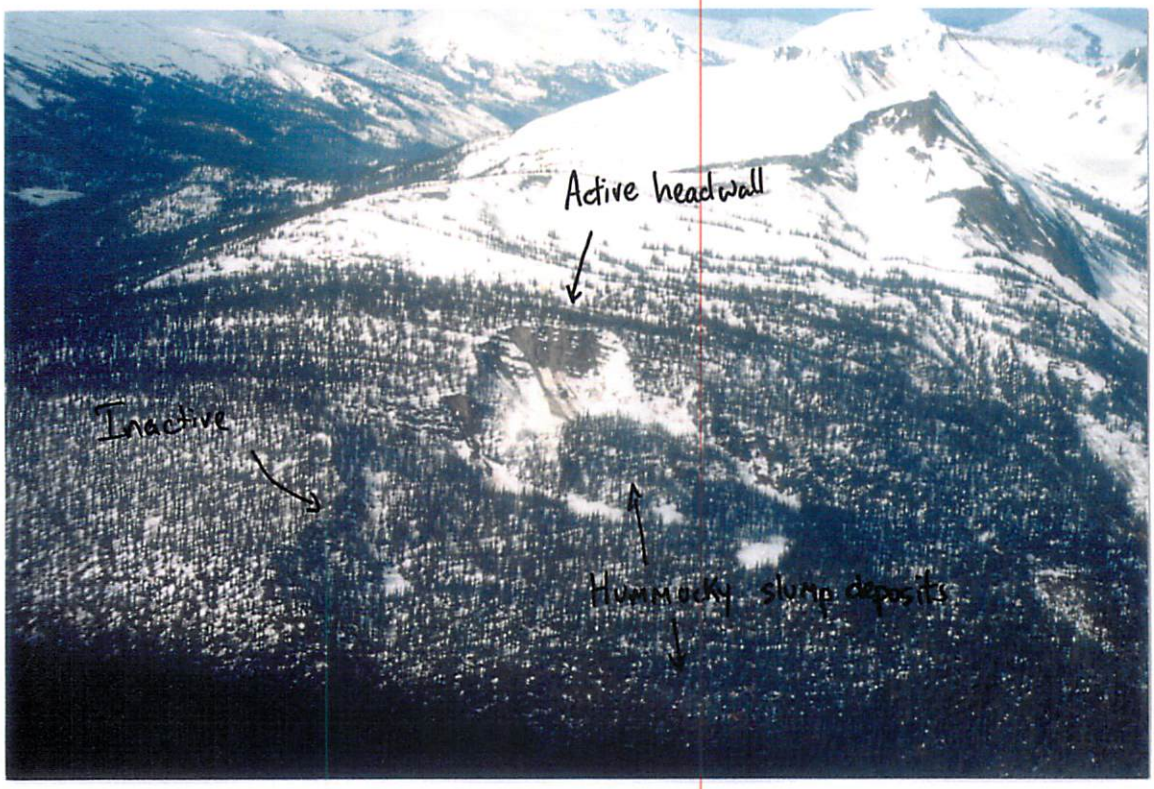


Plate 8: Large bedrock slump on the south slope of Ella Frye Creek. Note the active headwall zone on the right side of the slump, the relatively inactive sides of the slump, and the hummocky slump deposits below.

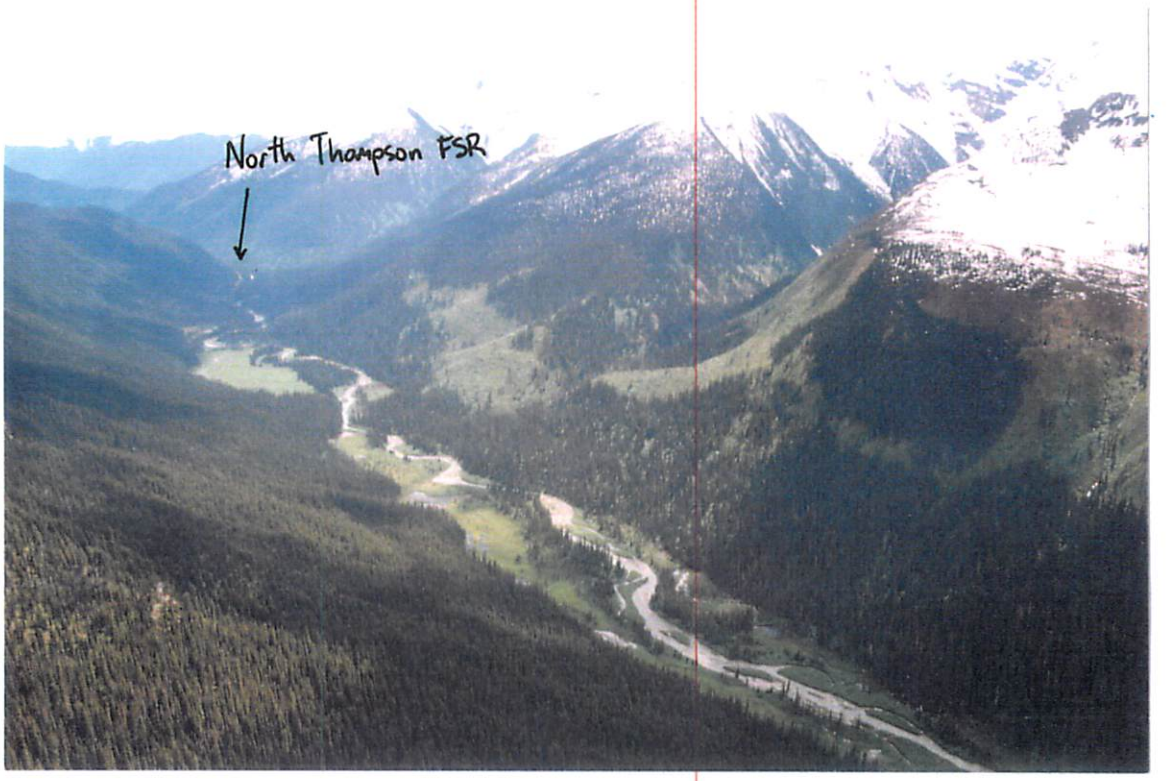


Plate 9: Irregular sinuous channel of the North Thompson River, looking down-valley from the north-east side near the confluence of Blackstone Creek and the North Thompson River.



Plate 10: Steep rock faces and associated rock fall deposits along the margins of McAndrew Creek.



Plate 11: Debris slide into a gully (upper plate) and the gully from the slide to just above the valley floor (lower plate). South side of the North Thompson River.



Plate 12: Rock slide on south-west facing slope of the North Thompson River. Note the steep, active headwall and the long transport zone. Particle sizes in the deposits below are up to 5 m diameter.