

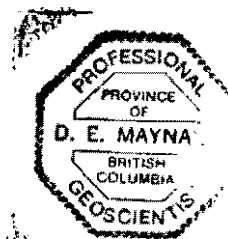
**TERRAIN CLASSIFICATION,
TERRAIN STABILITY,
AND SEDIMENTATION POTENTIAL
OF DURIEU RIDGE MAP AREA**

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- Terrain Polygons with Terrain Stability and Sedimentation Potential Ratings
Scale 1:10,000; parts of 92G 019, 029, 030

1.0 INTRODUCTION

A program of terrain stability assessment for the Durieu Ridge area was requested by the Chilliwack Forest District. This report discusses the methods and results of this program which consists of detailed mapping of terrain and terrain stability (Forest Practices Code of B.C., 1995).

The main product of this project is a 1:10,000-scale map, which classifies the terrain characteristics and provides interpretations for the potential effects of conventional forest harvesting on terrain stability and stream sedimentation potential. The data and interpretations are presented at a level which are suitable for helping to plan forestry development, but are not usually detailed enough to allow for site-specific, operational recommendations and decisions.

The map product is produced in digital and hard-copy (mylar) form. In addition, a paper map print is included with each copy of the report. The report is intended as a supplement to the mapping, documenting the mapping methods, describing important physical characteristics of the area, and summarizing the interpretations. Full documentation of legends explaining the terrain classification, terrain stability, and sedimentation potential assessments and a list of all terrain attribute data are provided in the report appendices.

2.0 SURVEY AREA

Durieu Ridge map area borders the east side of Hatzic Prairie, about 60 km east of Vancouver, BC. (figure 1). The map area consists of 1845 ha east of Sylvestor Road up to the crest of the ridge and extending from about the north end of Hatzic Lake to a large gully channel between Pattison and MacNab creeks. It occurs in parts of B.C.G.S. map sheets 92G 019, 029, and 030. A central point in the study area is 10 km north-east of Mission, B.C. and can be reached in 25 minutes by two-wheel drive vehicle from this community.

Topography of the area is highly variable. Elevations range from about 20 m a.s.l. along Sylvestor Road (Hatzic Lake elevation is 5 m a.s.l.) to 850 - 1100 m along the crest of Durieu Ridge. A relatively broad, stepped toe-slope separates Hatzic Prairie from the steeper, rocky, ridge sideslopes (photo 1).

A number of perennial creeks drain the ridge and flow into the main valley floor (Lagace Creek and Hatzic Slough). Pattison Creek drains the largest catchment area with a dendritic channel network incised into a headwall bowl. Six smaller drainage systems exist between Pattison and Scorey creeks. All these southern creeks have similar forms with steep, narrow headwall gullies occupied by one or two channels and lower-gradient, single-stem, toe-slope reaches narrowly incised into the bench-land. Scorey Creek, in the south of the area, flows entirely on bedrock but the streams to the north are mainly cut into thick surficial deposits across the toe-slope bench; mid-slope and headwall reaches are all bordered by bedrock-controlled slopes. Pattison Creek is a dramatic exception to this landscape with thick surficial deposits infilling much of its headwater bowl.

Processes of mass movement and erosion are recurrent, to various degrees, along all the creek systems. The greatest volume of sediment transported from the slopes occurs in Pattison Creek, mainly as the result of debris flow activity such as occurred in major events in 1960 and 1990 (Galey et al, 1992). Gully headwall instability is a well-documented erosion process in coastal British Columbia in both

logged and unlogged areas. In the nearby watersheds of Cascade and Norrish creeks the number of landslides initiating in clearcuts and mature forest are approximately equal (Howes, 1987).

The region is characterised by cool, wet winters and dry, warm summers. Howes (1987) provides rainfall data illustrating these conditions: annual precipitation in Mission (221 m elevation) is 1772 mm; 69% of it falls between the months of October through March; 1-day and 3-day extreme precipitation totals calculated for a ten-year return interval are 92.6 and 123.0 mm respectively. The winter months are characterised by these intense storms which are considered to be an important triggering mechanism of landslides.

Land-use of the region is a mixture of agriculture and rural residential on the valley lowlands and forestry on the uplands. About 270 ha of private land border the east side of Sylvester Road south from Pattison Creek. Upslope of this, lying south of Pattison Creek to the north side of Scorey Creek, is a small private woodlot; its eastern boundary crosses the valley sideslopes approximately in a mid-slope position. Active logging in the woodlot consists of small clearcuts accessed by roads crossing the subdued toe-slope bench-lands.

Older logging has also occurred in the study area. Most of the lower slopes were selectively logged earlier in the century. More recent clearcutting (probably mainly in the 1960's) extended across the ridge crest from Norrish Creek. In the south, around Dewdney Peak the logging was restricted to the ridged upland, but around the headwater bowl of Pattison Creek clearcutting was done on the steep upper slopes which could be reached from ridge-top roads and landings. In addition, a steep-grade, switchback road was built along the north valley wall of this creek. There is little doubt that logging and low-quality road building have contributed to the recurrent, natural instability of the Pattison Creek headwalls.

Many of the creek systems draining Durieu Ridge are used as domestic water sources. Therefore, an important consideration for land-use management of the area is adequately protecting the individual, small watersheds to maintain water quantity and quality. Terrain stability assessments provide a means

by which the potential impacts of logging development on slope erosion and stream sedimentation can be evaluated.

3.0 SURVEY MEHTODS AND RELIABILITY

The mapping program involved inventorying existing features, conditions, and processes of the landscape by field observations and by map and aerial photographic analysis. This inventory information was assessed to make interpretations relating to the stability and erodibility of slopes and gullies 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 (Agriculture Canada Expert Committee on Soil Survey, 1987).

Terrain units were stereoscopically delimited on 1993, 1:15,000, black-and-white aerial photographs. These units subdivide the land surface according to the origin and texture of surficial materials, landforms (surface expressions), and presence of modern geomorphic processes which modify the landscape. Drainage classes are mapped according to soil and vegetation patterns and landscape characteristics, and slope gradients were determined by a combination of field and contour-map measurements and aerial photographic interpretation. The Terrain Classification Legend presented in appendix I fully explains and describes all the component symbols and terms associated with this mapping system.

Two interpretive ratings were assigned to each terrain unit. Terrain stability is assessed in a five-class system according to the estimated slope stability 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 III. Descriptions and forest-management implications for the five terrain stability classes are also given in appendix I (Terrain Stability Legend). The second interpretive rating describes the potential for sedimentation caused by a landslide initiating in that particular terrain unit.

A three-class qualitative system (after Howes, 1987) is used to rate the likelihood of landslide debris entering a downslope water body if a landslide should occur within the map polygon. Descriptions of the sedimentation potential ratings are also given in appendix I (Sedimentation Potential Legend). These interpretive classification systems conform to those prescribed in Mapping and Assessing Terrain Stability Guidebook (Forest Practices Code of B.C., 1995).

Hugh Hamilton Ltd. of North Vancouver, B.C. was subcontracted to transfer polygon boundaries from the aerial photographs to the map base, and enter the map data into GIS digital files. Base mapping is extracted from B.C.G.S. TRIM digital files (92G 019, 029, and 030); a key map on the terrain stability map (back pocket) shows these sheet boundaries with respect to the study area. The TRIM - standard base mapping shows planimetric data (streams, surface features) and contours (20 m C.L.). Limited text (e.g. some place names and contour ladders) has been added to the files.

Transfer of the terrain polygon data from the aerial photographs onto the existing map base was done using a Mono-3D program. The program uses a Triangulated Irregular Network (TIN) surface and a rigorous photogrammetric mathematical model to transform photo coordinates to 3D ground coordinates in real time. Photographic control was derived from TRIM - controlled, high-level (small-scale) aerial photos and transferred down to the low-level photos (1993, 1:15,000) using photogrammetric principles. A least-square adjustment was performed on each controlled low-level photo to establish the mathematical fit of each photo and the comparison to the adjacent photo. Once this control was established, the terrain polygons are digitized directly from the aerial photographs into the TRIM digital files.

The polygon information was then processed to create closed polygons, each identified by a unique number. Terrain attributes and terrain stability and sedimentation potential ratings were entered into a data base and processed to link with each polygon number. While all this information is stored in the digital files and available to retrieve in any number of mapping themes, specific to this project is the highlighting of the terrain stability and sedimentation potential ratings. Therefore, the hard-copy maps accompanying this report (in mylar and paper print) show for each polygon: an identify number (1 to 189), a terrain stability rating (from classes I to V), and a sedimentation potential rating (high,

moderate, or low). Each polygon identity number is linked to the D-base file which is reproduced as hard copy in a list of terrain attributes in appendix II.

Field work was carried out during a hot, dry four-day period (July 18-21, 1995) in accordance with Guidelines and Standards for Terrain Mapping in British Columbia (Resources Inventory Committee, 1995). Foot traverses originated from various road-access points; on two days a helicopter was used for high-elevation drop-offs. The traverses and site inspections were selected to intersect representative terrain types and representative areas of potential instability. Detailed observations were recorded at 89 sites. In addition, many other reconnaissance-level notes (e.g. slope gradient) were made. Brief helicopter reconnaissance was done along the steeper, poorly accessible upper slopes with special attention paid to important features such as landslide scars and deep gullies. Traverse locations are identified on figure 1; locations of the detailed ground observation sites are shown on the terrain stability map (back pocket) and were marked in the field with three pink ribbons (labelled - e.g. Dur-20).

The reliability of the terrain mapping is considered very good. Ground access was more than adequate to characterize terrain conditions at the required Terrain Survey Intensity Level (TSIL) C (Forest Practices Code of B.C., 1995). Priority was given to field checking those areas which appeared topographically and geologically more complicated or exhibited evidence of active or potential instability. Many of these areas can be considered as undergoing TSIL B mapping. The quality and scale of the aerial photographs was optimal for detailed mapping of terrain and terrain stability features and processes; map polygons are expected to reliably describe on-ground conditions.

The assessment of terrain stability and stream sedimentation potential is presented with a high degree of confidence. The research by Howes (1987) provides some quantitative justification for the stability and sedimentation interpretations. However, it should be noted that Howes' (1987) work and a similar study by Thomson (1987) concentrated only on clearcut landslide predictions; road-related failures were not considered in their four-class rating system. The terrain stability ratings (five-class system) applied for this project describe the instability potential for both post-logging clearcut failures and road-related failures. Modifications to these interpretations are largely based on limited documentation

(Fannin and Rollerson, 1993, Rollerson et al, 1986, and Rollerson, 1992) and the writer's considerable experience in terrain stability assessments throughout coastal British Columbia. In particular, two recent studies have been completed in south-coast areas of similar climate and physiography where the procedures of Howes (1987) and Thomson (1987) were successfully incorporated (Maynard, 1994 and 1995). In general, the interpretive ratings have been conservatively assigned because of the greater sensitivity associated with domestic water supplies and private residential land.

Accuracy of the map plotting is excellent. Transfer of the original terrain polygon boundaries from the aerial photographs into the TRIM digital files was done efficiently and with a high standard of photogrammetric control. Polygon boundaries are considered to be accurately aligned with respect to contour and planimetric features shown on the TRIM base.

A cautionary note is necessary with regards to the scale of the map presentation. The mylar and paper copies were prepared at 1:10,000 in order to make the map easier to read. Detailed terrain stability mapping at TSIL B to C is usually intended to be presented at 1:20,000; this scale more accurately reflects the level of detail and reliability of the map data. Therefore, it must be stated that the larger presentation scale used for this project is only to increase the display quality and in no way implies an increased level of detail and accuracy.

4.0 GENERAL GEOLOGY AND PHYSIOGRAPHY

The mountain valleys and fiords of the south coastal area of British Columbia occur within the Southern Fiord Ranges of the Pacific Ranges of the Coast Mountains; Durieu Ridge is part of the southern mountain from where it abuts the Fraser Lowland Mountains; Durieu Ridge is part of the southern mountain front where it abuts the Fraser Lowland (Mathews, 1987). The rugged topography of the mountainous areas is the result of pre-Pleistocene uplift and dissection of an old land surface. During the Pleistocene Epoch, multiple glaciations further modified the landscape. 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 thick ice moving across the lower mountain ridges. Deposition of surficial deposits was most extensive in the Fraser Lowland and major tributary valleys, resulting in thick accumulations of glacial, inter-glacial, and post-glacial sediments in many areas.

Bedrock in the study area is entirely coarse-grained intrusives (granodiorite to quartz diorite) of the Coast Plutonic Complex. (Roddick, 1965). Fresh, unaltered intrusive rocks are usually very hard with widely-spaced, regular to irregular fractures. In places, where narrow zones of intense fracturing do occur, the bedrock may be more easily broken. The dominance of coarse-grained granitic bedrock in the region favours dominantly sandy matrix textures for most of the surficial sediments.

5.0 SURFICIAL GEOLOGY AND TERRAIN CLASSIFICATION

Although major valleys and fiords around the study area became established in early or middle Tertiary time during uplift of the Coast Mountains, it was the recurrent glacial erosion and deposition of the Pleistocene Epoch which modified the area to its present-day form. The early glacial events are less well known because the sedimentary record has been mainly covered or removed. However, the sediments and landforms generated during the last major (Fraser) glaciation and during late-stage local glacial readvances are well preserved in the Fraser Lowland near the study area (Armstrong, 1980). In addition, erosion and deposition occurring in Holocene (post-glacial) time have further modified the landscape in places.

At the beginning of the Fraser Glaciation, ice advanced out of the high mountain areas, flowing along pre-existing valleys. At the glacial maxima, most ridges around the study area were buried by a southerly to southwesterly flowing ice sheet. In places, bedrock and pre-existing surficial sediments were being scoured and removed and, in other places, glacial till (Vashon Drift) was being deposited beneath the thick (at least 1800 m) sheet of ice. Till deposition was most extensive in lowland areas where the erosive power of the glaciers was limited. The tributary valleys were subject to greater glacial erosion. Thus, valley sidewalls usually only have thin, discontinuous till mantles.

Deglaciation probably commenced relatively quickly and the ice sheet retreated from the western Fraser Lowland. As the ice front retreated into the fiords and larger valleys the glacier termini stabilized somewhat and the ice sheet divided into a series of valley tongues. With the uplands and ridges emerging, meltwater was eroding slope and valley-fill deposits. The sea followed retreating ice into the inlet valleys and across coastal lowlands; in early deglacial time sea level was as much as 200 m above present level. As the land surface gradually rebounded in response to the removal of heavy glacial ice, marine-glaciomarine and deltaic sediments which had been deposited on the submerged land were raised above lowering sea level. Thick accumulations of these deglacial deposits (Fort Langley Formation) are often associated with intermixed glacial and ice-contact sediments (Sumas Drift)

deposited by surging valley glaciers in the waning stages of the Fraser Glaciation when sea level was still at least 90 m higher than at present (Armstrong, 1984).

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 aprons at the base of the slopes and channels. Debris transportation by landsliding and gully erosion continues in the present as does active fan aggradation, albeit much slower than in early post-glacial time.

Surficial materials commonly produced by post-glacial erosion and deposition include colluvium from weathered bedrock, fluvial sediment from stream activity, and lacustrine sediment and organic matter from infilling of lakes, ponds, and lowland depressions.

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, but all rock exposures in the study area are granitic. Outcrops occur as hummocks and ridges or as steep cliff faces, usually with discontinuous colluvial mantles, mainly on the steeper valley walls and along all the deeply incised gully systems. Mid to upper slope positions are all bedrock controlled but rock also occurs in places on the lower slopes. A significant bedrock ridge exists on the south side of lower Pattison Creek (between Sylvester Road and the small lakes) and rock is at or close to the surface of the hummocky lowland from just north of Scorey Creek to the southern map boundary.

Fresh granitic bedrock is very competent and hard. For the most part, fractures in the rock are widely spaced and zones of weakness are infrequent. Bare rock surfaces, particularly at upper elevations, are subject to weathering processes which gradually cause surface disintegration of the bedrock and may lead to failures. Localized areas of highly fractured rock, are much more susceptible to breaking and erosion; the large gully headwalls along Durieu Ridge may be related to such fracture zones.

Colluvium and moraine (glacial till) are the most dominant surficial materials mantling the study area landscape. Colluvial debris is common on the ridge uplands, forming thin, continuous to discontinuous mantles on most of the mid to upper slopes and thick, continuous aprons on lower slopes below bedrock-dominated sites. On moderate to moderately steep slopes, away from major bedrock cliffs the colluvial soils have mainly sandy to rubbly textures. Coarse colluvium (blocky to rubbly) is more common immediately below bedrock cliffs, on steep slopes, and along rock-controlled gullies. Colluvial deposits are usually well to rapidly drained, but seepage and imperfectly drained soils may occur where slope gradients abruptly decrease or impermeable material (bedrock or till) is close to the ground surface.

Glacial till is material transported and deposited directly from glacier ice. It is a dense, compact, impervious sediment consisting of a poorly sorted mixture of sand, silt, and rock fragments. Moraine in the study area has a dominantly silty sandy matrix. Till deposits are thickest below about 250 m elevation where they overlie bedrock or pre-glacial sediments. This lowland till may include lodgement phases of both Vashon and Sumas Drift (photo 2). Looser flow tills and associated deglacial sediments are also common constituents of Sumas Drift and probably compromise much of the material on the toe-slope bench between Pattison and Scorey creeks.

Above about 250 m elevation, till mainly occurs as thin (usually less than 1.5 m), discontinuous mantles on isolated segments of moderate to steep slope. More continuous mantles are only observed on the broad subdued crest of Durieu Ridge. Thick sequences of upland till are only preserved in the central headwall bowl of Pattison Creek. As an example, at least 10 m thickness of till is exposed at a landslide scarp at 940 m elevation (photo 3); farther down this gully (600 m elev.) another large slide scar about 50 m deep shows a much thicker sequence of till (photo 4).

Drainage of moraine is largely dependent on topography and slope position. Till is typically well drained on sloping terrain but subdued and toe-slope landforms are often areas of seepage accumulation and drainage there may be moderately well to poor. Areas of restricted drainage may be indicated by the presence of small depressional wetlands.

Deglacial materials are part of the Sumas Drift and formed from meltwater associated with disintegration of late-stage valley glaciers. Granular glaciofluvial sediments are dominant with only minor exposures of fine-textured glaciolacustrine sediments intermixed. Glaciofluvial materials consist of valley-floor, sand and gravel outwash which occurs to the north and south of lower Pattison Creek. These may thickly overlie Fort Langley Formation glaciomarine silts and clays; however, no exposures of this latter sediment were observed in the map area. The other common glaciofluvial deposits in the map area are blankets of poorly-sorted sandy rubble, derived from erosion along the main gully systems and probably deposited as a series of kame terraces between Sumas valley ice and the Durieu Ridge sideslope. Thick sequences of down-slope bedded deposits occur up to about 620 m elevation in Pattison Creek (photo 4). The smaller gully systems to the south are all bordered by slope segments where similar bedded sandy rubble mainly overlies till (or, in places, bedrock) in a variety of landforms including gullied moderate slopes (photo 5), subdued benches, and creek-bank scarps. These well-drained deposits mainly occur between 200 - 450 m elevation, immediately adjacent to and above the toe-slope bench-land.

On the bench-land itself (below 200 m elevation), Sumas Drift deposits are much more variable but primarily consist of till with intermixed cappings of well-drained gravels and glaciolacustrine silts which will restrict subsurface water percolation. Surface textural changes may be abrupt and consequently, surface soil drainage may be highly variable over short distances.

Post-glacial fluvial activity has continued to modify the map-area landscape. Deposition along Pattison Creek fan is the most dramatic example, but similar processes created fans and toe-slope aprons at the mouths of all the main gully systems. These have coalesced into a relatively broad gently-sloping blanket (photo 6) of granular well-drained sediment at the bench-land-valley-wall interface (about 200 m elevation). Materials derived from the high-energy gully systems probably mainly deposited as a combination of debris flow-debris flood events; as a consequence, sediments are commonly poorly sorted, ranging in texture from silt to boulders (mixed fragments). Over time, fluvial processes have become more erosive and the small creeks have downcut into the bench-land surface, creating creek-bank scarps eroded into and through their ancestral deposits (photo 7) and down into glacial materials (Vashon and Sumas Drift). The other main type of fluvial deposit in the map area is along the western

boundary at Sylvester Road which borders and crosses part of Hatzic Prairie. Sands and gravels are associated with valley-floor sedimentation. A unique deposit in the map area is the small infilled lake in the hollow south of Pattison Creek. Silts and fine sands are actively washing into this depression from sideslope gullies gradually building up the surface so water only remains ponded for part of the year (photo 8).

Geomorphic processes have also contributed to post-glacial modification of the Durieu Ridge map-area landscape. Gullying and landsliding are the main processes; these are affected by complex interactions of many factors, including climate, bedrock geology, topography, and characteristics of unconsolidated materials. No significant landslides occur on open slopes although some high rock cliffs are susceptible to crumbling and ravelling of fractured bedrock surfaces. Instability is mainly restricted to headwalls and sidewalls bordering deeply-incised gully channels and to high scarps of incised creeks. The significance of these active systems is that they have a high capability for transporting sediment from the upland slopes to the valley lowland.

The smaller gully systems, including Scorey Creek and those north to Pattison Creek, have similar forms: dendritic to multi-channel, steep-gradient, bedrock-controlled headwalls; a mid-slope single-stem reach where channel-gradient decreases but confining walls remain steep and high with bedrock increasingly covered with till and glaciofluvial gravel toward the bottom; and a lower reach where gentle to moderate gradient channels are incised 3-10 m deep into thick surficial materials across the toe-slope bench (except Scorey Creek which is on bedrock).

Mass movement scouring and deposition is most dramatic in the watershed of Pattison Creek. Thick, deeply incised surficial materials in the central headwater bowl (photo 4) would usually be considered as having a high natural instability potential. Modifications caused by clearcutting and roadbuilding probably further destabilized the gullied slopes leading to a number of major landslides which have caused extensive sedimentation into the Hatzic Prairie lowland. An example of the magnitude of one of these events is described by Galey et al (1992) where an estimated 85,000 m³ of debris was transported from the initiating slide (photo 3) and downslope gully scour (photo 9) onto the valley-floor fan. Bedrock-colluvial headwalls on the upper, outer slopes of the headwater bowl also show

evidence of landsliding which has travelled into and along the gully channels (photo 10). There is a high probability of further debris flows in this gully system. A considerable volume of actively eroding sediment is exposed in the headscarp of a 1960 landslide scar (photo 4) which threatens to erode headward into a debris pile from the 1990 slide.

On a much reduced scale, small gullies eroded into steep slopes of glaciofluvial gravel over till are often sites of instability. Gully headwall slumps (photo 11) and bank undercutting during high-runoff events have caused debris flows of a few hundred cubic metres (photo 12) of material which accumulate at the toe-slope apron.

6.0 TERRAIN STABILITY ASSESSMENT AND SEDIMENTATION POTENTIAL

Individual terrain units have been assessed according to their estimated stability , erosion and sedimentation potential following conventional logging. This classification, indicating the expected response of the landscape to clearcut forest harvesting and road development, is shown on the accompanying Terrain Stability and Sedimentation Potential Map. Explanations of the terrain stability and sedimentation potential classifications are detailed in appendix I; criteria used for determining the stability class ratings are described in appendix III.

Terrain stability ratings 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 and forest engineering personnel. Problems of instability are expected to be most severe in classes IV 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.

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 ground which are too small to identify during reconnaissance mapping. Similarly, inclusions of stable ground may occur within class IV and V units.

Sedimentation of stream and lake systems by direct mass-movement deposition is an important concern when assessing post-logging terrain stability in a sensitive area (e.g. domestic water supply or important fish habitat). For this reason, each terrain polygon has been subjectively rated according to the likelihood of landslide debris entering a downslope water body if a landslide should occur within the polygon. Factors used to assess the potential impact of landslides on a receiving water body include

slope angle, the presence or absence of a runout zone, the length of the runout zone, and the presence of gullies which provide direct linkage between the slope and valley floor (appendix I contains a chart explaining how these factors are assessed).

Sedimentation potential ratings are classed as high, moderate, or low depending on the likelihood of landslide debris impacting upon a stream system or lake (a modifier symbol attached to the rating, e.g. M+, indicates that the ultimate receiving water body is a lake). Sedimentation from landslide deposition will be mostly contained within a larger lake basin but in a stream system the debris is available for episodic transportation and deposition. A stream system is assumed to include stream order one and two channels, gullies, and small lakes and wetlands that drain directly into main creek channels.

Terrain stability concerns are greatest in those areas having actual or high potential for instability combined with close proximity to receiving creeks. Accordingly, all steep slopes bordering the main gully systems are considered highly sensitive to forestry activity. These are denoted by a stability rating of V with a H or M sedimentation potential rating or a stability rating of IV with a high (H) rating of sedimentation potential. Almost all the headwater bowl areas are included (e.g. photos 3, 4, 9, and 10), as are narrower zones along mid-slope gully reaches and on incised creek banks along lower-slope reaches (photo 7). This high potential for direct sedimentation impact on the stream systems normally precludes most logging development from these landscape types. A landslide event of similar magnitude to the 1990 Pattison Creek debris flow is not expected in any of the other gully systems because of the bedrock control in most of their watersheds. However, any increase in sediment yield to the creek channels may negatively impact on current downstream water uses and thus, their watersheds should remain as protection forest.

Small, steep-gradient gullies along a lower slope segment also create a potential sedimentation threat to adjacent lowland sites. Evidence of narrowly-confined debris flows and channel scour were seen on the slope east of the infilled lake (photos 11 and 12). Much of this eroded sediment is probably contributing to the depression-floor sedimentation (photo 8). Sediment is not going into an active

stream channel but the slope erosion processes will pose constraints to logging development in the affected areas.

Unstable slopes that are disconnected from the stream systems (i.e. stability class V, sedimentation potential L) usually involve steep, upper colluvial-bedrock terrain where the failures are associated with crumbling rock and colluvial sloughs and ravel. These slides rarely travel far because of their dryness and the irregular, bedrock topography which often creates confined runout areas. Nevertheless, logging opportunities are extremely limited on these slopes and any development must be carefully considered.

All open colluvial-bedrock slopes over 65% average gradient and incised small, dry gullies which show no evidence of mass movement are rated stability class IV. These are scattered throughout the map area but occur mainly on the mid to upper valley slopes between gully headwalls. Some steep, rock-controlled slope segments also extend to the lower valley walls (photo 13); discontinuous rock cliffs border the ridge to the south of lower Pattison Creek. Despite their apparent surficial stability, class IV ratings are applied because of their steepness and the potential for road-sidecast failure. Careful harvesting on such slopes does not usually lead to significant instability problems; 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 are possible in all class IV units, particularly in thicker surficial deposits, so proximity to a water body and sedimentation potential must be considered in any development plan. Gullied units will have a higher potential for debris transport.

Most of the toe-slope bench-land, lower valley-wall slopes, mid-slope benches, and upland ridge crests are rated as stable (classes I to III) where post-logging instability and erosion are not expected to be a concern. This includes most well-drained ground of less than 70% slope and most gullied or wet slopes of less than 60%. There is very little, if any, evidence of significant erosion activity in most of these areas. However, it is possible that some minor inclusions of potentially unstable ground may be encountered within some class III units. Where these inclusions are obvious (e.g. narrow gullies) a minor component may be mapped (e.g. III/IV). Any class III unit which has a high sedimentation potential rating should be considered as a sensitive area.

Colluvial slopes between 45-70% are the most common class III terrain type whereas morainal and glaciofluvial-fluvial landforms with slopes less than 50% are dominant class II units. Valley-floor and depressional fluvial surfaces are mapped as stability class I.

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APPENDIX I

**TERRAIN CLASSIFICATION, TERRAIN STABILITY,
AND SEDIMENTATION POTENTIAL LEGENDS**

INTRODUCTION

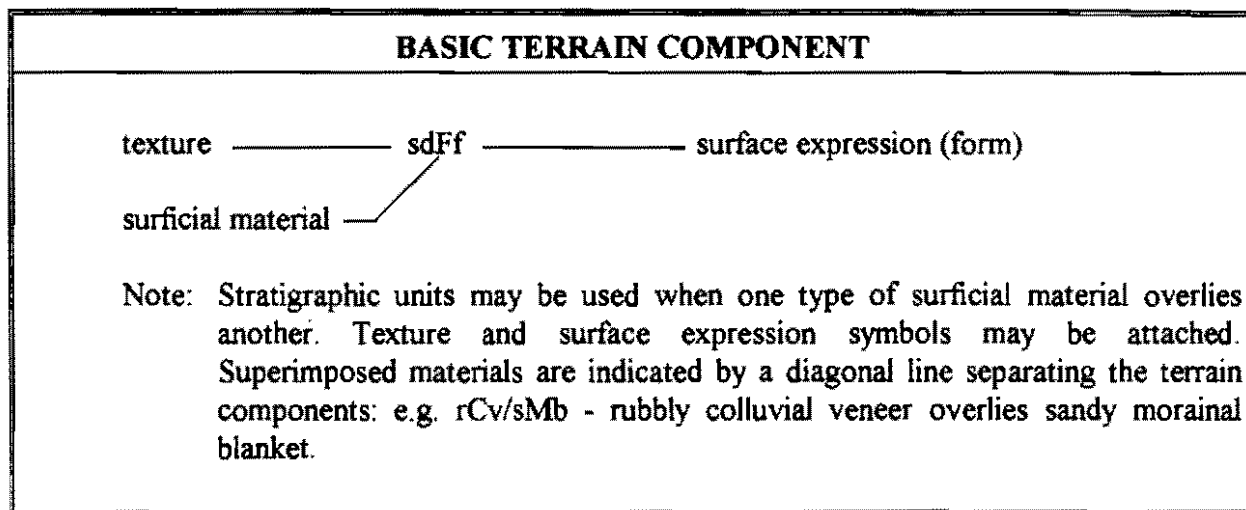
Following are legends explaining the Terrain Classification System of mapping and the interpretive descriptions for terrain stability and sedimentation potential and a complete list of attribute data for each terrain polygon (appendix II). Slight modifications to the mapping system have been made in order to allow easier entry of the data into a digital file. A total of 189 terrain polygons are mapped in the Durieu Ridge study area. The numbered terrain polygons with terrain stability and sedimentation potential ratings shown are portrayed on the accompanying 1:10,000 map (map pocket).

The terrain polygon numbers which appear on the map provide the reference to the data listed in the various columns as explained in the following table and compiled in appendix II.

TERRAIN DATABASE DESCRIPTION

<u>Field Name</u>	<u>Description of Field Name</u>
POLYGON	Terrain polygon number
TC1, TC2, TC3	Basic terrain components consisting of surficial material type and texture, surface form, and stratigraphic information; up to three components may be used and are written in order of decreasing importance.
TC DELIM	Terrain component delimiters are used to indicate the relative percentage of each basic terrain component in a polygon; deciles are used (e.g. 10=100%, 6=60%) and are written in order of decreasing importance (up to three).
GEO PROC	Geomorphic processes which are actively affecting or modifying a polygon are indicated.
SOIL DR	Soil drainage is presented as a unique class (DOM) or as a dominant (DOM) and subdominant class (SUB).
SLOPE %	Slope gradient is presented in percent as a range of values (MIN -MAX) or as an average (MIN).
TERRAIN STABIL	Terrain stability rating is presented as a unique class (from a 5-class system) which indicates the expected response of the landscape to forest harvesting and road development.
SED POT	Sedimentation potential rating is presented as a unique class (from a 3-class system) which estimates the likelihood of landslide debris entering a downslope water body if a slide should occur within the polygon.

TERRAIN CLASSIFICATION LEGEND



TEXTURE

Texture refers to the size, roundness, and sorting of particles in clastic sediments, and the proportion and degree of decomposition of plant fibre in unconsolidated organic sediments.

Clastic Terms

<u>Symbol</u>	<u>Name</u>	<u>Size and Description</u>
a	blocks	angular, greater than 256 mm
b	boulders	rounded and subrounded, greater than 256 mm
k	cobbles	rounded and subrounded, 64 to 256 mm
p	pebbles	rounded and subrounded, 2 to 64 mm
s	sand	.062 to 2 mm
z	silt	.002 to .062 mm
c	clay	less than .002 mm
d	mixed fragments	mix of rounded and angular, greater than 2 mm
g	gravel	mix of boulders, cobbles & pebbles, greater than 2 mm
x	angular fragments	mix of rubble and blocks, greater than 2 mm
r	rubble	angular particles, 2 to 256 mm
m	mud	mix of clay and silt, less than .062 mm

Organic Terms

<u>Symbol</u>	<u>Name</u>	<u>Characteristics</u>
e	fibric	least decomposed organic material
u	mesic	intermediate decomposition between fibric and humic
h	humic	advanced decomposed organic materials

Explanatory Notes:

1. The absence of a textural term from a terrain component symbol indicates that texture of the material was not observed in the field and cannot be reliably interpreted from aerial photos or from a knowledge of the bedrock geology. The reader is referred to surficial material descriptions for general textural information.
2. Where two or three textural terms are used together, they are written in reverse order of importance and indicate that either the various textures are intermixed or interstratified.

SURFICIAL MATERIALS

Surficial materials are classified according to their mode of formation or deposition. This influences their physical characteristics such as texture, structure, and compaction, which in turn control conditions of drainage and slope stability.

Each surficial material has an assumed status of activity which is indicated in brackets by (A), active - there is evidence that the process of formation of a surficial material is operative at the present time or (I), inactive - the process of formation of a surficial material has ceased.

<u>Symbol</u>	<u>Name</u>	<u>Description</u>
A	alluvial (I)	Materials deposited by rivers, streams, and gullies with flow regimes different than present-day; alluvium usually consists of gravel with interstitial sand and sand with minor silt and tends to be moderately to well sorted and stratified; includes raised terraces, deltas, and fans and alluvial flats and fans with incised channels.
C	colluvial (A)	Product of mass wastage; generally consists of massive to moderately well-stratified to non-sorted sediments with a variety of particle sizes and shapes; includes talus slopes, mantles of weathered bedrock, and landslide debris.

D	weathered bedrock (A)	Bedrock decomposed in situ by processes of mechanical and/or chemical weathering; the character of the bedrock debris depends on the process of formation and type of bedrock.
F	fluvial (A)	Materials transported and deposited by present-day streams and rivers; mainly consists of gravel and/or sand; gravels are typically well-rounded and contain interstitial sand; sediments tend to be moderately to well-sorted and stratified; includes active floodplains and fans.
G	glaciofluvial (I)	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. These usually occur in raised terraces and as lower-slope aprons bordering present-day streams.
L	lacustrine (I) 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 occur in complex association with till and glaciofluvial materials in raised terrace landforms.
M	morainal (I)	Material deposited directly by glaciers, till; generally consists of well-compacted material that is non-stratified and contains a heterogenous mixture of particle sizes, shapes and lithologies in a matrix of mainly sand and silt; occurs usually as continuous to discontinuous mantles of varying thickness in valley-floor to upper-slope positions.
O	organic (A)	Material resulting from the accumulation and decay of vegetative matter; generally consists of peat, although minor amounts of marl and inorganic detritus may be included; includes bogs, fens, and swamps on a range of landscapes from valley-floor depressions to upper-slope plateaus.
R	bedrock (I)	Outcrops and rocks covered by less than 10 cm of unconsolidated material.

W	marine (I)	Sediments deposited in marine waters, or reworked by wave action along marine shorelines during a time of higher sea levels (early post-glacial time); they consist mainly of surface mantles of sand and gravel but some are silty or stony clay.
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SURFACE EXPRESSION

Surface expression is the topography or form of the land surface. In general, the terms listed here are used to describe features that are not adequately shown on a topographic base map.

<u>Symbol</u>	<u>Name</u>	<u>Description</u>
a	moderate slope	An unidirectional surface with a slope gradient 26% to 50%; local surface irregularities are less than 1 metre.
b	blanket	A mantle of unconsolidated materials which derives its general surface expression from the topography of the unit which it overlies; it masks minor topographic irregularities in the underlying unit and is more than 1 metre thick; if the underlying unit consists of unconsolidated materials, it is shown in the unit symbol; if no underlying unit is shown, it may be assumed to be bedrock.
c	cone	A cone or segment of a cone with a relatively smooth slope gradient greater than 26%.
d	depression	Circular or irregular area of lower elevation than the surrounding terrain; relief greater than 2 m.
f	fan	A smooth segment of a cone with a slope gradient less than 26%.
h	hummocky	Steep-sided hillocks and hollows that are rounded or irregular in plan; slopes of 26% - 70% predominate on unconsolidated materials and slopes of 26% - 150% predominate on bedrock; local relief is greater than 1 metre.
j	gentle slope	An unidirectional surface with a slope gradient 5% - 26%; local surface irregularities have a relief less than 1 metre.
k	moderately steep	Unidirectional surface with a slope gradient 50% - 70%; local surface irregularities have a relief less than 1 metre.

m	rolling	Elongate hillock(s) with slopes dominantly between 5% - 26% with local relief less than 1 metre; in plan an assemblage of parallel or sub-parallel linear forms with subdued relief.
p	plain	A level or gently sloping unidirectional surface with gradients up to 5%; local surface irregularities have a relief of less than 1 metre.
r	ridged	Elongate or linear, parallel or subparallel hillock(s) or ridges with slopes predominantly between 26% - 70% on unconsolidated materials and between 26% - 150% on bedrock; local relief is less than 1 metre.
s	steep	Steeply inclined slopes (scarps) with gradients greater than 70% on both unconsolidated materials and bedrock.
t	terraced	Step-like topography; includes both scarp face and the horizontal or gently inclined surface above it.
u	undulating	Gently sloping hillock(s) and hollow(s) with slopes up to 26%; local relief is less than 1 metre; in plan, an assemblage of non-linear, chaotic forms.
v	veneer	A mantle of unconsolidated materials which has no constructional form of its own, but derives its surface expression from the topography of the underlying unit; it reflects minor irregularities of the underlying surface, is generally between 10 cm and 1 metre in thickness, and outcrops of the underlying unit are common; if the underlying material is unconsolidated, it is included in the unit symbol; if no underlying unit is indicated, it is assumed to be bedrock.

Explanatory Notes:

1. The use of two or three surface expression symbols together implies that there is a mixing of discrete forms, not a set of intermediate forms.
2. Where more than one surface expression symbol is used, the symbols are written in order of decreasing importance based on their areal extent.

GEOMORPHIC PROCESSES

These terms indicate geomorphic processes that are currently modifying or have recently modified surficial materials and surface expressions.

<u>Symbol</u>	<u>Name (Assumed Process Status)</u>	<u>Description</u>
A	snow avalanching (A)	Rapid downslope movement of snow and ice, as well as incorporated rock, surficial material, and vegetation debris by flowing or sliding; applied to the initiation area, track, and runout zone.
F	slow or small-scale mass movement (A)	Downslope movement of large to small masses of cohesive or non-cohesive surficial material and/or bedrock by creeping, flowing, or sliding; applied to all areas affected by the moving debris as well as to the failure-initiation zone.
R	rapid mass movement (A)	Rapid downslope movement of dry, moist, or saturated debris derived from surficial material and/or bedrock by falling, sliding, or flowing. Includes debris slides, flows, and torrents and may include small bedrock failures; applied to areas of mass movement initiation only.
Rb	rapid bedrock failure (A)	Rapid descent of a mass of disintegrating bedrock by sliding or of large rock fragments by falling, bounding, and rolling; applied to failure initiation areas only.
V	gully erosion (A)	Modification of unconsolidated or consolidated surfaces by flowing water, and/or mass movement that results in the formation of individual or subparallel ravines.

Explanatory Notes:

Geomorphic process symbols are used where a relatively large portion of a terrain polygon is affected by the process or where the process is a dominant feature of that particular landscape.

Composite units are employed where two or three types of terrain are intermixed or occupy such small areas that they cannot be designated as separate units at the scale of mapping. Deciles are used to indicate the relative amounts of each terrain type, and the components are always written in decreasing order of importance.

- ## SOIL DRAINAGE

- Note:** drainage is given as a unique class or as a dominant and subdominant class.

Slope gradient is given in percent as minimum and maximum values or as an average value estimated to occur within the polygon.

Agriculture Canada Expert Committee on Soil Survey, 1987. The Canadian System of Soil Classification. Ottawa, Ont.

- Note:** Slight modifications to these mapping systems have been made in order to allow easier entry of the data into the digital file.

TERRAIN STABILITY LEGEND

TERRAIN STABILITY CLASSES

	DESCRIPTION	FOREST MANAGEMENT IMPLICATIONS
I	Stable, subdued terrain. No evidence of instability	Road construction and clearcutting will not cause any instability.
II	Mainly stable, gently to moderately sloping terrain. No evidence of instability; minor occurrences of potentially sensitive ground.	Very low potential for forestry-induced instability. Minor road-cut slumps and bank sloughing are possible. Periodic maintenance may be required.
III	Moderately stable, moderately steep to steep terrain. Natural landslides should not initiate within this unit; however, sites potentially sensitive to logging development do occur.	Low potential for forestry-induced instability. <u>A field inspection by a terrain-stability specialist is not usually required; sensitive microsites may require geotechnical review.</u> Road construction may lead to minor cut-bank instability and erosion but, the likelihood of fill-slope failures is low. Regular inspection and maintenance of roads, ditches, and culverts is recommended. Clearcut harvesting should not significantly reduce terrain stability. There is usually low likelihood of post-logging failure, although minor instability may occur in sensitive microsites.
IV*	Marginally stable steep slopes, deep gullies, 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 failures. <u>On-site geotechnical evaluation by a qualified terrain stability specialist is required.</u> Probable severe constraints to wet-season and cut-and-fill road construction. Roads should be minimized in these areas but, where they are necessary, special construction techniques, on-site supervision, and regular inspection and maintenance are often required. The potential for significant landsliding following clearcutting ranges from moderately low to high. <u>Prior to logging, a qualified terrain stability specialist should carry out a detailed field assessment of mass-wasting potential.</u>
V*	Unstable terrain showing evidence of recurrent, natural mass movements or significant small-scale instability. Landslides initiate	High to extreme potential for continued or accelerated mass movement. <u>Conventional logging activity (road building and clear-cutting) should normally be precluded; any</u>

within the unit which normally occurs on steeply sloping ground or along gullies.

development must be preceded with a detailed field inspection by a qualified terrain stability specialist. On-site geotechnical evaluation may determine that locating specially constructed roads or careful logging of selective sites is feasible. Any activity requires detailed engineering, on-site supervision, and site rehabilitation.

- * These rankings provide a relative assessment of mass movement potential, but give no indication of expected landslide frequency, magnitude, or impact. Rankings are intended to "flag" potential problem areas; actual decisions on logging and road construction should be based on detailed, on-site geotechnical evaluations by a qualified terrain stability specialist.

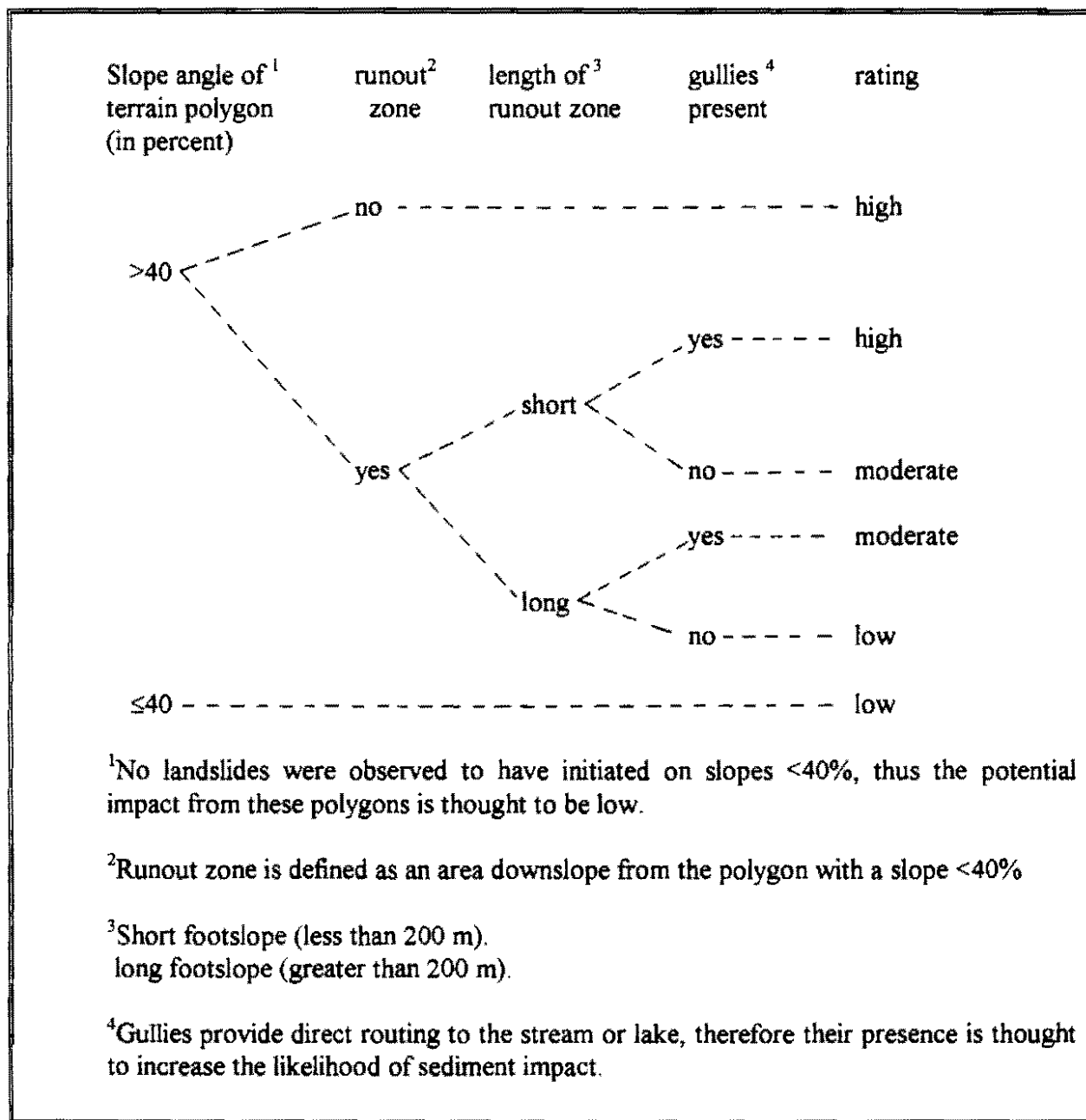
SEDIMENTATION POTENTIAL LEGEND

The potential for sedimentation is a qualitative rating of the likelihood of landslide debris entering a downslope water body if a landslide should occur within the polygon. A stream system includes stream order one and two channels, gullies, and small lakes and wetlands that drain directly into main stream channels. Differentiation is made if the ultimate receiving water body is a lake. Sedimentation from landslide deposition will be contained within a larger lake basin but in a stream system the debris is available for episodic transportation and deposition.

Rating	Description
H	There is high likelihood of landslide debris impacting upon a stream system if a landslide should occur in these terrain polygons. Most failures (rapid mass movements and slumps) occurring in these areas are expected to directly enter a stream system.
M	There is moderate likelihood of landslide debris impacting upon a stream system if a landslide should occur in these terrain polygons. Some failures occurring in these areas are expected to directly enter a stream system; some will deposit on the toe slope.
L	There is low to very low likelihood of landslide debris impacting upon a stream system if a landslide should occur in these terrain polygons. Few, if any, failures occurring in these areas are expected to directly enter a stream system. Also applied to any polygon where the mass movement potential is nil to very low.
+	This symbol is attached as a modifier to indicate that the potential depositional area for any landslide debris may be a lake. It is only applied for H and M ratings (e.g. M+).

Factors used to assess the potential impact of landslides on a receiving water body include slope angle, the presence or absence of a runout zone, the length of the runout zone, and the presence of gullies which provide direct linkage between the slope and the valley floor. The following diagram shows this assessment process.

Qualitative rating system assessing the likelihood of a landslide impacting upon the stream system (from Howes, 1987).



APPENDIX II TERRAIN ATTRIBUTE DATA LIST

TERRAIN STABILITY AND SEDIMENTATION POTENTIAL

POLY- GDM	TC1	TC2	TC3	TC- DELIM	GEO PROC*	SOIL DR DOM SUB	SLOPE % MIN MAX	TERRAIN STABIL	SED POT
1	sFv/gAp			10		r	1 7	I	L
2	gAut			10		r	2 35	II	L
3	gAak			10		r	40 60	III	M
4	bgAf			10		r	2 20	I	L
5	bgAf			10		r	2 20	I	L
6	bgAf			10		r	2 20	I	L
7	bgAf			10		r	2 20	I	L
8	gsGb/sMu			10		r	5 40	II	L
9	sMbv	Rh		8:2		r	40 65	III	L
10	srCv	Rs		8:2		r	65 100	IV	L
11	sMb			10		m	20 40	II	L
12	srCv	sMbv		6:4	P	r	60 100	V	H
13	xCv	Rs	sxCb	5:3:2		r	65 130	IV	H+
14	sMbv			10		r	50 60	III	H+
15	bgAf			10		r	2 20	I	L
16	bPf			10		r	2 20	I	L
17	srCb			10		r	55 70	III	H
18	gGk			10		r	40 65	III	M
19	gGak			10		r	40 60	III	L
20	gGut			10		r	5 30	II	L
21	gGut			10		r	5 30	II	L
22	gsGbh/sM			10		r	25 50	II	L
23	gsGbv/sM			10	V(I)	r	50 70	III	L
24	sMk			10	P	r	60 75	V	L
25	sMbv			10		r	40 60	III	L
26	srCb			10		r	50 70	III	L
27	xCv	Rs		6:4	VP	r	70 130	V	L
28	sxCv	Rs		8:2		r	70 110	IV	L
29	sxCv	Rs		8:2		r	70 110	IV	H
30	sxCvb	Rs		8:2	VPR	r	70 150	V	H
31	srGk			10		r	50 70	III	H
32	srGu	rCvb/G		8:2		r	10 45	II	L
33	srGk			10	V	r	60 70	IV	H+
34	srGa			10		r	20 50	II	H+
35	dAfe			10		m	2 30	I	L
36	srGk			10		r	40 65	III	M+
37	sxCvb			10	VP	r	65 90	V	L
38	srGh			10		r	20 65	III	L
39	sxCb			10		r	50 70	III	L
40	sxCvb			10		r	65 90	IV	L
41	xCv	Rs	sxCb	5:3:2	VPR	r	65 150	V	L
42	rCbv			10		r	60 70	III	H
43	sMb	srCv/sM		6:4	P	r	60 75	V	H
44	sMb			10		m	40 55	III	H
45	sMb			10	VR	r	50 80	V	H
46	srCb			10		r	45 65	III	H
47	srCb			10	V	r	60 75	IV	H
48	srCbv	Rhk		8:2		r	50 75	III	H
49	srCvb	Rhk		8:2		r	45 75	III	L
50	sHvb	srCv		6:4		r	15 50	II	L
51	sxCv	Rs		8:2	V	r	70 110	IV	L
52	xCv	Rsh	sxCb	5:3:2	VPR	r	65 150	V	L
53	sxCb	rCv/sM		6:4		r	45 70	III	M
54	sMbv	rCv/sM		8:2	V(I)	r	45 65	III	H
55	sMb			10		r	30 50	II	H
56	sMb			10		r	30 50	II	H

*Geological Processes (GEO PROC) are active unless indicated as (I)inactive

10/25/95

TERRAIN STABILITY AND SEDIMENTATION POTENTIAL

POLY- CON	TC1	TC2	TC3	TC- DBLIM	GEO PROC*	SOIL DR DOM SUB	SLOPE % MIN MAX	TERRAIN STABIL	SED POT
57	sMb	srCv		8:2		r	40 65	III	H
58	srCbr/sMh			10	VRP	r	50 100	V	H
59	srCb/sM			10		r	5 40	II	L
60	srCb/sM			10		r	5 40	II	L
61	srCb			10	V	r	20 70	III	H
62	sMb			10		r	30 50	II	M
63	sMb			10		r	30 50	II	M
64	sMb	srCvb		5:5	VP	r	45 80	V	H
65	sMb			10		r	30 50	II	M
66	rCv	sMv		6:4		r	40 65	III	L
67	sMv	Rh		8:2		r	20 50	II	L
68	xCv	Rs		6:4	VPR	r	70 150	V	M
69	sMb	srCv		8:2		r	40 65	III	H
70	sMb	rCvb/sM		6:4	VPR	r	50 80	V	H
71	sMb	srCv		8:2		r	40 65	III	H
72	sMb	srCv		8:2		r	40 65	III	H
73	sMvb	Rh		8:2		r	15 50	II	L
74	sMb	srCv		8:2		r	40 65	III	H
75	sMb	srCv		8:2		r	40 65	III	H
76	sMb	srCv		8:2		r	40 65	III	H
77	sMvb			10		r	10 40	II	L
78	rCv			10		r	45 70	III	L
79	sMb	rCvb/sM		6:4	VPR	r	50 90	V	H
80	xCb			10		r	40 70	III	H
81	sMvb	Ruh		8:2		r	10 50	II	L
82	sMvb			10	V(I)	r	50 65	V	H
83	srCv			10		r	60 90	IV	H
84	srCv			10		r	50 70	III	L
85	sMvb			10		r	40 60	III	M
86	srCv			10		r	45 70	III	L
87	srCv			10		r	45 70	III	L
88	srCv			10		r	45 70	III	L
89	xCv	Rs	srCb	5:3:2	VRP	r	65 150	V	L
90	srCb			10		r	65 85	IV	L
91	srCb/sM			10	V(I)	r	40 75	III	L
92	srCb/sM	srCb		6:4	V	r	60 90	IV//V	M+
93	srCb/sM			10	V	r	45 70	III	M+
94	dAb/sM			10		r	10 40	II	L
95	sHu			10		m	5 30	II	L
96	sMb			10		r	50 70	III	L
97	srCvb			10		r	40 65	III	M+
98	sMbv			10		r	10 50	II	L
99	srCv	Rs		8:2		r	65 100	IV	L
100	sMb			10		r	10 40	II	L
101	rCv	sMv	Rh	5:3:2		r	60 90	IV	L
102	sMak	dAv/M	sLbv/M	7:2:1	V	r	40 60	III	M
103	sMah			10		r	25 40	II	L
104	gAfp			10		r	2 10	I	L
105	sMk			10	V	r	50 65	IV	H
106	sHu			10		m	5 30	II	L
107	dAsk			10	P	r	60 90	V	H
108	sLp			10		p	0 2	I	L
109	srCvb	Rs		8:2		r	70 100	IV	L
110	srCb			10		r	65 80	IV	L
111	srCb/R	srCb/M		6:4	V(I)	r	45 70	III//IV	L
112	srCb/sM			10		r	20 55	II	M

*Geological Processes (GEO PROC) are active unless indicated as (I)inactive

TERRAIN STABILITY AND SEDIMENTATION POTENTIAL

POLY- GON	TC1	TC2	TC3	TC- DELIM	GEO PROC*	SOIL DR DOM SUB	SLOPE % MIN MAX	TERRAIN STABIL	SED POT
113	srGb/sM			10		r	40 65	III	H
114	srCv	Rhk		8:2		r	40 75	III	L
115	srCvb			10	V(I)	r	60 85	IV	H
116	srCvb			10	V(I)	r	60 85	IV	H
117	srCvb			10		r	45 70	III	M
118	srCvb	Rs		8:2	VP	r	70 120	V	H
119	srCb			10	V(I)	r	50 70	III	H
120	srGb			10	V	r	50 70	IV	H
121	srGb/sM			10		r	20 55	II	M
122	srGb/sM			10	F	r	65 90	V	H
123	srGb/sM			10	V	r	50 75	III/IV	M
124	srCvb	Rs		8:2	VP	r	70 120	V	H
125	srCvb			10		r	65 85	IV	M
126	srCv			10		r	65 90	IV	M
127	srCvb			10		r	45 70	III	M
128	srCv			10		r	65 90	IV	L
129	sMb	rCv		6:4	VP	r	60 100	V	H
130	srCvb			10		r	65 85	IV	M
131	srGb/sM			10	V	r	50 75	III/IV	M
132	sMb			10	V(I)	r	45 70	III/IV	L
133	dAb/sM			10		r	10 40	II	L
134	dAsk			10	F	r	60 90	V	H
135	dAb/sM			10		r	10 40	II	L
136	sMak			10	V(I)	r	40 60	III	L
137	srGb/sM			10		r	15 45	II	L
138	bAc			10		r	20 45	II	L
139	sMu	dAf/sM	sLbv/sM	7:2:1		r	5 30	II	L
140	sMak	sLbv/sM		8:2		r	40 60	III	M
141	sMa			10		r	25 40	II	L
142	srLb/sMb			10		r	15 30	II	L
143	dAf			10		r	3 15	I	L
144	sMb	dAbv/sM		8:2		r	20 55	II	L
145	sMvb			10		r	20 55	II	L
146	sMb	dAbv/sM		8:2		r	20 45	II	L
147	srCa			10		r	20 50	II	L
148	srCb			10		r	55 70	III	L
149	srCv			10		r	65 85	IV	L
150	srCvb			10		r	40 70	III	L
151	srCv			10		r	65 85	IV	H
152	sMv	Rh		8:2		r	10 50	II	L
153	xCv	Rs	xCb	5:3:2	VPR	r	65 150	V	H
154	sMv	Rh		8:2		r	40 60	III	M
155	sMvb	Ruh		8:2		r	10 50	II	L
156	srCvb	sMvb	Rh	5:3:2		r	40 80	III	M
157	srCvb	sMvb	Rh	5:3:2		r	40 80	III	M
158	srCvb			10	V(I)	r	55 80	IV	L
159	srCv	Rs		6:4	VP	r	75 150	V	L
160	xCvb	Rs		6:4	PRb	r	65 150	V	L
161	xCv	Rs	xCb	5:3:2	VPR	r	65 150	V	H
162	srCsk			10	F	r	60 90	V	H
163	xCc			10		r	20 40	II	L
164	sMvb	rCv	Rh	5:3:2		r	45 80	III	L
165	sMvb	rCv	Rh	5:3:2		r	45 80	III	L
166	rCv	Rh		6:4	V	r	40 90	III	R
167	gAf/rUh			10		r	10 40	II	L
168	sMb	sMv		8:2		r	20 40	II	L

*Geological Processes (GEO PROC) are active unless indicated as (I)inactive

TERRAIN STABILITY AND SEDIMENTATION POTENTIAL

POLY- GON	TC1	TC2	TC3	TC- DELIM	GEO PROC*	SOIL DR DOM SUB	SLOPE % MIN MAX	TERRAIN STABIL	SED POT
169	gAf			10		m	2 10	I	L
170	sMb			10	V	r m	40 60	III	H
171	sMb	sMv		8:2		r m	20 40	II	L
172	sMvb	Rh		8:2		r m	20 60	II	L
173	sMb			10	V(I)	r m	40 60	III	L
174	sMb			10		r m	20 40	II	L
175	xCa			10		r	25 50	II	L
176	srCv			10		r	45 70	III	L
177	xCb			10		r	55 70	III	L
178	sMv/Ruh	srDv/Ruh		6:4		r	15 55	II	L
179	sMv/Ruh	srDv/Ruh		6:4		r	15 55	II	L
180	sMv	srCv	Rh	5:3:2		r	40 65	III	L
181	szCb			10		r	25 50	II	L
182	szCb			10		r	50 70	III	L
183	xCv	Rs		6:4	PRb	r	70 150	V	H
184	xCbv	Rh		8:2		r	10 50	II	L
185	szCvb	Rs		8:2		r	65 100	IV	L
186	xCvb	Rs		6:4	PRb	r	65 150	V	L
187	szCv	Rh	srCb	5:3:2		r	45 75	III	L
188	szCvb			10		r	50 70	III	L
189	szCvb			10		r	50 70	III	L

*Geological Processes (GEO PROC) are active unless indicated as (I)inactive

APPENDIX III TERRAIN STABILITY CLASSIFICATION AND CRITERIA

TERRAIN STABILITY CLASSES AND CRITERIA

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 forest harvesting and road development. Terrain factors which are considered important in assessing this estimated stability are surficial material genesis and texture, slope angle, 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.

Criteria for determining the various terrain stability classes have been developed based on the experience of the mapper and some limited research into predicting post-logging stability potential. Studies of relevance carried out on the mainland coast of southwestern B.C. include Howes (1987), Thomson (1987), and Maynard (1994 and 1995).

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

Stability Class I

- fluvial floodplains, fans, and low terraces with gentle surface gradients
- depressional wetland infillings; fine-textured and organic sediments with near-level slopes and restricted drainage.

Stability Class II

- gently hummocky to moderate slopes of fluvial and glaciofluvial deposits; associated with valley-floor terraces, toe-slope aprons, and benched surfaces. Gradients are usually less than 50% and soils are well drained.
- subdued to moderate slopes of thick bench-land till with minor cappings of granular sediment and glaciolacustrine silt. Slopes are mainly less than 40% and surface drainage is variable.
- valley-wall till mantles; well drained blankets and veneers up to 50% but usually less than 40%. May be on gully interfluve ridges.
- mid-slope to ridge crest benched surfaces with thin till and lesser colluvial veneers and minor rock outcrops; mainly well-drained slopes with hummocky surface gradients up to 50%.

- bedrock lowland slopes with thin, discontinuous mantles of till and colluvial rubble; slopes are well drained except in hollows and gradients may be up to 55-60% on rock outcrops.
- colluvial deposits consisting mainly of well-drained sandy rubble to rubbly blocks as toe-slope cones and aprons and upland slope mantles; gradients less than 55%.
- any other subdued areas occurring immediately above steeper slopes.

Stability Class III

- well-drained, thick deposits of till on slopes and gully and creek banks where gradients are dominantly 40-60%; highly dissected or wetter till slopes should be less than 55%.
- thin mantles of till, often with minor colluvium and small rock outcrops; slopes are mainly well drained and variable between 40-70% gradient.
- fluvial and glaciofluvial sediments with uniform slopes of 45-65% or variable hummocky ground less than 70%; granular material usually overlies till (bedrock in a few places) and is well drained. Includes creek and gully banks and gullied slopes where gradients are mainly less than 60%.
- incised creeks and gullies with low to moderate channel gradients and banks between 3-7 m height and less than 65% gradient.
- colluvial aprons and talus slopes; coarse, rapidly-drained material on uniform slopes of 55-70%.
- thin mantles of colluvium with minor till and rock outcrops; well to rapidly drained uniform slopes of 50-70%, irregular slopes of 40-75%, and gullied slopes less than 65%.

Stability Class IV

- steep colluvial slopes with well-drained rubbly mantles and average slope gradients in excess of 65%; bedrock crops out as mid-slope hummocks and discontinuous cliffs.
- colluvial gully headwalls, in excess of 60% with no indication of active instability.
- uniform slope of thick, well-drained sandy rubbly colluvium dissected by small gullies; slopes of 60-80%.
- moderately steep to steep (greater than 60%) lower valley wall mantled by glaciofluvial gravel overlying till with subparallel gullies eroded through to bedrock.
- gullied scarp of thick glaciofluvial sandy rubble with uniform gradients near 70%; gullies are inactive.

- stream and gully scarps eroded into thick till or till and gravel stratigraphy; slopes are mainly less than 70% and bank height is greater than 5 m; seepage sites may occur on the mainly well-drained slopes but there is no evidence of significant instability.

Stability Class V

- deeply incised, steep-sided gully headwalls and sidewalls in colluvium and bedrock which have experienced natural recurrent instability or been subject to post-logging failures.
- incised, steep-sided gullies where there is widespread evidence of small-scale instability on the colluvial-bedrock sideslopes or headwalls creating a high potential for debris failure.
- thick gullied till and till-glaciofluvial stratigraphy in headwall bowl where considerable post-logging instability has occurred; evidence of natural instability conditions also occur.
- high steep escarpments bordering middle reaches of main gully systems where evidence of instability occurs in thick till, gravels over till, or colluvial mantles on bedrock.
- continuous till mantles and intermixed till and glaciofluvial sediment or colluvium on uniform slopes greater than 60% which are gullied; active erosion occurs along forested channels and older clearcut areas show evidence of more widespread post-logging failure.
- steep colluvial-bedrock open slopes where there is evidence of recurrent bedrock crumbling and active ravelling of thin colluvial mantles. Slopes are in excess of 70% and rapidly drained.
- high (greater than 5 m), oversteepened, actively ravelling banks eroded into thick deposits of fan rubble and toe-slope gravels; banks are being actively undercut and destabilized by creek erosion.

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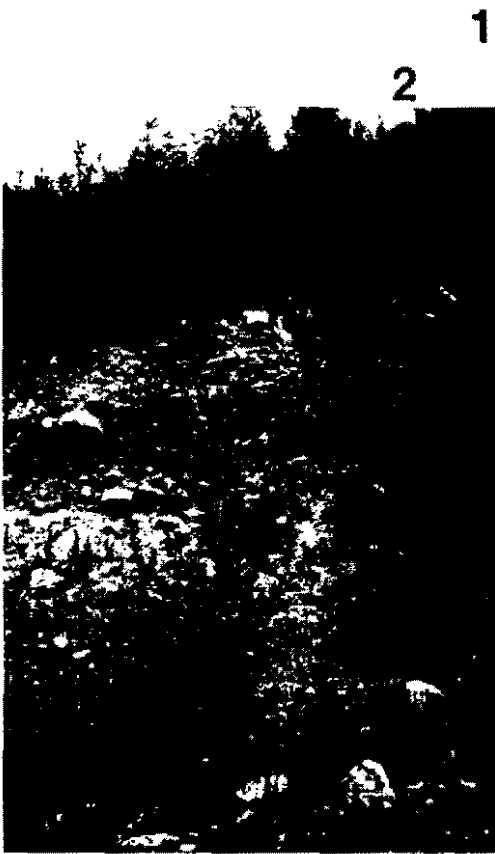
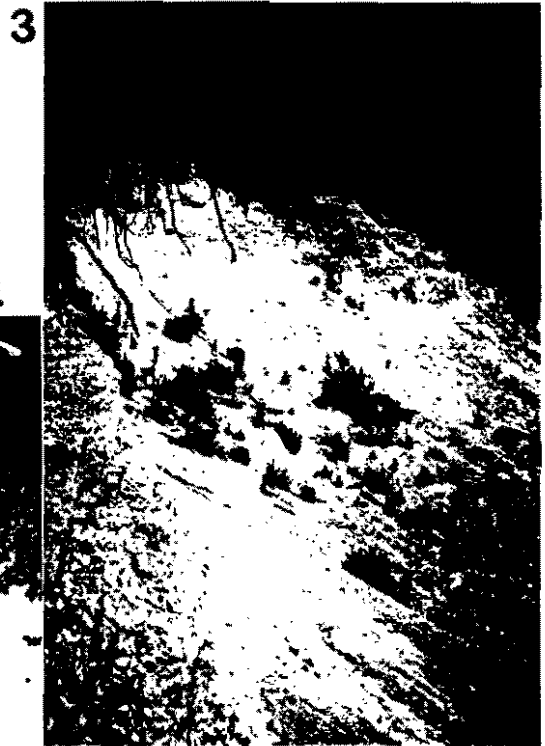
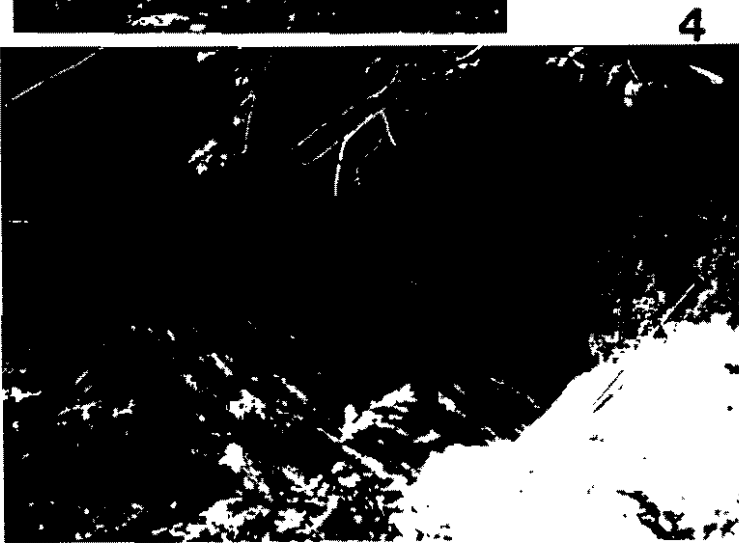
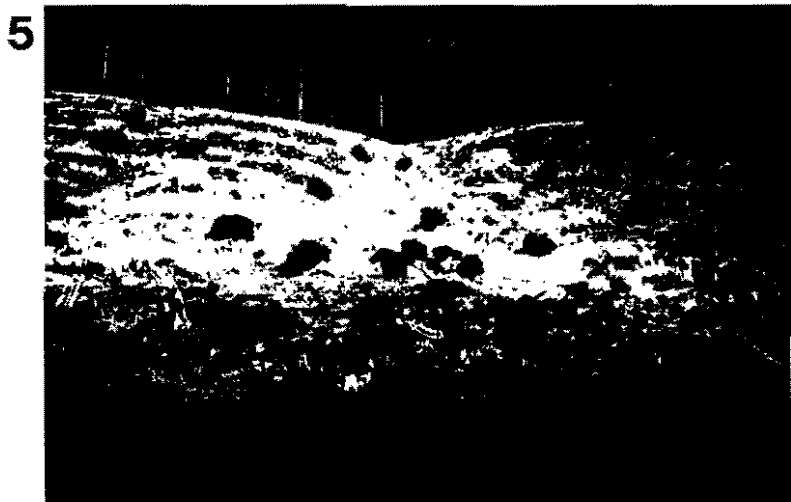
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APPENDIX IV PHOTOGRAPHS

LIST OF PHOTOGRAPHS

1. View south across the toe-slope bench bordering Hatzic Prairie. Valley wall of Durieu Ridge is partially obscured by fog.
2. Example of compact glacial till in a 3 m high roadcut. Site is in polygon 96 on 60% slope; rated stability class III.
3. Landslide headscarp in thick till (partially overlain by rubbly colluvium) at 940 m elevation in Pattison Creek headwall bowl. Slide initiates at a road crossing of the gullied unit (polygon 70) which has been rated stability class V with high sedimentation potential.
4. View into deep headwall bowl (about 50 m deep) of a Pattison Creek gully at 610 m elevation (polygon 58). Dipping beds of sandy rubbly glaciofluvial sediment overlies thick glacial till. This slide scar is the site of a 1960 debris flow but it continues to enlarge and erode headward.
5. Well drained stability class III slope consisting of a blanket of sandy rubbly glaciofluvial sediment on slopes ranging between 45-70% (polygon 111).
6. Toe-slope apron of granular colluvial-fluvial sediment accumulating from steep adjacent slopes and gully deposition. Stability class II is rated for polygon 94.
7. Creek has downcut into thick granular fluvial deposits on the toe-slope bench. Material originated from gully erosion of the Durieu Ridge slopes. High banks (5-10 m) are actively ravelling and the narrow polygon (134) is rated stability class V with high sedimentation potential.
8. Small lake (polygon 108) actively infills with slope-wash silts, fine sands, and organic detritus. Stability class I.
9. View downslope along the landslide scar below the 1990 failure (photo 3).
10. Bedrock headwall failure on the south side of Pattison Creek. Part of polygon 30 (stability class V) which actively contributes debris to the creek system
11. Small headscarp at top of steep gradient gullied slope of glaciofluvial sandy rubble over till (polygon 92). Polygon is rated stability class IV with a minor component of class V gullies.
12. Downslope in polygon 92, recent scouring by a debris flow along a narrow gully deposits debris on a toe slope adjacent to the infilled lake (photo 8).

13. Polygon 109 is rated stability class IV because of steepness. Thin rubbly colluvium and minor rock outcrops on slopes of 70-100%. Upslope of photo 6. These dry slopes rarely experience clearcut failures but pose some constraints to road building.





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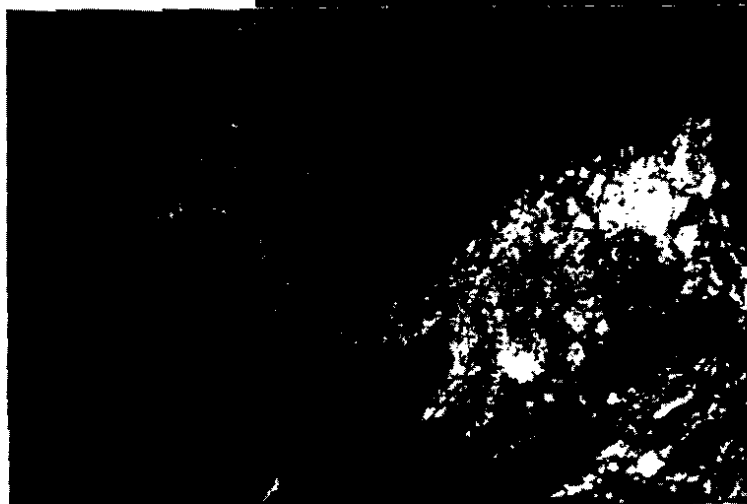
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