STRATHCONA TIMBER SUPPLY AREA

RECONNAISSANCE

TERRAIN STABILITY (CLASS P) MAPPING

Prepared for

Ministry of Forests
Campbell River Forest District
Campbell River, B.C.

by

Sidney Tsang, B.Sc., G.I.T.

December 1997

J. M. Ryder and Associates Terrain Analysis Inc.

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December 17, 1997

Maddalena Di Iorio Dunn
Campbell River Forest District
370 South Dogwood Street,
Campbell River, B.C. V9W 6Y7

Dear Maddalena,

The objective of reconnaissance terrain stability mapping is to identify relatively large areas where detailed mapping is required. Reconnaissance terrain stability maps are also *useful for long-range planning and for establishing operability lines and annual allowable cut netdown procedures* (Mapping and Assessing Terrain Stability Guidebook, FPC 1995).

Reconnaissance Terrain Stability Mapping for potentially unstable (P) areas at terrain survey intensity level (TSIL) E was completed for the Strathcona Timber Supply Area (TSA). The current mapping incorporates the existing Es1 (unstable area) mapping outlined as blue polygons on the maps. In addition, polygons were rated for stream sedimentation potential. The original typed air photos, one stamped mylar copy of each map, polygon hectare reports per mapsheet on CD-ROM, terrain database in Excel and dBASEIV formats, the digital data in both "positional" and "representational" formats on CD-ROM, and two copies of the report (one bound and one unbound copy) have been delivered to you.

The report provides a general overview of the physiography of the TSA, descriptions of the terrain mapping methodology, information about surficial materials, a discussion on slope stability, estimates of net-down for each Timber Supply Block, and recommendations for forest land management.

Portions of the mapping were reviewed by J.M. Ryder, P.Geo., D. Maynard, P.Geo. and T. Rollerson (MOF-Vancouver Region) to ensure that the mapping was carried out at the appropriate level of reliability.

Please call if you have any questions. Thank you for entrusting JMRATA with this terrain work.

Sincerely,

J.M. Ryder and Associates, Terrain Analysis Inc.

Sid Tsang

per Sid Tsang, G.I.T. and J.M. Ryder, P.Geo.

PROFESSIONAL GEOSCIENTIST
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CONTENTS

(1) INTRODUCTION

The project objective was to complete reconnaissance terrain stability maps for the Strathcona Timber Supply Area (TSA) by mapping potentially unstable (Class P) areas, by reviewing and incorporating the existing Es1 (unstable areas) mapping, and combining the two. The Es1 mapping was completed by various mappers (Lewis 1992; Maynard 1992; Young, Ryder and Tarle 1994). Since the introduction of the Forest Practices Code of B.C. Act in the Spring 1995, reconnaissance terrain stability mapping (sometimes referred to as UPS mapping) has replaced the Es (environmentally sensitive areas) mapping. The reconnaissance stability classes "unstable" (U) and "potentially unstable" (P) are equivalent to the older Es1 and Es2 designations; the stable class (S) has no Es equivalent. The maps will be used by the Campbell River Forest District to estimate the annual allowable cut (AAC) for the TSA. The Strathcona TSA is divided into the west (Kyuquot) and east (Loughborough and Sayward) Timber Supply Blocks (TSBs) (Figure 1).

Terrain mapping -- delimitation of potentially unstable polygons only -- was carried out according to provincial standards (Section 2) at terrain survey intensity level (TSIL) D for Nootka Island (see Section 2.2) and at TSIL E for the remainder of the area. Terrain mapping was done on 1:15 000 scale black and white air photos by air photo interpretation. No field work was carried out, although field data from previous terrain work were incorporated into the present mapping. Each terrain polygon was classified according to surficial material type, surface form, modifying geomorphic processes, slope steepness classes, and assessed for stream sedimentation potential (Appendices 1 and 2). Digitizing was done by Pacific International Mapping Corporation (PIMC) onto 1:20 000 scale TRIM base maps.

This report provides a description of mapping methods and reliability, criteria used for interpretations for slope stability and stream sedimentation potential (Section 2), and a general overview of the physiography of the study area (Section 3). Descriptions of surficial materials are included in Section 4. A discussion of slope stability (Section 5) and estimates for net-down follow in Section 6. Recommendations for forest land management that arise out of this terrain work are discussed in Section 7. A polygon hectare report on CD-ROM was provided by PIMC estimating the area of each polygon per map sheet.

(2) METHODS

Terrain mapping and interpretations for slope stability were carried out in accordance with current provincial standards: Terrain Classification System (Howes and Kenk, Edition 2.0, 1997); Guidelines and Specifications for Terrain Mapping (RIC, 1995); Terrain Database Manual, (RIC, 1996), and Mapping and Assessing Terrain Stability Guidebook (Forest Practices Code, 1995).

(2.1) Reconnaissance Terrain Stability Maps

This type of mapping is used for rapid and hence inexpensive surveys of relatively large areas with the objective of identifying areas where stability problems may be encountered.

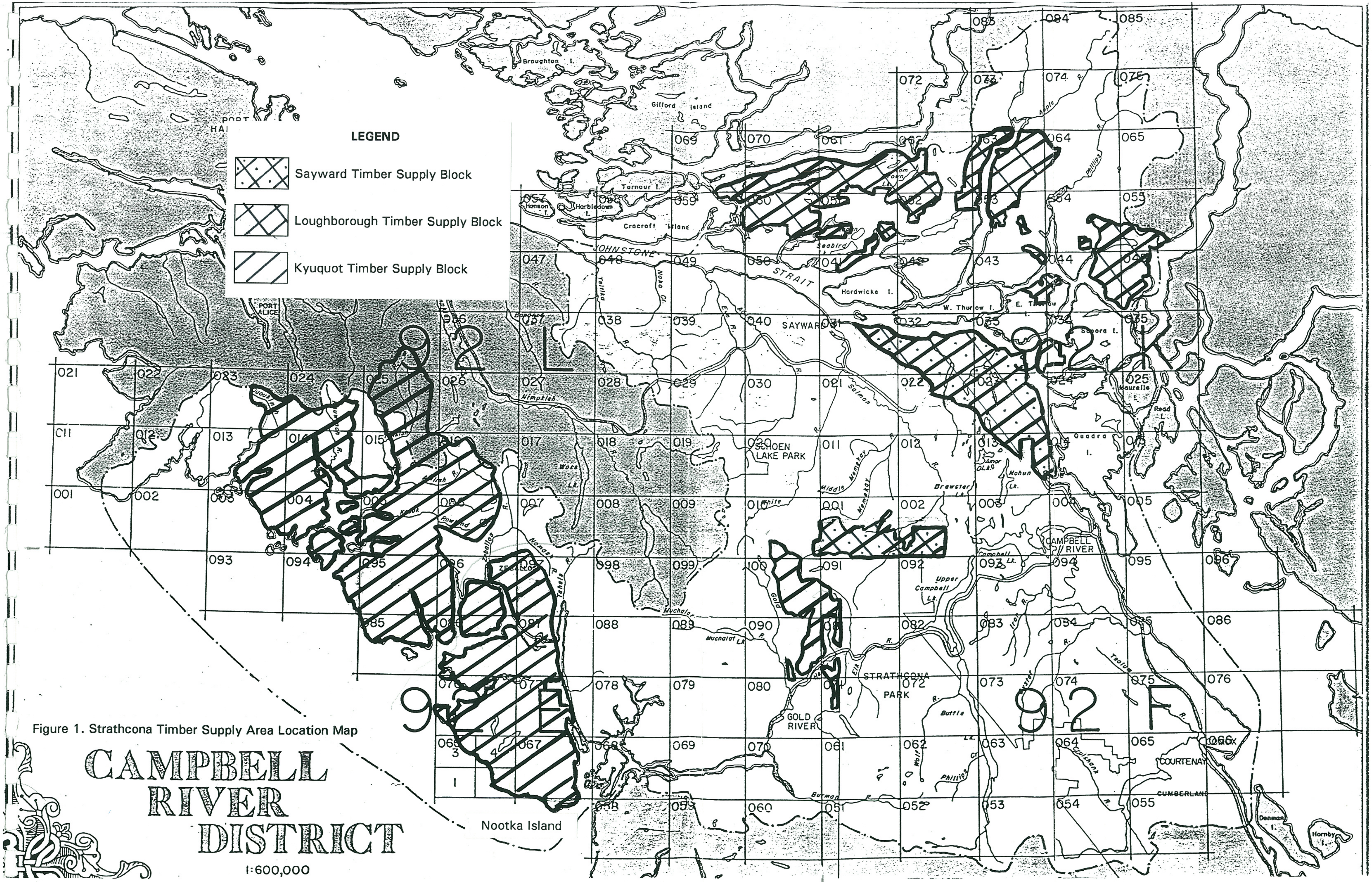

Figure 1. Strathcona Timber Supply Area Location Map

The completed map shows unstable (U) and potentially unstable (P) slopes, with symbols for terrain, slope steepness, and stream sedimentation potential attached to all U and P polygons. The original Es1 labels were not changed to U because there is no database for the Es1 polygons. Stable areas are not subdivided into terrain polygons.

(2.2) Terrain Mapping

Mapping was carried out by air photo interpretation on the large scale (1:15 000) black and white air photos (Appendix 3) originally used for the Es1 mapping project, using a mirror stereoscope with 3x binoculars for close viewing of landscape details in critical areas. Terrain attribute data collected on Nootka Island by the Ministry of Forests, Research Branch, was incorporated into the current mapping. Es1 mapping for parts of the Kyuquot TSB (Lewis 1992) was not delimited on the air photos and had to be hand-transferred back onto the air photos from checkplots in order to maintain consistency between mapping projects. Minor additions to the original Es1 mapping were made and designated as U (unstable). Stability interpretations were made according to criteria discussed in Section 2.4. Each terrain polygon was numbered and a terrain attribute database was created.

Slope steepness classes (Appendix 1) were determined by using contour spacing on the TRIM maps to provide slope estimates for long, uniform slopes (the only slopes where steepness can be reliably determined from the TRIM data). Limited field measurements of slope steepness were recorded on the air photos on Nootka Island in the terrain attribute study areas. Once the mapper's eye was calibrated by this means, visual slope steepness estimates were made for short slopes and narrow areas that are inadequately represented by TRIM contours.

(2.3) Transfer and Digitizing

Terrain polygon boundaries will be transferred from the photos onto a TRIM digital elevation model (DEM) using Pacific International Mapping Corporation's Mono-Restitution software (MONO 3D). A digital database for polygon symbols has been compiled and used to create terrain polygon labels. At the time of writing (June 1997), the mapped air photos and database have been forwarded to Pacific International Mapping Corporation for digitizing and map production. Checkplots of the final maps were returned to JMRATA for a final check.

(2.4) Slope Stability Interpretations

For reconnaissance terrain stability mapping, unstable slopes are defined as those with visual evidence of instability. This includes the presence of landslide features, such as headscarps, scars, tracks, and displaced material of various types of landslides and flows; indicators of presently on-going, slow slope movement, such as tension cracks, earth bulges and pressure ridges; and, vegetation indicators, such as tilted trees. Thus, the identification of unstable slopes is usually fairly straightforward because it relies on the observation of specific features.

Potentially unstable slopes are those where instability could develop in the future due to disturbance by logging operations. Thus, there are no obvious signs of instability to aid identification. For reconnaissance terrain stability mapping, potentially unstable slopes are considered to be those of similar appearance to nearby unstable slopes, but with no (or very limited) signs of actual slope movement. In this context, "similar appearance" means having similar steepness, the same surficial materials and bedrock types, and similar moisture conditions; (slope position is used as a surrogate for moisture because moisture is commonly not a visible condition).

(2.5) Interpretations for Stream Sedimentation Potential

Stream sedimentation potential (Appendix 2) ratings are based on a subjective assessment of the distance and slope configuration between unstable and potentially unstable areas and valley-bottom streams and other waterbodies. The travel distance of existing natural failures provides an estimate of potential mass movement transport.

(2.6) Reliability and Limitations of the Mapping

The accuracy of terrain mapping, and hence the reliability of slope stability interpretations, depends on numerous factors, including the skill and experience of the mapper, scale and quality of air photos used, type and density of vegetation, field access, length of time spent in the field, quality of base maps, type of terrain and surficial materials present. Only the more relevant of these factors are discussed here.

For this project, quality of air photos and base maps was excellent. Air photo interpretation was carried out by various mappers, but all typed air photos were thoroughly reviewed by the writer in order to ensure consistency. The writer obtained some on-the-ground experience in the map area (Nootka Island) during data collection in 1993 for a terrain attribute study for the Ministry of Forest Research Branch (Vancouver Region), and has carried out extensive work in similar terrain elsewhere for the Forest Service and private sector during the past five years.

Portions of the mapping were reviewed by J.M. Ryder (Sayward) and D. Maynard (Loughborough Inlet). Representative air photos for the entire map area were reviewed by T. Rollerson (MOF-Vancouver Region) to ensure that mapping was carried out at the appropriate level of reliability in lieu of field work.

Transfer of information from air photos to base maps by Mono-Restitution has proven to be very reliable provided that adequate control points are captured. Because the original Es1 air photos were used, control points for about one-third of the photos had been previously established.

Map users should bear in mind that terrain mapping was carried out at 1:20 000 scale. Hence the smallest polygons mapped are about 1 cm^2, or about 200x200 m (4 ha) at low elevations and 150x150 m (2.25 ha) at high elevations. Thus local variations in terrain conditions over distances of less than about 150-200 m were not mapped. Also, where terrain was mapped through dense forest cover, local variations in slope steepness, material characteristics and soil moisture could not be recognized on the air photos, possibly resulting in significant within-polygon variations of terrain conditions. Therefore, any polygon mapped as P, for example, may include small areas of unstable and/or small areas of stable ground, and the large, undivided stable areas may well include small areas that are potentially unstable or even unstable.

(3) PHYSIOGRAPHY

The study area encompasses parts of several physiographic regions (Figure 2): the Nanaimo and Georgia Lowlands of the Georgia Depression; the Estevan Coastal Plain; the Vancouver Island Ranges of the Vancouver Island Mountains; and the western flank of the Pacific Ranges of the Coast Mountains (Holland 1976).

(3.1) Topography

The Georgia Depression is characterized by low-lying topography less than 610 m above sea level (a.s.l.). The Vancouver Island Mountains are the most rugged ranges on the Island, with the highest peak at Golden Hinde (2200 m a.s.l.). In contrast, most of the narrow Estevan Coastal Plain is below 75 m a.s.l. The Coast Mountains are extremely rugged; the highest peak in the Loughborough TSB is Mt. Pratt (1770 m a.s.l.).

(3.2) Geology

Most of the Sayward TSB is underlain by volcanic rocks of the Karmutsen Group (Figure 3) with intrusions of quartz diorite (Muller 1977, Roddick et al. 1976). The Kyuquot TSB is underlain by Bonanza volcanic rocks that contain intrusions of Early Tertiary and Middle Jurassic quartz diorite and quartz monzonite. Outcrops of sandstone and shale of Eocene age (Carmanah Group) are found along the outer coast of Nootka Island and Kyuquot. On the mainland, the Loughborough TSB is underlain by Coast Intrusives (quartz diorite, granodiorite, diorite). In general, all the intrusive rocks have high strength and widely spaced joints (planes of weakness), and consequently, slopes are steep. The Karmutsen and Bonanza volcanics are relatively weaker and may weather more rapidly. Some failures in the Kyuquot TSB may be related to these rock types.

(3.3) History of Glaciation

The area was glaciated many times during the last two million years (Pleistocene Epoch). During the most recent glaciation, known as Fraser Glaciation, ice began to accumulate in the Coast Mountains and Vancouver Island Ranges before 28 800 years BP (before present) (Clague, 1981). As the Cordilleran Ice Sheet developed, ice flowing westward from the Coast Mountains and eastward from the Vancouver Island Ranges coalesced to form glaciers which flowed southeastward and southward down the Strait of Georgia and

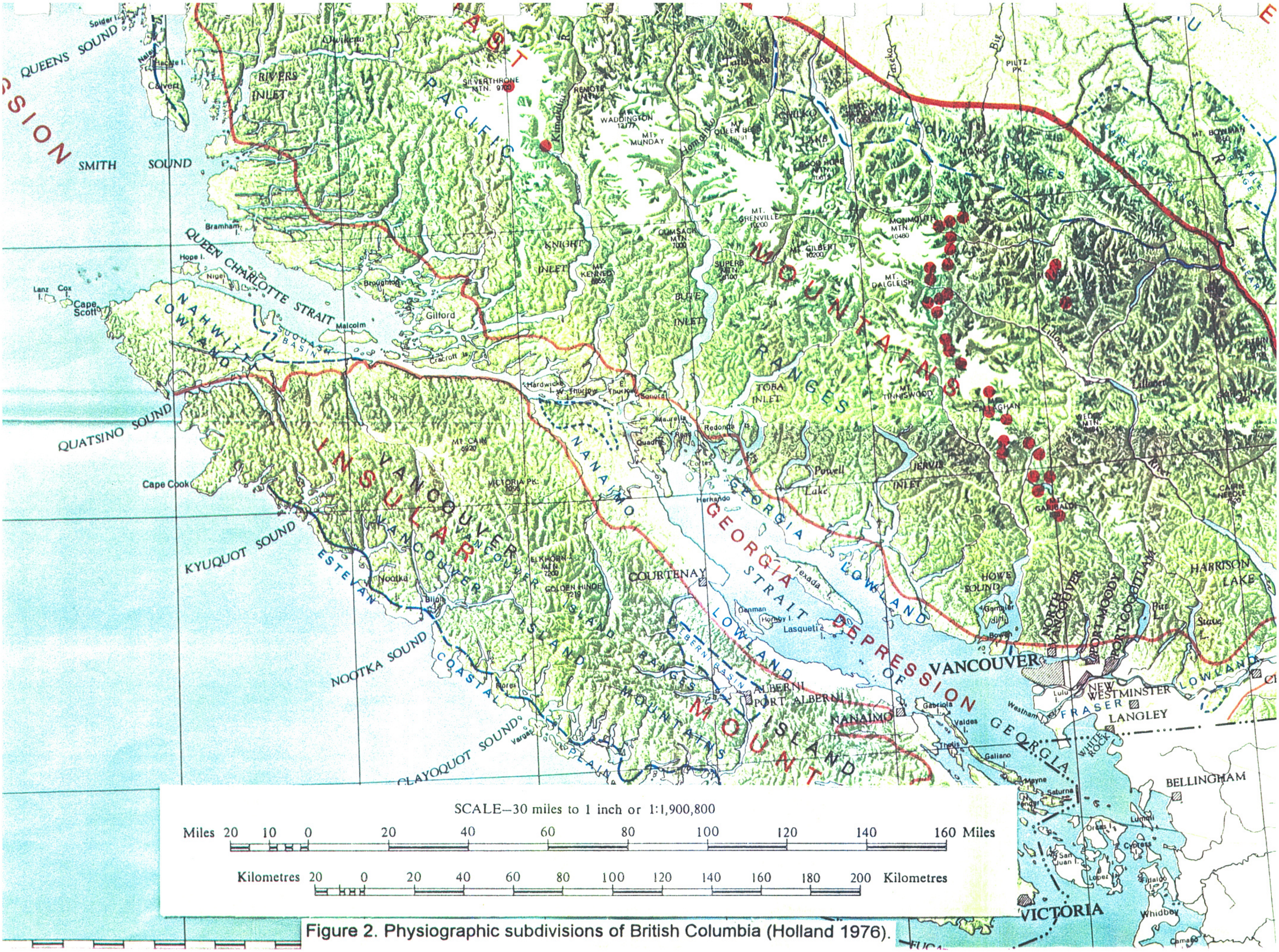

Figure 2. Physiographic subdivisions of British Columbia (Holland 1976).

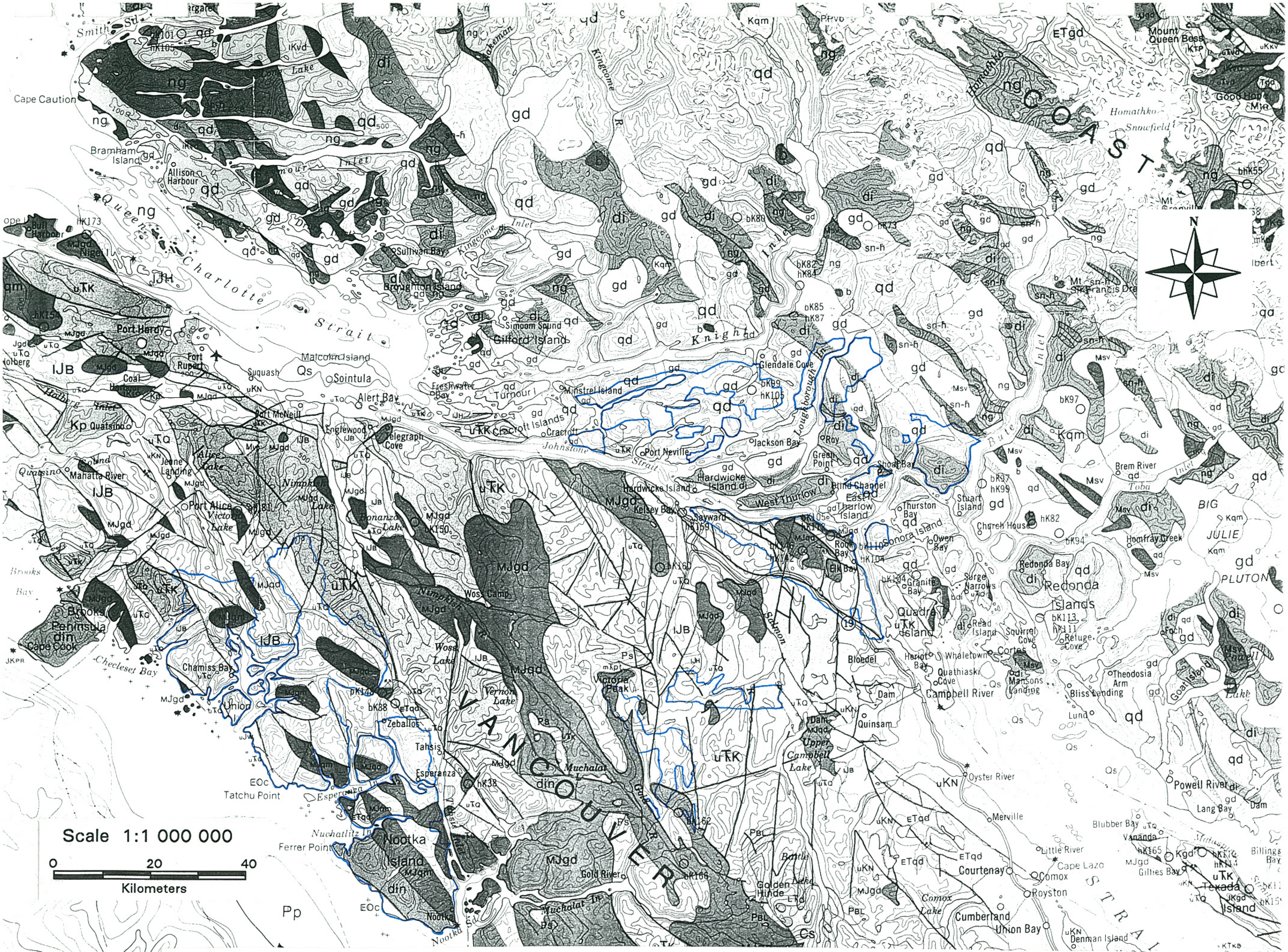

Figure 3. Bedrock geology of the Strathcona Timber Supply Area. (Roddick, J.A. et al., 1976, GSC Map 1386A)

GEOLOGY MAP LEGEND

EARLY TERTIARY

ETqd quartz diorite

EOCENE AND OLIGOCENE

EOc Carmanah Group: sandstone, shale

MIDDLE JURASSIC

Vancouver Island Intrusions, Penask Batholith

MJqm quartz monzonite, granite, monzonite

MJgd granodiorite

MJqd quartz diorite

LOWER JURASSIC

lJB Bonanza: andesite, dacite, rhyolite

lJH Harbledown: argillite, greywacke

UPPER TRIASSIC

uTc limestone

uTQ Quatsino and Parson Bay: limestone, argillite

uTK Karmutsen: basalt, pillow lava

AGE UNKNOWN

Coast Plutonic Complex

gd granodiorite

qd quartz diorite

di diorite

din foliated to gneiss diorite, amphibolite

Province boundary

Subprovince boundary

Other

Fault

Geological contact (mapped, assumed)

Fault (mapped, assumed)

Transcurrent fault (mapped, assumed)

Thrust, reverse fault (teeth on hanging wall, mapped, assumed)

Normal fault

Anticline

Syncline

Diapir

Isograd:

- *biotite*
- *garnet*
- *kyanite-staurolite*
- *sillimanite*

west-northwestward through Queen Charlotte Strait to the sea. On the west coast of Vancouver Island, ice flowed westward and southwestward from the Vancouver Island Ranges and calved into the ocean.

At the glacial maximum, about 15 000 years BP, all but the highest peaks were buried by ice. Major valleys were deepened relative to their tributary valleys creating hanging valleys and waterfalls. Erosion by valley glaciers have left steep-sided troughs.

Deglaciation along the outer coast of Vancouver Island was underway by about 12 500 years BP (Clague 1981). Glacier melting was rapid as the climate warmed abruptly. On the west coast of Vancouver Island near Kyuquot, the marine limit (sea level at the time of deglaciation) was at about 45 m a.s.l. On the east coast of Vancouver Island and the mainland coast near Sayward and Loughborough Inlet, the marine limit ranges from 100 to 175 m a.s.l. Glaciers calved back to fiord heads and protected embayments, whilst inland, the ice surface became lower, peaks and ridges emerged, and the more or less continuous ice sheet was replaced by a system of valley glaciers. Beneath the ice, glacial till accumulated on most surfaces. As the ice melted, glaciofluvial sands and gravels were deposited here and there by meltwater streams. Freshly exposed till was unstable on steep slopes, and subject to the erosional effects of meltwater. Thus, large quantities of material were rapidly reworked and redeposited at lower elevations.

(3.4) Postglacial Processes

During the 10 000 years of postglacial time there have been minor changes to the terrestrial landscape. Postglacial processes include frost shattering of rock faces and local outcrops, leading to active raveling and the accumulation of rockfall debris as talus slopes. Commonly, disintegration of these blocks combined with soil creep, has resulted in a thin veneer of colluvium overlying bedrock and till downslope. Thicker colluvial deposits are also present at the base of some steep slopes. Debris slides and debris flows from steep slopes have removed material from the higher elevations, and transported materials have accumulated on gentler lower slopes, forming a mantle of colluvium on bedrock and till, as well as colluvial fans. Erosion by debris flows and streams has created gullies in the till and bedrock of valley sides, exploiting joints and faults in the latter. Streams have deposited fluvial gravels, forming fans and floodplains.

(4) SURFICIAL MATERIALS AND ASSOCIATED LANDFORMS

Because virtually no information about the physical characteristics of surficial materials was collected for the map area, the following descriptions consist of general definitions followed by brief descriptions of the local materials that are based on the writer's prior experience in similar areas.

(4.1) Till (M)

Till (morainal material) is defined as material deposited directly from glacier ice. Basal till was deposited subglacially by melting of ice at the sole of an ice sheet or glacier. Typically, it is massive (non-stratified), poorly-sorted material, with clasts (particles >2 mm) supported in a fine-grained matrix of sand, silt and clay. It is usually the most highly consolidated (densest) and strongest of all the surficial materials and it is highly cohesive. The permeability of basal till is generally low. Ablation (supraglacial) till consists of debris that melted out on top of a glacier as the ice surface melted and lowered during deglaciation. It is relatively gravelly with little silt and clay. Typically, it is non-consolidated, loose, relatively rapidly permeable, and characteristics such as clast size vary markedly over short distances. Ablation till commonly contains pockets of till reworked by debris flows (flow till), glaciofluvial sand and gravel, and fine-textured (fine sand, silt, clay) glaciolacustrine/glaciomarine sediments. Both basal and ablation tills may be highly variable, with gradations in characteristics such as texture and consolidation over short distances.

In the study area, basal till is the most widespread of all the surficial materials and underlies most gentle to steep slopes at all elevations. It is likely thickest on gentle slopes, valley floors, and in other depressions and concavities, and relatively thin on crests and convexities.

Till derived from the Coast Mountains typically consists of a matrix of medium to fine sand supporting 30-50% clasts that are mostly pebbles, with a few cobbles and scattered boulders. The unweathered material is moderately to highly consolidated. Till derived from the Vancouver Island Mountains would be much more variable due to the variable bedrock. In the study area, till derived from the Vancouver Island Mountains has a slightly higher percentage of silt than till from the Coast Mountains.

Where postglacial stream erosion has created steep slopes in thick basal till, e.g., many stream-side scarps (Section 3.4), unstable and potentially unstable slopes are common.

(4.2) Colluvium (C)

Colluvial materials have accumulated during postglacial time as a result of gravity-induced movements, such as debris flows and rockfall. The physical characteristics of colluvium are closely related to its mode of accumulation and source material. Thus, the texture of colluvium varies widely.

In the map area, rockfall colluvium is widespread at the foot of cliffs; talus slopes (e.g., aCk, arCk) flank open cliffs, and talus cones (e.g., xCc, srCc) have formed where rockfall is funneled down gullies. Typically, the material consists of large angular blocks (>25.6 cm) and rubble. It is loosely packed and non-cohesive, well drained and relatively dry. Talus slopes and cones are not prone to debris slides and they constitute relatively stable substrates for roads, although surface ravelling upslope of roads may result from undercutting. Commonly a thin veneer of rubbly colluvium overlying steep bedrock was mapped as U and P.

(4.3) Glaciofluvial Materials (FG)

Glaciofluvial sediments were deposited by glacial meltwater streams during glacial advance and recession. Proglacial deposits were laid down in deltas and outwash plains (which may now be terraces) downstream from the glacier. Glaciofluvial materials consist predominantly of sands and gravels, and may contain a small proportion of silt. These materials are a good source of aggregate.

Glaciofluvial materials are not extensive in the map area, although small areas of outwash gravels may be present in the Sayward lowlands and some small terraces along the lower valleys are probably kame terraces formed between a melting glacier and the adjacent valley side.

Glaciofluvial sands and gravels present below, within, or on top of till have relatively high permeability. The differences in permeability between materials may lead to seepage, thereby contributing to slope destabilization and erosion on unstable and potentially unstable terrain.

(4.4) Glaciolacustrine Materials (LG)

Glaciolacustrine (glacial lake) sediments consist of fine sand, silt, and clay carried by meltwater streams and settled out in temporary, ice-dammed lakes. Typically, these sediments are thinly bedded or laminated (= beds thinner than 1 cm), and layers of coarser and finer texture alternate. Glaciolacustrine sediments that contain even a modest proportion of silt and clay are only slowly permeable or impermeable, and so the presence of this material is sufficient to cause impeded drainage, perched watertables, and surface seepage. All these conditions promote instability. These fine materials are also susceptible to surface erosion by running water.

No glaciolacustrine materials were observed in the map area, but, as in the case of glaciofluvial materials, small bodies of lake sediments could be present almost anywhere that till has been mapped. (See also Section 4.3.)

(4.5) Marine (W) and Glaciomarine Materials (WG)

Glaciomarine materials were deposited by settling of sediments and gravity flows in brackish or marine waters in close proximity to glacier ice. They range from finely laminated silts and clays to massive deposits with pebble to block-sized dropstones. Glaciomarine sediments are fine grained, typically laminated silts and fine sands. Due to their fine texture these deposits are slowly permeable. Marine materials are very similar to glaciomarine materials and include sediments accumulated along present day shorelines by wave action or longshore drift.

In the map area, glaciomarine deposits mapped as potentially unstable or unstable are identified along the coastline east of Sayward. They are prone to sliding and surface erosion on moderate to steep slopes.

(4.6) Undifferentiated Materials (U)

Undifferentiated materials include all types of glacial drift (M, FG and LG) and colluvium. The symbol U, most commonly Us, was used in the map area to describe scarps composed of all or some of FG, LG, WG, and till.

(4.7) Bedrock (R)

Bedrock was mapped where it outcrops and where it is overlain by only a few centimetres of weathered rock, soil, or organics. (See also Section 3.2.)

(4.8) Other Materials

Other materials present in the map area, but not mapped because they are not associated with unstable or potentially unstable slopes, include organic (O) materials (peat, muck) and fluvial (F) deposits. Organic materials are present in poorly drained areas of the uplands and the floors of the glacial troughs. Fluvial deposits are located close to stream-level, have a high water table and are moderately to imperfectly drained.

(5) SLOPE STABILITY

In the map area, presently unstable slopes were found in two situations: (i) steep rocky valleysides, and (ii) stream-side scarps underlain by thick glacial materials.

Instability was noted in many places on the steep (> 70%) rocky slopes of the major valleys. In the upper valleys, the effects of rockfalls and debris flows were noted on the precipitous sides of glacial troughs on slopes steeper than 80%. On till-covered slopes, debris slides occur on slopes steeper than 60-65%.

Stream-side scarps have been cut into glacial materials, chiefly till, by streams during postglacial time. The highest and steepest scarps have developed along the lower, steep reaches of the streams, but low scarps flank some streams within the upper, trough-like sections of their valleys. In a few places, lowland streams are bounded by scarps.

Instability on the scarps is restricted to small sites where several conditions are concurrent, including steep slopes, high groundwater table or moist soils, and thick surficial materials. Slope steepness is controlled largely by the proximity of the stream to the toe of the slope, and slides probably occur after stream undercutting has oversteepened the slope. The strength of dry till and other glacial materials is relatively high. However, in relatively wet coastal areas, the addition of water by subsurface seepage from upslope, or seepage through bedrock fissures or glaciofluvial gravels, for example, can trigger local instability.

Potentially unstable slopes show no overt signs of instability under natural conditions, but may be otherwise similar to nearby unstable areas. Detailed terrain stability mapping (e.g., TSIL C) should be considered for extensive areas mapped as potentially unstable, such as in the Kyuquot TSB and the southern half of Nootka Island. Where proposed road alignments or cut blocks occur on potentially unstable slopes an on-site assessment is required under the Forest Practices Code.

Typically, potentially unstable areas were mapped on till-covered, moderately steep to steep slopes. Steep rock cliffs and combinations of surficial materials on moderately steep to steep slopes were also mapped as potentially unstable. Other local factors considered when rating instability include:

- Slope smoothness/irregularity: The "bumps" on irregular slopes are usually formed by near-surface bedrock which acts to pin surficial materials in place. Thus, the potential for instability on an irregular slope is lower than that on a slope of similar overall steepness but with a smoother profile.

- Moisture: In general, wet slopes are more unstable and more erodible than dry ones. High pore water pressure, such as that which develops in a perched water table in weathered till, leads to a reduction in normal stress and slope failure. Overland flow, which develops more readily in wet than dry areas, leads to surface erosion.

- Slope position: In general, lower slopes and concavities are relatively wet because they receive moisture from a large area upslope and the water table tends to be at relatively shallow depth; thus, they tend to be potentially unstable if steep, and erodible even if moderately sloping.

(6) NET-DOWN ESTIMATES

Net-down estimates are used to determine the net land base, which is the number of hectares of forest land which actually contribute to the annual allowable cut (AAC). For terrain polygons, the net-down figure (%) is an estimate of the proportion of a polygon (area) that should not be harvested, i.e., the extent of truly unstable and/or inoperable ground in P and U polygons. At the reconnaissance level, precise net-down figures applicable to large areas (such as a TSA) are very difficult to estimate because the extent of unstable slopes varies from polygon to polygon in accordance with details of the terrain characteristics and other conditions that influence slope stability, such as subsurface hydrology and geology, most of which cannot be adequately assessed from air photo interpretation.

The following estimates for net-down are based on the mappers judgement and experience.

(6.1) Kyuquot Timber Supply Block

The Kyuquot TSB includes Nootka Island, most of the area surrounding Nootka Sound, and the area east of Gold River. In general, the terrain is rugged and dissected by major glaciated valleys that feed into the numerous inlets that make up the west coast of Northern Vancouver Island, with the exception of the outer coast along the Estevan Coastal Plain. Most of the major valley bottoms have been logged, however many post-logging failures have occurred on the steeper mid to upper slopes and are road-related. Unstable (U) terrain and potentially unstable (P) terrain is widespread throughout the TSB. The highest concentration of unstable terrain is found on southern Nootka Island, the headwaters of Kauwinch and Kashutl Rivers, and west of Port Eliza.

Estimated net-downs for the Kyuquot Timber Supply Block are:

U polygons: 95% net-down. Most unstable terrain consists of steep rock slopes overlain by a veneer of colluvium and/or till, and steep gullies. In these areas, there are very few gentler slopes or benches. Here only 5% of the areas are estimated to be harvestable.

P polygons: 40% net-down. Irregular and benched, moderately steep to steep slopes controlled by bedrock include significant areas that may be relatively stable.

(6.2) Sayward Timber Supply Block

The Sayward TSB includes all of the area east of Sayward to Menzies Bay on northern Vancouver Island and a small area adjacent to and north of Strathcona Provincial Park. In general, the terrain is gentle and hummocky to the east of Sayward with steep terrain in the Prince of Wales Range to the west. The area adjacent to Strathcona Provincial Park has moderate relief. Overall, the terrain is much gentler and the percentage of U and P terrain is significantly lower than in the Kyuquot and Loughborough TSBs; however, net-down estimates for P terrain are slightly higher than for the Kyuquot.

Estimated net-downs for the Sayward Timber Supply Block are:

U polygons: 95% net-down. Unstable terrain consists of steep rock slopes overlain by a veneer of colluvium and/or till, steep gullies, steep slopes underlain by materials such as glaciomarine sediments, and thick deposits of gullied till and glaciofluvial sediments. An allowance of 5% harvestable timber was made for the local areas of stable terrain (e.g., benches) that exist on these slopes.

P polygons: 50% net-down. Most of the potentially unstable terrain consists of steep (> 70%) rocky slopes with a veneer of colluvium. Therefore, the potential for post-logging failure here is higher than in the Kyuquot TSB.

(6.3) Loughborough Timber Supply Block

The Loughborough TSB includes various areas on the mainland between Knight and Bute Inlets and parts of East Thurlow Island and Sonora Island. In general, the terrain along the coast is hummocky with has moderate relief (elevations below 1310 m a.s.l.) and becomes increasingly rugged inland where elevations rise to 1770 m a.s.l. east of Loughborough Inlet. Unstable (U) and potentially unstable (P) terrain are widespread throughout the TSB.

Estimated net-downs for the Loughborough Timber Supply Block are:

U polygons: 95% net-down. Most unstable terrain consists of steep rock slopes overlain by a veneer of colluvium and/or till, and steep gullies. An allowance of 5% harvestable timber was made to accommodate the restricted areas of stable terrain (e.g., benches) that exist on these slopes.

P polygons: 50% net-down. Most of the potentially unstable terrain consists of steep (> 70%) rocky slopes with a veneer of colluvium. Therefore, the potential for post-logging failure here is higher than in the Kyuquot TSB. In contrast, hummocky and irregular topography consists of local areas of stable ground resulting in a greater area of harvestable terrain.

(7) RECOMMENDATIONS

The Forest Practices Code guidebook (FPC, 1995), recommends that where logging operations are planned in areas with extensive unstable and potentially unstable terrain, detailed terrain stability mapping should be carried out prior to finalization of logging plans and be incorporated into the planning process. Then, on-site inspections are required for slopes mapped as stability classes **IV** and **V** (defined, respectively, as moderate and high likelihood of landslide initiation following timber harvesting or road construction by conventional means). Where reconnaissance mapping shows that unstable and potentially unstable slopes are restricted to relatively small, widely scattered areas, detailed mapping can be omitted, although on-site inspections of blocks and roads that lie within U and P polygons are still required.

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APPENDIX 1. STANDARD TERRAIN LEGEND LONG VERSION

(1) TERRAIN UNIT SYMBOLS

Simple Terrain Units: e.g.,

texture ----> gFt - J <---- process
surficial material ____/ ____ surface expression

Note: Two or three letters may be used to describe any characteristic other than surficial material, or letters may be omitted if information is lacking.

Composite Units: Two or three groups of letters are used to indicate that two or three kinds of terrain are present within a map unit.

e.g., Mv • Rs indicates that "Mv" and "Rs" are of roughly equal extent

Mv/Rs indicates that "Mv" is more extensive than "Rs" (about 2/1 or 3/2)

Mv//Rs indicates that "Mv" is much more extensive than "Rs" (about 3/1 or 4/1)

Stratigraphic Units: Groups of letters are arranged one above the other where one or more kinds of surficial material overlie a different material or bedrock:

e.g., Mv/Rr (Mv above Rr) indicates that "Mv" overlies "Rr".

/Mv/Rr (/Mv above Rr) indicates that "Rr" is partially buried by "Mv"

(2) MATERIALS

A	Anthropogenic materials	Artificial materials, and materials modified by human actions such that their original physical appearance and properties have been drastically altered.
C	Colluvium	Products of gravitational slope movements; materials derived from local bedrock and major deposits derived from drift; includes talus and landslide deposits.
D	Weathered bedrock	Bedrock modified *in situ* by mechanical and chemical weathering.
E	Eolian sediments	Sand and silt transported and deposited by wind; includes loess.
F	Fluvial materials	Sands and gravels transported and deposited by streams and rivers; floodplains, terraces and alluvial fans.
FA	"Active" fluvial materials	Active deposition zone on modern floodplains and fans; active channel zone.

(2) MATERIALS cont'd

FG	Glaciofluvial materials	Sands and gravels transported and deposited by meltwater streams; includes kames, eskers and outwash plains.
I	Ice	Permanent snow and ice; glaciers.
L	Lacustrine sediments	Fine sand, silt and clay deposited in lakes.
LG	Glaciolacustrine sediments	Fine sand, silt and clay deposited in ice-dammed lakes.
M	Till	Material deposited by glaciers without modification by flowing water. Typically consists of a mixture of pebbles, cobbles and boulders in a matrix of sand, silt and clay; diamicton.
M1	Ablation till	Material accumulated on top of a melting glacier; coarse textured and less consolidated than basal till.
O	Organic materials	Material resulting from the accumulation of decaying vegetative matter; includes peat and organic soils.
R	Bedrock	Outcrops, and bedrock within a few centimetres of the surface.
U	Undifferentiated materials	Different surficial materials in such close proximity that they cannot be separated at the scale of the mapping.
V	Volcanic materials	Unconsolidated pyroclastic sediments.
W	Marine sediments	Sediments deposited by settling and gravity flows in brackish or marine waters, and beach sands and gravels.
WG	Glaciomarine sediments	Sediments laid down in marine waters in close proximity to glacier ice.

(3) TEXTURE

Specific Clastic Terms

c	clay	< 4µm	k	cobbles	64 - 256 mm
z	silt	62.5 - 4µm	b	boulders	> 256 mm
s	sand	2 mm - 62.5µm	a	blocks	angular boulders
p	pebbles	2 - 64 mm			

Common Clastic Terms

f	fines	any or all of c, z, and fine s
d	mixed fragments	pebbles and larger clasts in a matrix of fines
g	gravel	any or both of p and k
r	rubble	angular gravel
x	angular fragments	mix of both r and a
m	mud	mix of both c and z
y	shells	shell or shell fragments

Organic Terms

e	fibric
u	mesic
h	humic

Bedrock Classification Codes

Sedimentary Rocks

	EITHER		OR	
Clastic, calcareous	fine grained	**kf**	calcareous siltstone calcareous mudstone calcareous shale	**kz** **kd** **kh**
	medium grained	**km**	calcareous sandstone calcareous greywacke calcareous arkose	**ks** **kg** **ka**
	coarse grained	**kc**	calcareous conglomerate calcareous breccia	**kn** **kb**
Clastic non-calcareous	fine grained	**uf**	siltstone mudstone shale	**zl** **md** **sh**
	medium grained	**um**	sandstone greywacke arkose	**ss** **gk** **ak**
	coarse grained	**uc**	conglomerate breccia	**cg** **bx**
Precipitates	calcareous	**pk**	travertine limestone dolomite	**tv** **ls** **do**
	non-calcareous	**pu**	gypsum limonite barite	**gy** **li** **ba**
Organic	calcareous	**ok**	marl	**ma**
	carbonaceous	**oc**	lignite coal	**lg** **co**

Igneous Rocks

	EITHER		OR	
Intrusive	acid (felsic)	**ia**	syenite granite quartz monzonite granodiorite	**sy** **gr** **qm** **gd**
	intermediate	**ii**	quartz diorite diorite	**qd** **di**
	basic	**ib**	quartz gabbro gabbro pyroxenite peridotite dunite	**qg** **gb** **py** **pd** **du**
Extrusive	acid (felsic)	**ea**	trachyte rhyolite dacite	**tr** **rh** **da**
	intermediate	**ei**	andesite	**an**
	basic	**eb**	quartz basalt basalt	**qb** **bs**
	recent lava flow	**la**		
	pyroclastic	**ep**	tuff volcanic breccia agglomerate	**tu** **vb** **ag**

Metamorphic Rocks

	EITHER		OR	
Foliated	fine grained	**ff**	slate phyllite	**sl** **ph**
	medium to coarse grained	**fm**	schist gneiss granite gneiss diorite gneiss	**sc** **gn** **gg** **dg**
	coarse grained	**fc**	migmatite	**mi**
Non-foliated	fine grained	**nf**	argillite serpentinite	**ar** **sp**
	medium to coarse grained	**nm**	granulite quartzite hornfels	**gl** **qt** **hf**
	coarse grained	**nc**	amphibolite hornblendite	**am** **hb**
	calcareous	**nk**	marble dolomite marble serpentine marble	**mb** **dm** **sm**

(4) SURFACE EXPRESSION

a	moderate slope(s)	predominantly planar slopes; 15-26^{O} (27-49%)
b	blanket	material >1-2m thick with topography derived from underlying bedrock (which may not be mapped) or surficial material
c	cone	a fan-shaped surface that is a sector of a cone; slopes 15^{O} (27%) and steeper
d	depression	enclosed depressions
f	fan	a fan-shaped surface that is a sector of a cone; slopes 3-15^{O} (5-27%)
h	hummocky	steep-sided hillocks and hollows; many slopes 15^{O} (27%) and steeper
j	gentle slope(s)	predominantly planar slopes; 3-15^{O} (5-27%)
k	moderately steep slope	predominantly planar slopes; 26-35^{O} (49-70%)
m	rolling topography	linear rises and depressions; <15^{O} (27%)
p	plain	0-3^{O} (0-5%)
r	ridges	linear rises and depressions with many slopes 15^{O} (27%) and steeper
s	steep slope(s)	slopes steeper than 35^{O} (70%)
t	terrace(s)	stepped topography and benchlands
u	undulating topography	hillocks and hollows; slopes predominantly <15^{O} (27%)
v	veneer	material <1-2m thick with topography derived from underlying bedrock (may not be mapped) or surficial material; may include outcrops of underlying material
w	variable thickness	material of variable thickness with topography derived from underlying bedrock (may not be mapped) or surficial material
x	thin veneer	a subset of v (veneer), where there is a dominance of surficial materials about 10-25 centimeters thick

(5) GEOMORPHOLOGICAL PROCESSES AND MASS MOVEMENT SUB-CLASSES

A	Avalanches	Slopes modified by frequent snow avalanches.
Af	Avalanches: major tracks	In zones of coniferous forest: broad avalanche track(s) occupied by predominantly shrubby, deciduous vegetation.
Am	Avalanches: minor tracks	Similar to above, but generally narrower than the height of adjacent trees.
Aw	Avalanches: mixed major and minor tracks	Includes both major and minor avalanche tracks
Ao	Avalanches: old tracks	Clearly visible on air photos, but less well defined than active tracks because they are partly or completely occupied by young conifers.
B	Braiding channel	Channel zone with many diverging and rejoining channels; channels are laterally unstable.
C	Cryoturbation	Heaving and churning of soil and surficial materials due to frost action.
D	Deflation	Removal of sand and silt particles by wind action.
E	Glacial meltwater channels	Areas crossed by meltwater channels that are too small or too numerous to map individually.
F	Failing	Slope experiencing slow mass movement, such as sliding or slumping.
H	Kettled	Area includes numerous small depressions and/or lakes where buried blocks of ice melted.
I	Irregularly sinuous channel	Channel displays irregular turns and bends.
J	Anastomosing channel	Channels diverge and converge around semi-permanent islands.
K	Karst processes	Solution of carbonates (limestone, dolomite) resulting in development of collapse and subsidence features.
L	Surface seepage	Zones of active seepage often found along the base of slope positions.
M	Meandering channel	Channel characterized by regular turns and bends.
N	Nivation	Surface modified by hollows developed around semi-permanent snowbanks.
P	Piping	Subsurface erosion of silty sediments by flowing water resulting in the formation of underground conduits.
R	Rapid mass movement	Slope or parts of slope affected by processes such as debris flows, debris slides and avalanches, and rockfall.
S	Solifluction	Slope modified by slow downslope movement of seasonally unfrozen regolith.
U	Inundated	Areas submerged in standing water from a seasonally high watertable.
V	Gullying	Slope affected by gully erosion.
W	Washing	Winnowing of fines by flowing water resulting in development of lag deposits.
X	Permafrost processes	Processes related to the presence of permafrost; permafrost aggradation and degradation.
Z	Periglacial processes	Solifluction, nivation and cryoturbation occurring together in a single terrain unit.

Mass Movement Modifiers

-F"	Slow m.m. (initiation zone)	-Fx	Slump-earthflow
-Fc	Soil creep	-F1	Sackung (sagging slopes)
-Fe	Earthflow	-R"	Rapid m. m. (initiation zone)
-Fg	Rock creep	-Rb	Rockfall
-Fj	Lateral spread in surficial materials	-Rd	Debris flow
-Fk	Tension cracks	-Rf	Debris fall
-Fm	Slump in bedrock	-Rr	Rockslide
-Fp	Lateral spread in bedrock	-Rs	Debris slide
-Fu	Slump in surficial material	-Rt	Debris torrent

(6) SLOPE CLASSES

1	0-3° (0-5%)	**3**	15-26° (28-49%)	**5**	>35° (>70%)
2	3-15° (6-27%)	**4**	26-35° (50-70%)		

APPENDIX 2. STREAM SEDIMENTATION POTENTIAL

Map Code	STREAM SEDIMENTATION POTENTIAL
1	None
2	Open-slope instability unlikely to directly introduce sediment into a stream system; any mass movement sedimentation which does occur will be minor.
3	Instability in or into a gully system where mass movement deposition directly into a stream system is unlikely; any mass movement sedimentation which does occur will be minor.
4	Open-slope instability where direct mass movement deposition into a stream system is likely.
5	Instability in or into a gully system where direct mass movement deposition into a stream system is likely.
6	Instability on stream escarpments; direct mass movement into a stream system is very likely.
7	Instability will likely cause direct mass movement deposition into a major stream or river estuary.
8	Instability will likely cause direct mass movement deposition in a lake or depressional wetland.
9	Instability will likely cause direct mass movement deposition onto a narrow marine foreshore or into deep ocean.

Note: Sedimentation potential is based on a subjective assessment of the distance and slope configuration between unstable areas and valley-bottom streams and other waterbodies; travel distance of existing natural failures provides an estimate of potential mass movement transport.

APPENDIX 3. LIST OF AIR PHOTOS

Flight Line	Photo Numbers
BCB 90013	13-22, 41-53, 58-71, 91-107, 111-124, 148-150, 155-157, 172-174, 182-188,
BCB 90020	67-73, 83-100, 106-126, 134-156, 164-177
BCB 90021	4-33, 39-47, 56-72, 88-103, 109-117, 137-149, 151-158, 167-196, 202-216, 222-238, 256-288
BCB 90022	4-17, 22-36, 71-85, 90-100, 110-116, 121-135, 164-177, 180-187, 193-202, 205-210, 213-220, 239-241, 249-263, 266-270
BCB 90023	5-23, 29-48, 63-80, 88-99, 103-115, 120-150, 157-187, 195-225
BCB 90045	66-105, 120-156, 161-195
BCB 90048	20-28, 33-40
BCB 90049	4-9, 13-18, 29-33, 43-51, 54-62, 71-78, 81-86, 101-105, 118-125, 133-135
BCB 91024	212-215, 260-267
BCB 91025	212-221
BCB 91031	126-136, 208-228, 236-256
BCB 91032	22-28, 73-82, 146-161, 205-220, 254-267
BCB 91033	43-64, 86-105, 107-110, 151-155, 180-205, 231-238, 244-247
BCB 91034	8-16, 24-27, 43-46, 50-63, 78-86, 91-95, 114-118, 225-259
BCB 91037	12-23, 30-48, 61-68, 75-81, 83-97, 155-163, 180-188, 191-197, 249-252
BCB 91038	8-14, 20-26, 165-171, 187-202, 240-244, 246-265
BCB 91039	132-135, 137-162, 188-208, 226-232
BCB 91040	40-48, 160-167, 210-219, 225-231