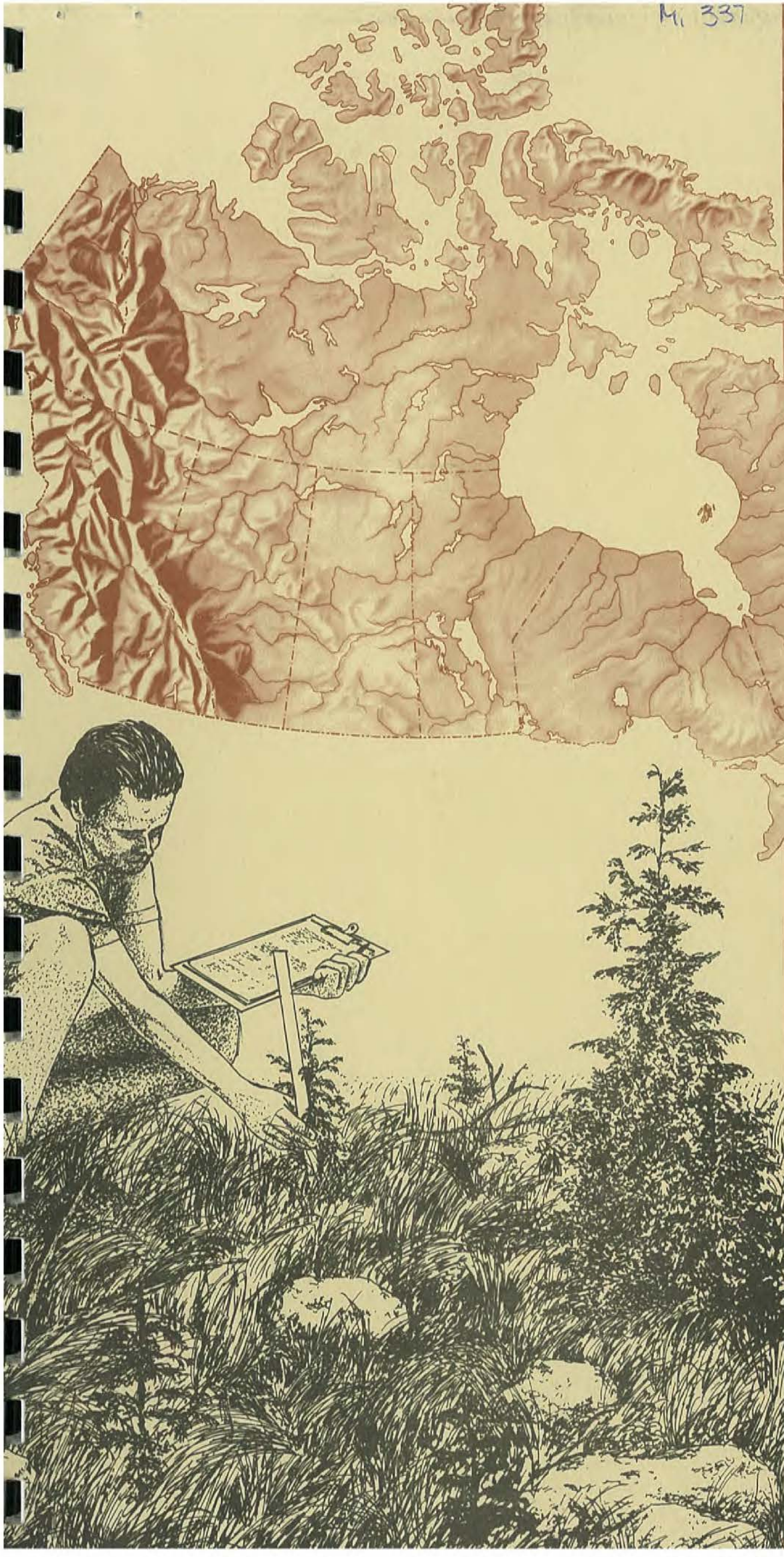

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EDMONTON, CANADA

JUNE 1978

GUIDEBOOK TOURS V1-V3

PODZOLIC SOILS AND FOREST MANAGEMENT IN THE MAPLE RIDGE RESEARCH FOREST

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GUIDEBOOK

FOR

A TOUR FEATURING STUDIES ON PODZOLIC SOILS AND FOREST MANAGEMENT IN THE UNIVERSITY OF BRITISH COLUMBIA, RESEARCH FOREST MAPLE RIDGE, BRITISH COLUMBIA

TOURS V1 and V3

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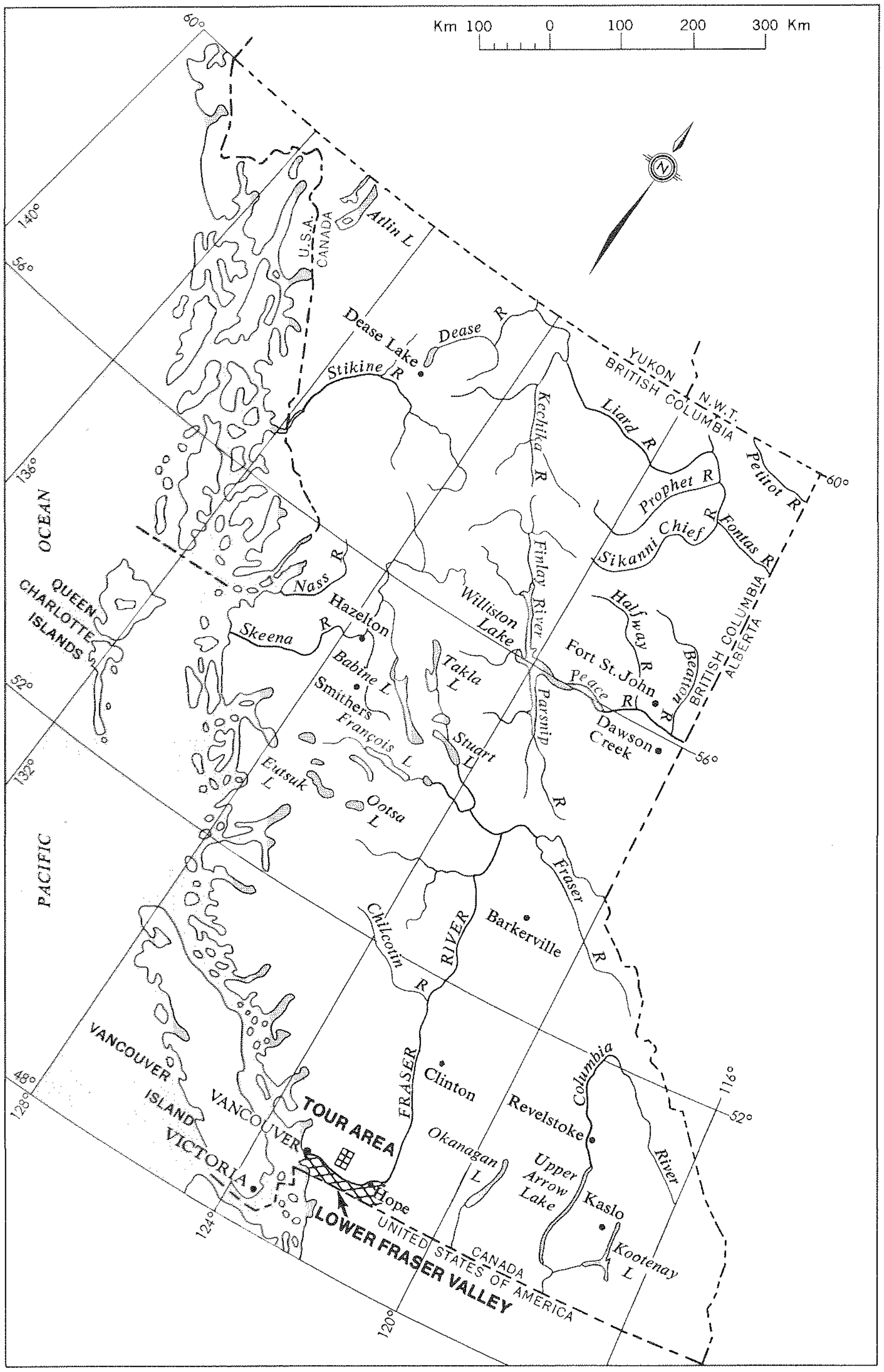


FIG. 1 THE LOCATION OF THE UBC RESEARCH FOREST AND THE LOWER FRASER VALLEY IN THE PROVINCE OF BRITISH COLUMBIA

THE LOWER FRASER VALLEY

Introduction

The Lower Fraser Valley, in the southwest corner of the province of British Columbia (Fig. 1) represents a unique geographic unit in Canada. With a moderate Mediterranean-like climate and fertile soils it has become the major food producing region in a province which has only 2.9% of its land suited for intensive food production. It is also the region in which over half of the province's population lives.

This small geographic unit, approximately 400 000 ha in size, is struggling to find room for its rapidly growing population, expanding industrial uses and agricultural production. These uses complexed with wildlife and recreation needs have brought this area into the forefront of land use planning in British Columbia.

History

The Lower Fraser Valley was not always characterized by the agricultural and urban/industrial mosaic so predominant today. Before the arrival of the white man this area was prized by the native peoples. There were 18 local groups known as the Stalo Indians, a branch of the Coast Salish tribe. The Fraser River supplied them with a major transportation artery, but to native Indians the river was more than a transportation route. It was their supplier of food, giving yearly runs of salmon and steelhead, eulachon and other fishes. It also provided habitat for a bounty of water fowl and animal species. The abundant growth of fruit-bearing shrubs, such as salmonberry, thimbleberry, and huckleberry, attracted native peoples from as far away as Vancouver Island.

Since Simon Fraser first navigated the Fraser River in 1818, the surface expression of the Lower Fraser Valley has changed rapidly. The earliest developments centred around the Hudson's Bay Company and the fur trade. Large beaver populations formed the basis for the fur trade. In 1827, Fort Langley, located on the Fraser River, became the first British settlement actively trading in furs, agricultural products (grown on a Hudson Bay farm located on Langley Prairie), and manufactured products. Fort Langley became the capital of the crown colony of British Columbia on November 19, 1858. The capital was moved to New Westminster in 1859 and finally to Victoria in 1868.

In the 19th century the Fraser River was the only transportation route and by the 1850's steamboats began giving regular service to settlements which developed along their routes. The discovery of gold in the Fraser Canyon in 1858 gave impetus to the development of the area. Gold placer mines along the Lower Fraser and miners travelling into the Interior provided a market for "Lower Mainland" farms. Land clearing of large farm settlements first took place around Langley, Chilliwack, Sumas and Agassiz. Agricultural development of the Cloverdale, Abbotsford, and Fraser Delta areas soon followed.

The logging industry was well established in the 1860's and with the completion of the Canadian Pacific Railway in 1885 the Lower Mainland was destined to become an area of important commercial development based largely on the forest industry. Vancouver with its large natural harbour, and as the terminus of two transcontinental railways, became the major trade and commercial centre of the west coast.

Physiography

The Lower Fraser Valley lies within two major physiographic divisions, namely, the Coastal Mountain area and the Coastal Trough (Holland, 1964).

The Coast Mountains, (Fig. 2) characterized by peaks rising abruptly to 1500 to 2150 m a.s.l. (above sea level), constitute the northern boundary of the Fraser Lowland (Fig. 3). The mountain peaks to the east and southeast of the valley form a portion of the Cascade Mountains and are also considered part of the Coastal Mountain area.

The mountainous areas are separated by large U-shaped valleys with floors up to approximately 100 m a.s.l. The principal valleys in the region are associated with the Pitt, Alouette, Stave, and Harrison rivers, north of the Fraser Valley proper, and the Chilliwack River to the southeast of the Fraser River. Indian Arm forms a major coastal inlet to the west.

The Coastal Trough lies between the Coast Mountain area and the Outer Mountain area of Vancouver Island. The Fraser Lowland, commonly referred to as the Lower Fraser Valley or Lower Mainland, is considered to be part of the Georgia Depression within the Coastal Trough physiographic division.

The Fraser Lowland physiographic region is characterized by wide, flat-bottomed valleys and extensive uplands ranging in elevation from 15 to 122 m a.s.l. The upland areas have a generally rolling topography and a core of unconsolidated material of glacial, preglacial and interglacial origin.

Lowland areas are represented by a variety of surficial deposits of more recent origin which overlie glacial, preglacial and interglacial deposits. Bedrock is felt to play a rather minor role in controlling the present landscape configuration within the Fraser Lowland.

Glacial History and Surficial Deposits*

Vertical cross sections in upland areas indicate there were three major periods of glaciation (Armstrong and Brown, 1954) between approximately 10 000 and 2.5 million years ago (referred to as the Pleistocene Epoch). A fourth glaciation (approximately 10 000 years ago) was smaller and probably glaciated only the valleys. Each major glaciation reached ice sheet proportions during its maximum advance (thought to be at least 2280 m thick over the valleys). Each glacial, interglacial and non-glacial period, concomittant with a fluctuating sea level, saw the deposition of a variety of surficial materials. Ice, fresh water and salt water were all agents active in the deposition and erosion of surficial sediments, each playing a more dominant role than others during a certain geologic-climatic environment. At present we are in a non-glacial period where geological processes of erosion and deposition have been continuing in the absence of ice for about the last 10 000 years (referred to as the Holocene Epoch).

The present surficial deposits (Fig. 4) of upland and some lowland areas are a result of the last two major glacial ice advances and more recent erosion and deposition by major rivers in the area (Armstrong, 1960). The second last glaciation (between 12 000 and 25 000 years ago) formed a portion of the continental

* Contributed by J.E. Armstrong, Dept. of Mines and Technical Surveys, Vancouver.

Courtesy of British Columbia Government

FIG. 2 VANCOUVER AND COAST MOUNTAINS

CANADIAN CORDILLERA			
OUTER MOUNTAIN AREA	Insular Mountains		
COASTAL TROUGH	Georgia Depression		Fraser Lowland
COAST MOUNTAIN AREA	Coast Mountains	Pacific Ranges	
	Cascade Mountains	Skagit Range	

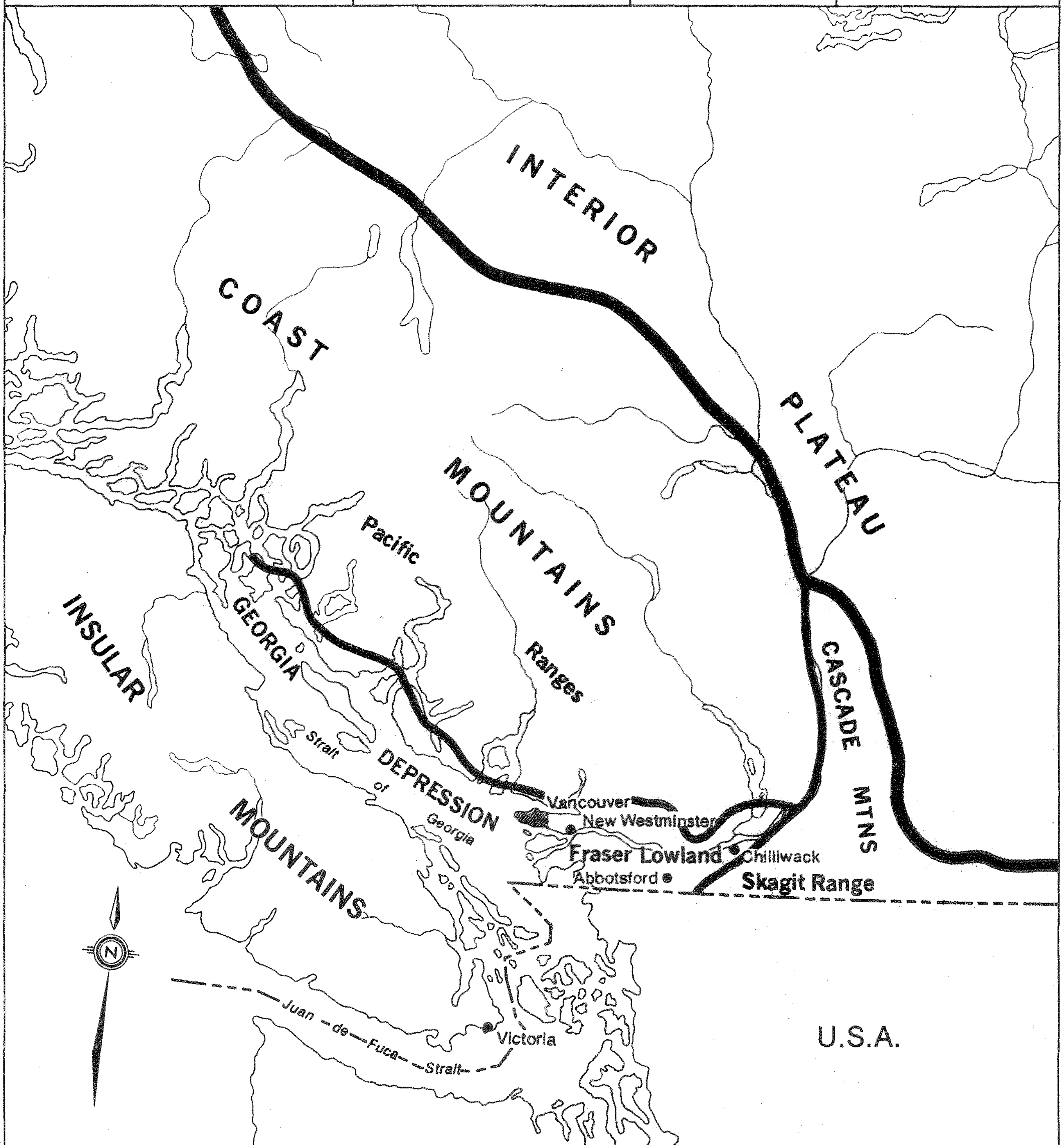
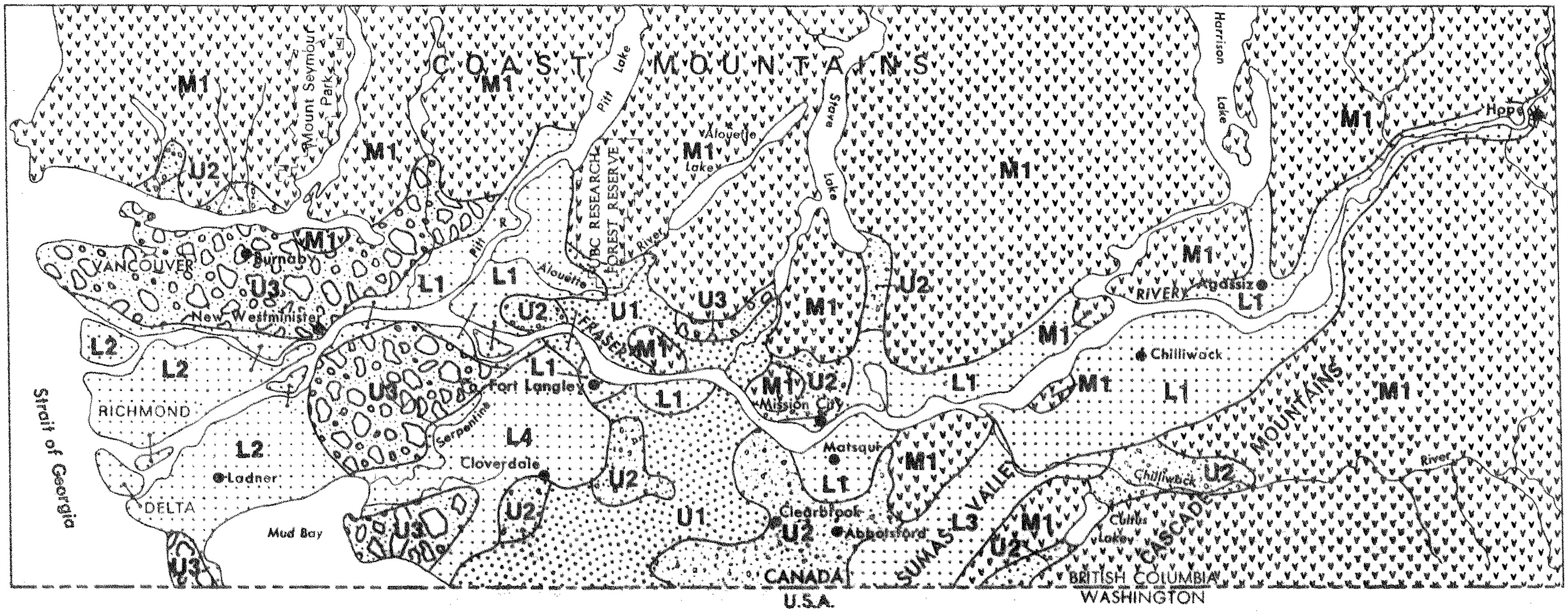


FIG. 3 PHYSIOGRAPHIC SUBDIVISION OF SOUTHWESTERN BRITISH COLUMBIA



LEGEND

LOWLAND DEPOSITS*

L1 Fraser River floodplain

L2 Fraser River delta

L3 Lacustrine deposits

L4 Marine deposits

UPLAND DEPOSITS

U1 Fine and Medium Textured glaciomarine and till deposits.

U2 Coarse Textured glaciofluvial deposits

U3 Coarse Textured glaciofluvial and beach deposits

MOUNTAIN SLOPE DEPOSITS

M1 Mountain slope deposits dominantly till and glaciofluvial deposits on lower slopes and colluvial deposits on upper slopes

*Large organic deposits occur throughout the lowlands

FIG. 4 SURFICIAL DEPOSITS AND LANDFORMS IN THE FRASER LOWLAND ice sheet which advanced from the north across the Fraser Lowland causing the land to be depressed relative to the sea by possibly as much as 300 m. Glaciofluvial material was laid down in advance of the ice sheet with morainal deposits plastered on the pre-existing hills. As this ice sheet retreated, by wasting, it thinned and floated, depositing stony-clay glaciomarine sediments below 150 m a.s.l. Glaciofluvial deposits located north of the Fraser River were deposited above 150 m a.s.l. After the ice melted, and as the land rose above the sea, marine clay sediments and beach deposits of sand and gravel were laid down. These deposits are located in upland areas at the western portion of the Fraser Lowland. It is not certain how far the land rose relative to the sea after this advance.

After a period of interglacial deposition of glaciofluvial and stream sediments an ice sheet representing the last glaciation advanced in a westerly direction down the Fraser Valley. The land surface was depressed 150 m relative to its present elevation. This advance occurred approximately 11 000 years ago and glaciomarine materials were again deposited during this ice advance. Wasting of the ice sheet left some areas ice-free while others remained covered with ice. During the wasting period the glaciofluvial plains deposited near Abbotsford often exhibited kettled and pitted topography. An ice block caused the formation of a glacial lake in what is now the Matsqui Valley.

It is believed an ice block remained in the Sumas channel diverting the Fraser River to its present channel from its preglacial route through the Sumas Lowlands. With the final melting of the ice the land surface rebounded to its present level. A shallow lake was formed in the Sumas Lowland. This lake, drained in 1926, represents the major lacustrine deposit in the Fraser Lowland.

Recent surficial deposits are represented by four major types: floodplain deposits, lacustrine deposits, organic deposits and sub-marine sediments occurring below the normal high water level.

Climate

The prevailing air flow over British Columbia is westerly with the tropospheric circulation being primarily controlled by two pressure systems the Alaskan Low (Aleutian Low) and the Pacific High (Hawian High), although other minor systems disrupt this principal west to east pattern. Low pressure systems influence the area over a larger percentage of the year. However, from May to September high pressure systems dominate. The climate of the Lower Fraser Valley is further influenced by the abruptly rising Coast Mountains to the north, the Cascades to the south, and the Fraser Canyon to the east.

The numerous low pressure systems bring most precipitation during the winter months. Precipitation generally increases from the southwest area of the valley to the north and east. This increase is associated with the increasing height of the land and distance from the ocean. At Ladner on the edge of the delta, the annual precipitation is 958 mm. About 40 km to the northwest at Coquitlam Lake, lying at the base of the Coast Mountains, the annual precipitation is 3631 mm.

In winter, occasional outbreaks of cold air of a continental origin and the subsequent arrival of a disturbance from the west bring snow and freezing rain to the area. Precipitation falling as snow amounts to only about 3 to 6% of the total precipitation.

As a result of the prevailing westerlies and moderating efforts of the Pacific Ocean and Strait of Georgia, the Lower Fraser Valley has mild winters, warm but not hot summers, and a small range of temperatures. The average January minimum temperature is just slightly below freezing, getting colder as one goes north and east from the coastline. High summer temperatures also increase in a northeastern direction away from the moderating sea breezes.

The Lower Fraser Valley has the longest frost free period in B.C. and in Canada with the exception of Vancouver Island. Frost free period is a localized factor within the Valley depending on the availability of cold air drainage. In the more exposed areas the frost free period exceeds 200 days. Areas at higher elevations such as the University of B.C. Research Forest north of Haney have shorter frost free periods.

Vegetation*

The vegetation (Appendix B) of the Lower Fraser Valley varies greatly over rather short distances in response to rapid gradients in climate, physiography, and parent materials. Traces of a coastal rain shadow from both the Olympic and Island mountains are still evident in the southern upland area of the delta and estuary region. The reduced rainfall and modifying marine influence permits the development of a high proportion of both seral and climax forest stands of Coast Douglas Fir (the Coastal Douglas Fir zone) with the understory of Salal, Oregon Grape, Red Huckleberry, Ocean Spray and wild roses. The increasing gradient in precipitation in a northeasterly direction causes a progressive shift from the drier Coastal Douglas Fir zone to the wetter Coastal Western Hemlock zone. This wetter zone occurs for the most part on the northern Surrey and Langley uplands, the Burrard Peninsula and on the slopes of the Coastal mountains to about 900 m a.s.l. A typical forest community consists of Western Hemlock, Western Red Cedar with moss and blueberry understory. Upper subalpine landscapes, above 1000 m a.s.l., generally have a longer snow duration, and are inhabited by forests of Mountain Hemlock, Pacific Silver Fir, and Yellow Cedar.

The vegetation of the Fraser delta and floodplain deposits is constantly influenced by changes in sediment distribution, salt water infiltration and high water tables. Those areas not under cultivation contain a variety of alluvial plant communities, mostly deciduous. Species typical of the floodplain area on mineral soils are: Black Cottonwood, Red Alder, Bigleaf Maple, Paper Birch and Trembling Aspen, with understories of Thimbleberry, Salmonberry, Western Red Osier Dogwood, and Twinberry Honeysuckle on well drained sites, and willows, sedges, and American Skunk-cabbage on poorly drained sites. Organic substrates support Shore Pine, Salal, Common Labrador Tea, Black Crowberry, Bog Laurel, Bog Blueberry, Bog Cranberry and *Sphagnum* species.

Soils and Landforms

The complex glacial history of the Lower Fraser Valley and subsequent erosion and deposition by major rivers have resulted in a wide range of landforms and

*Contributed by R.K. Jones, Soil Research Inst., Agric. Canada. Guelph, Ont.

parent materials (Fig. 4) being deposited within the region. These landforms range from relatively fine textured marine deposits to coarse textured colluvial materials of mountain slopes. All landforms are subjected to relatively high rainfall conditions and moderate yearly temperatures.

Land Use

A wide range of agricultural activity occurs within the Lower Fraser Valley. (Fig. 5). The moderate climate allows for the maximum possible range of crops which can be grown in Canada. Soil variability then dictates which crop is best suited to any area within this region.

The Lower Fraser Valley is the major vegetable producing area of British Columbia. The wet lowlands Organic and Gleysolic soils are well suited for vegetable production.

The dairy industry is one of the oldest and largest industries of the area. Efficient marketing and a large local urban market have created reasonable stability within this industry.

Small fruit production, including raspberries, strawberries, blueberries and cranberries, is concentrated within adaptable areas of the Valley.

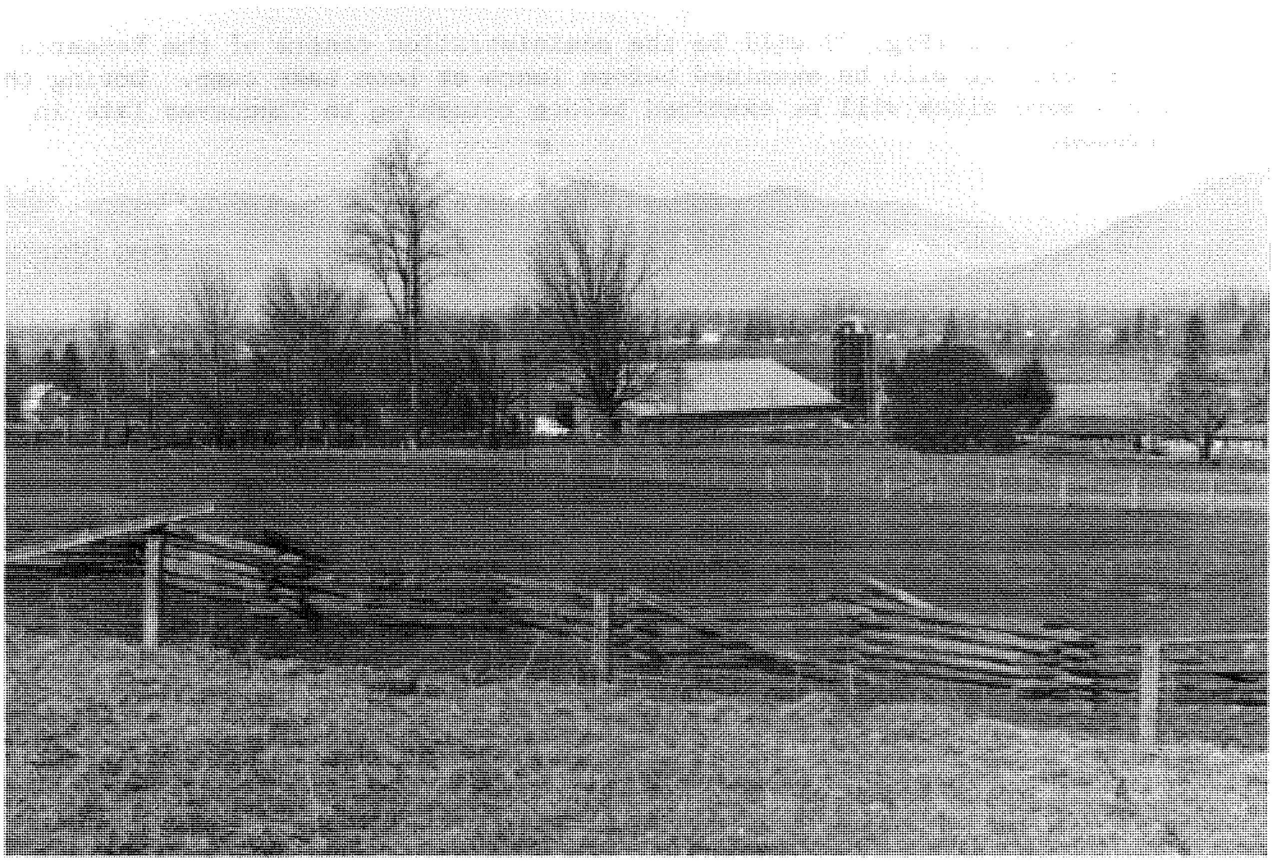
The nursery business is a large industry which has experienced rapid growth with the increased urban population. Urban geography dictates the location of nursery growers rather than physiography.

The mushroom and greenhouse industries are expanding industries which supply processed and fresh mushrooms, tomatoes, and cucumbers to the local population on a year round basis. These industries are located throughout the Valley but are largely concentrated in its western portions close to the major urban centres.

The poultry industry is well established in the Lower Fraser Valley, producing eggs, broiler chickens and turkeys. Large concentrations of this industry are located in the upland areas around Langley and Abbotsford.

Beef and hog finishing industries play smaller roles in Fraser Valley agriculture. Small goat dairy operations are also starting within the Lower Mainland.

In one and a half centuries the Lower Mainland has undergone drastic land use changes. Only recently has the delicate ecological balance of this region been recognized. This finite region must find room for its fish, wildlife, forest and agricultural industries and its urban industry and population. Land use conflicts have become increasingly more evident. Agricultural drainage schemes may cause the loss of our limited natural wildlife habitat. Urban development of the upland areas causes increased runoff and flooding of agricultural lands in the lowlands. Industrial and urban expansion is causing critical pollution problems in the Fraser River. Urban expansion is rapidly encroaching on the remaining highly productive agricultural lands.



Courtesy of British Columbia Government

FIG. 5 FARM, LOWER FRASER VALLEY

THE UNIVERSITY OF BRITISH COLUMBIA RESEARCH FOREST

General Itinerary

The trip (Fig. 6) to the University of British Columbia Research Forest begins in Vancouver and progresses eastward for approximately 47 km to Haney and then north for a further 7 km. The route passes through the urbanized and industrial areas of Burnaby and Coquitlam District Municipalities and the urban and rural settings of the Municipality of Coquitlam. It crosses the Pitt River bridge and traverses Pitt Meadows Municipality before turning north near Haney in the Municipality of Maple Ridge to arrive at the Research Forest.

The first stop (Fig. 7) will be the administration centre of the Research Forest. A soil pit will be examined before lunch at Loon Lake camp. During the afternoon 4 more sites will be examined before returning to Vancouver late in the afternoon.

Introduction

History.

The 2255 ha^{2} University of British Columbia Research Forest was established in 1949 as a facility for demonstration and instruction in the practice of forestry. It is managed by the U.B.C. Faculty of Forestry to provide an optimal environment for education and research in all aspects of forest science.

The area is typical lower coast topography - mountain lakes, steep slopes and rock outcrops in the north, and gradual slopes of glacial till in the south. Elevations in the forest range from sea level at Pitt Lake to 1006 m a.s.l. on the slopes of Mount Blanchard. There are six major lakes in the area and numerous small ones. The north fork of the Alouette River and Blaney Creek take most of the drainage water from the forest.

Forests of Coast Douglas Fir, Western Hemlock and Western Red Cedar originally dominated the forest. However, in 1868 a large fire started by settlers in Maple Ridge burned about 1215 ha of what became the research forest. This area now supports 100-year-old stands of conifers which have naturally regenerated on the site of the fire. Nearly 2800 ha of large virgin timber were harvested between 1920 and 1931 by one of the largest railway logging operations in the Pacific Northwest. Thus by the time the Research Forest was granted, much of the area was second growth.

Forest Management.

Since 1949 a further 600 ha of mature forest have been harvested. The cutting has been done as part of the regular management of the area and the revenues from the timber largely pay for the day-to-day running of the Research Forest. To ensure that the Research Forest will produce wood in perpetuity, the land is managed on a sustained yield basis, whereby only the quantity of timber that is grown over a certain period of time is removed over that period. The calculation of the amount to be harvested is based on the site index, a measure of wood productivity, which varies considerably over the different parts of the Research Forest. The forest reserves, which are areas of special ecological or educational

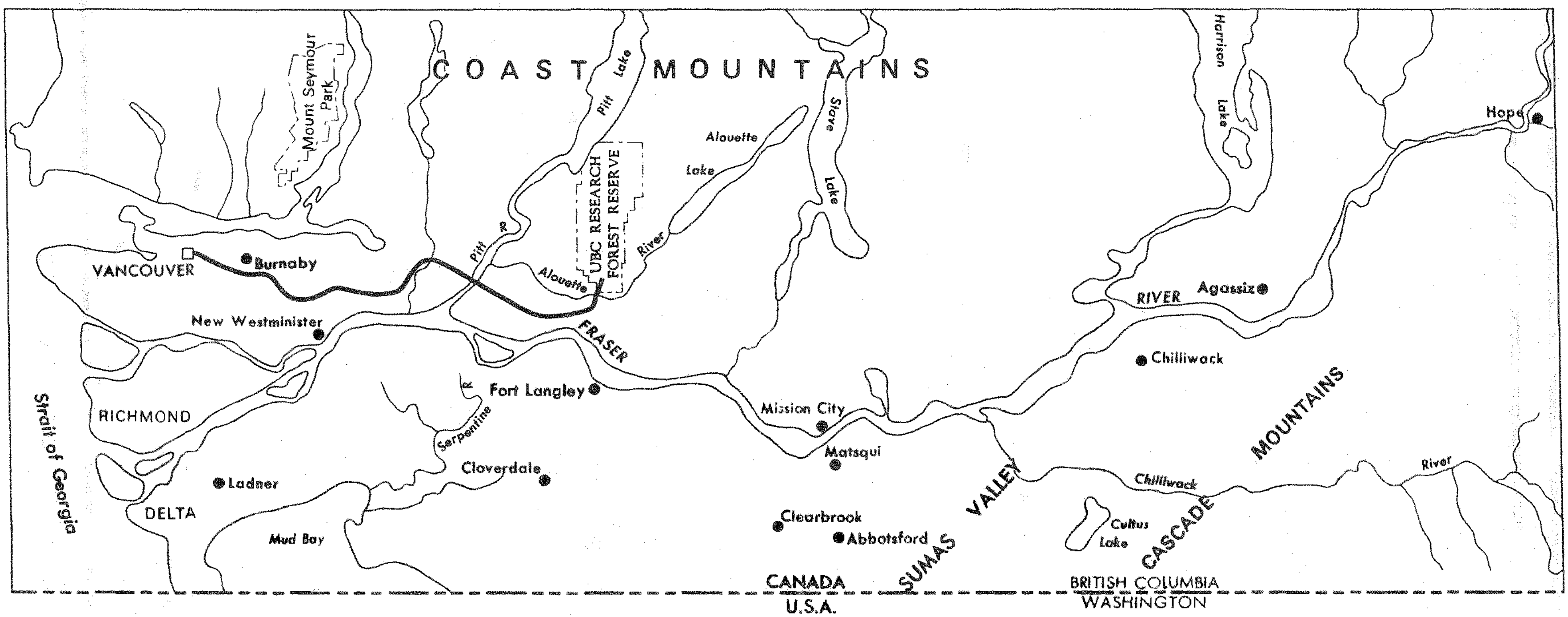


FIG. 6 ROUTE FROM VANCOUVER TO UNIVERSITY OF BRITISH COLUMBIA RESEARCH FOREST

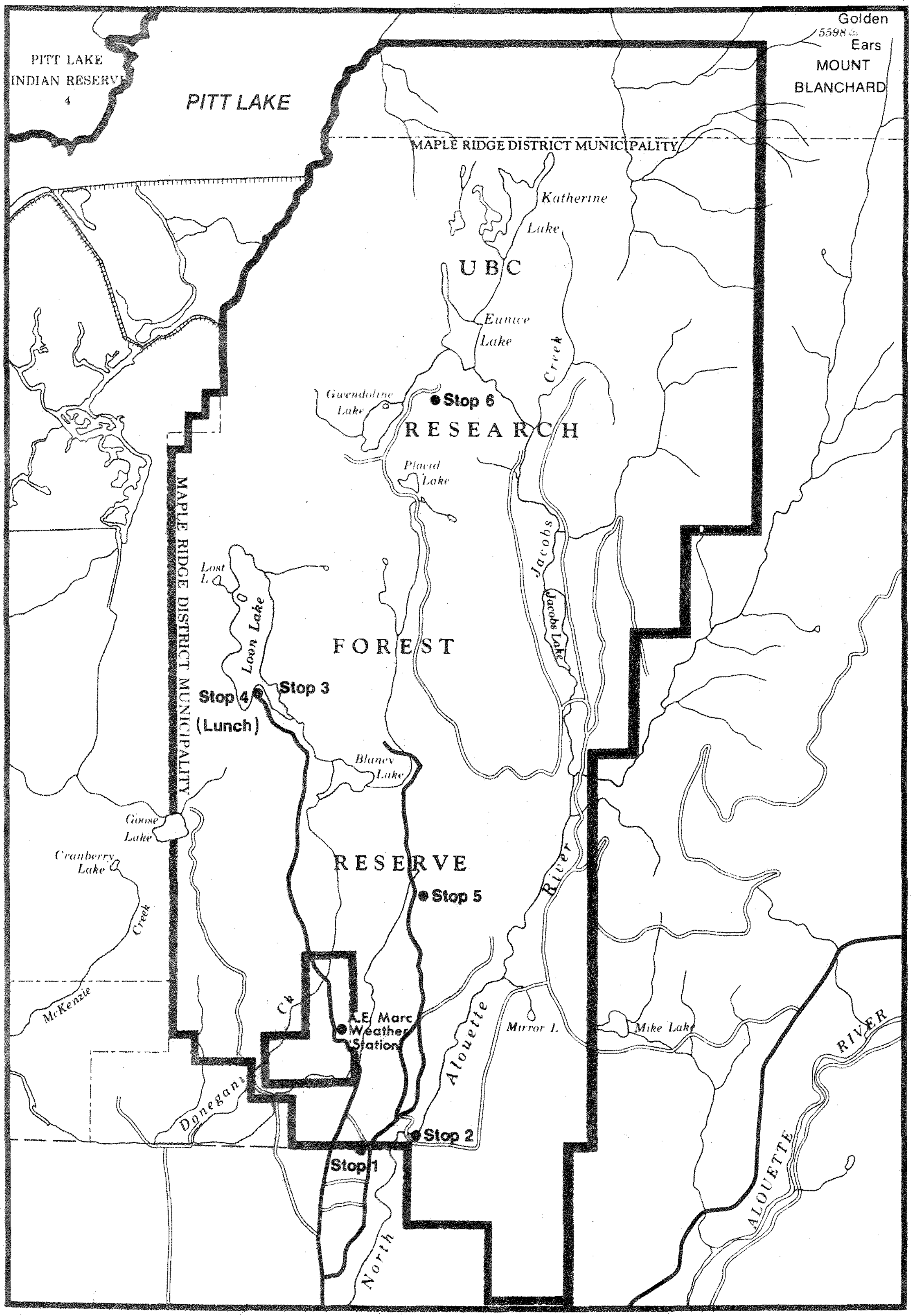


FIG. 7. TOUR STOPS IN THE UBC RESEARCH FOREST

significance, are not included in this calculation. About 42 780 cubic m of wood grow annually on the research forest and this amount called the "annual allowable cut", is harvested each year from about 36 ha of land. After logging, the land is regenerated either naturally or by planting selected young trees (usually Coast Douglas Fir) at the optimum spacing for a new forest.

It is proposed to manage the research forest under a policy of "best use". This means that it will be zoned into areas such that each is put to the use it is best able to fulfil. Water production, intensive timber production, wildlife, nature reserves, and education reserves are some of the uses regarded as best serving the needs of society and the forest will be zoned into areas for these uses.

Research.

Research on the Research Forest is carried out by U.B.C., Simon Fraser University, and the federal and provincial governments. Over 300 research projects have been initiated on the forest. There are currently some 100 projects underway, many of a long term nature. Much of the research work has received international recognition for contributions to science. Research includes many aspects of the forest sciences including fish and deer biology, lake and stream ecology, soil studies, small mammal ecology, microclimatology, forest genetics, forest regeneration, forest productivity, tree pathology, tree measurement, tree physiology, forest ecology, and forest hydrology.

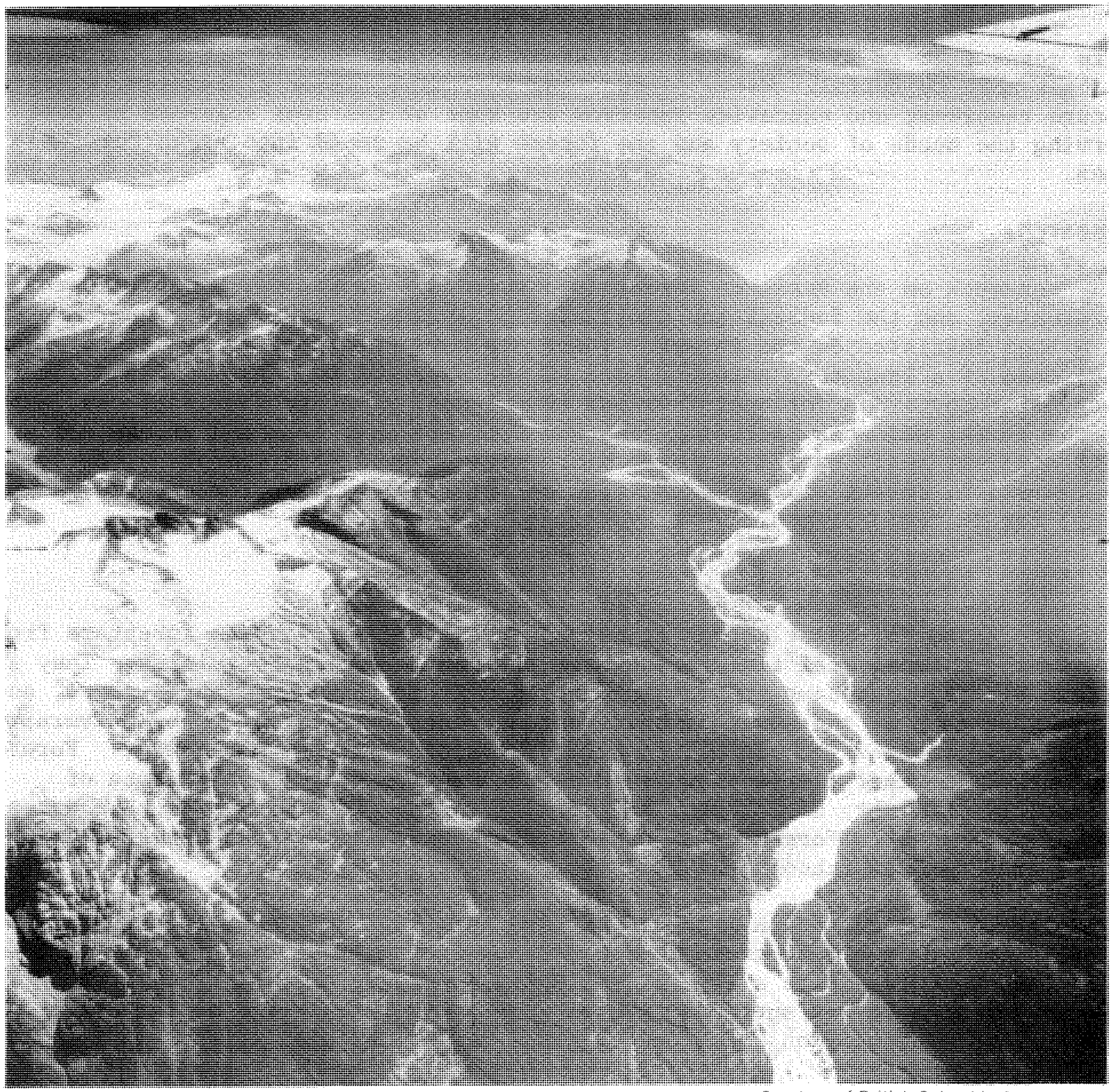
Education.

The Research Forest serves as a training ground for student foresters from U.B.C. who make several field trips over the course of their training. They also attend a three-week camp at Loon Lake between their third and fourth years, and a two-week camp at the start of their second year of Forestry at the University. These field courses include all aspects of practical forest management. Forestry students from other institutions such as the British Columbia Institute of Technology, Ministry of Forests, and Selkirk College also visit and make extensive use of the Research Forest as an outdoor classroom, as do students of biology and soils from various schools and colleges.

The outdoor education program was used by almost 3000 school children and teachers during the year ending March, 1975. Over half of these stayed at the Loon Lake Camp for up to a week of residential outdoor education. A large area of the Research Forest surrounding Loon and Blaney lakes has been set aside for the purpose of education under the best-use management plan.

Physiography

The topography (Fig. 8) of the Research Forest is very broken. In general the area is rolling to fairly steep foothill country. Elevations range from sea level at Pitt Lake in the northwest and Pitt Meadows on the southwest to 1020 m a.s.l. near the north boundary. Two thirds of the Research Forest is located below the 500 m contour. The general slope of the country is towards the south, but several north-south ridges provide variation in aspect and sites which give a great variety of forest conditions. The flat agricultural land of Pitt Meadows is less than a half kilometer from the west boundary. To the south



Courtesy of British Columbia Government

FIG. 8 TYPICAL COAST MOUNTAINS

LEGEND

Quaternary

A
Alluvial, marine and glacial deposits

Mesozoic Pre-Jurassic

B
Hornblende-granulite, amphibolite, gneiss, schist, conglomerate, quartzite, meta-arkose, lime-silicate rock; migmatite.

Coast Plutonic Rock

C1
Granodiorite

C2
Quartz diorite

C3
Diorite

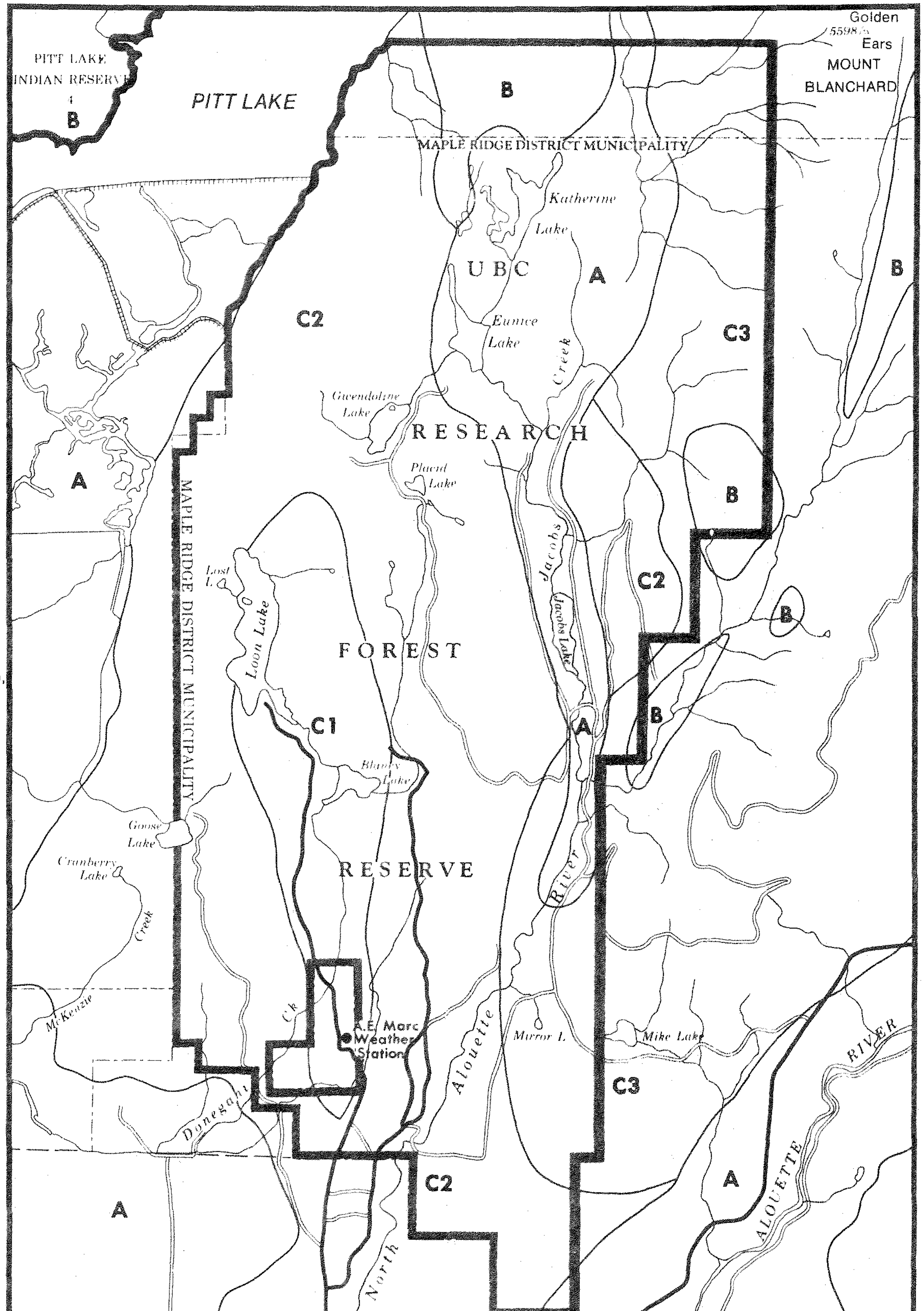


FIG. 9. GEOLOGY OF THE RESEARCH FOREST

is the rolling farm and woodlot land of the Maple Ridge countryside, now rapidly becoming urbanized.

The main drainages of the Research Forest are provided by the North Alouette River in the east and Blaney Creek in the west.

The central portion of the Research Forest contains three parallel north-south valleys. The western valley contains Loon Lake (49 ha in area and 1.6 km long), the largest lake in the research forest and the site of Loon Lake Camp. The ridges vary in steepness but all contain numerous rock outcrops or bluffs. North of Loon Lake a rolling area forms a high pass from the lake to a steep slope down to Pitt Lake.

The central ridge continues into the northern portion of the Research Forest following the top of the Pitt Lake escarpment. The Pitt Lake shore is rocky. South of the lake the bottom of the slope meets flat, wet, grassy tidal flats contained by dykes.

The south portion of the Research Forest has a generally southerly aspect but varies greatly in steepness. There are numerous knolls of various sizes whose sides are quite steep and spotted with rock outcrops and bluffs. Several creeks flowing south drain most of this portion.

Bedrock Geology

The research forest is located in the foothills of the Coast Mountains (Fig. 8). These rugged mountains form a part of the huge complex of plutonic and metamorphic rocks (Fig. 9). The predominant rock type is quartzdiorite, containing more than 10% quartz and less than 10% potassium feldspar (Roddick, 1966). The most abundant medium grained h-quartzdiorite has a higher amount of bases and a lower amount of quartz than granite. The till derived from quartzdiorite is commonly coarse textured (loamy sand to sandy loam) with a high amount of coarse fragments. Soil base status can be expected to be low due to lack of clay rather than to the mineralogical composition of the bedrock. The distribution of the main rock types is shown in Fig. 9.

Surficial Geology

In the research forest area, till underlies most of the terrain. This till often displays a pattern of long streamlined ridges or "drumlinoids", which, with intervening "grooves", record the direction of movement of the last rapidly moving ice sheet.

Meltwater draining from the ice usually followed the edge of the ice tongues along the valley walls, rather than in the centre of the valley floors which, at that time, were plugged by ice. In valleys draining towards the ice sheet the water became ponded to form ice-dammed lakes. Within these lakes, silt and clay were deposited locally in great volumes, to form lacustrine deposits. Along the lake margins, terraces of sand and gravel were laid down, mainly near the mouth of the drainage channels.

Climate

The first weather station to serve the research forest area was established in June 1945. This station, referred to as the A.E. Marc weather station (Fig. 7), is located at an elevation (Table 1) of 165 m a.s.l. in the southwest portion of the Research Forest on the old Marc property.

In 1958 another weather station was established at the administration office. This station is at the southern boundary of the research forest at an elevation of 145 m a.s.l. In 1962 two other stations were established, one near Loon Lake at an elevation of 370 m a.s.l. and the other, south of Spur 17, at an elevation of 375 m a.s.l. Records of the Loon Lake station have not been continuous and are not reported here.

The general climate of the Research Forest classified as Cfb (Koppen, 1936), is influenced by the Pacific Ocean to the southwest and by the Coast Mountains to the north. Temperatures are not extreme; summer temperatures of 32 C or over are not common and the lowest recorded winter temperature at any of the four stations was -20 C. Average annual precipitation is about 230 cm in the southern part of the Research Forest but increases in the higher areas to the north. Approximately 11 percent of the precipitation falls in the three summer months; and 20 percent falls in the spring and summer months, respectively. Winter snowfall in the southern part of the Research Forest averages about 107 cm annually, but this does not increase considerably in the north.

The prevailing summer winds are from the southwest during June, July, and August. Winds from the northeast through to southeast are more common during the late fall and winter months, but there is considerable variation year by year, for all months except June and July. The strongest wind experienced on the Research Forest was on the night of October 12, 1962 when "Typhoon Frieda" swept over the area. An estimated ten million board feet (6125 m^3) of timber was blown down and winds were estimated to be 130-160 km per hour. At that time no records of winds were being made. In November 1966 a wind of 85 km per hour, and in March 1967 a wind of 99 km per hour were recorded. Usually, however, the winds are steady and light to moderate during the summer and are variable but moderate to strong in fall, winter, and spring.

No record of sunshine was made until 1968 when readings were started at the Branch E20 weather station. However, such records have been maintained at the Agriculture Canada research station at Agassiz, 56 km east of the Research Forest since 1946.

Periods of frost are generally confined to the months of December, January, February and March. Due to the maritime influence of the Pacific Ocean, low temperatures are extremely variable in occurance. Occasionally, freezing temperatures occur as early as September and as late as May. The average frost free period is 193 days.

Forest History and Land Use

The University of British Columbia Research Forest lies within the Coastal Western Hemlock biogeoclimatic zone (Krajina, 1965). The primary tree species of the area are Coast Douglas Fir, Western Hemlock and Western Red Cedar. Other

Table 1. Precipitation and temperature records at the A.E. Marc weather station, research forest (1946-1957)

	Jan.	Feb.	Mar	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
						Precipitation (cm)							
Highest	54.4	46.0	41.6	25.3	14.4	24.3	14.7	18.5	25.3	44.0	50.1	56.5	265.0
Average	31.0	26.9	24.9	14.3	8.9	12.0	7.1	7.9	10.6	23.0	28.8	36.6	232.0
Lowest	2.5	13.8	10.5	3.2	1.4	3.1	0.1	1.4	3.3	6.4	7.1	18.2	157.6
						Snowfall (cm)							
Average	49.8	38.4	33.0	1.0	-	-	-	-	-	-	4.8	20.3	147.3
						Temperature (C)							
Highest Mean	5.0	3.9	6.2	10.1	14.0	16.2	17.9	17.4	16.8	11.8	8.4	4.5	9.5
Average	0-0	2.2	3.9	7.8	11.8	14.0	16.2	16.2	14.0	9.0	5.0	2.2	8.4
Lowest Mean	-7.8	0.0	1.1	6.2	9.0	12.9	15.1	15.1	12.3	6.7	1.7	-1.7	7.3
Highest Absolute	10.6	14.0	16.8	25.8	31.9	34.2	34.2	34.2	35.3	18.5	19.0	13.4	
Lowest Absolute	-14.6	-16.8	-14.6	-5.0	1.7	3.4	1.7	3.9	0.0	-3.9	-14.6	-14.0	

species of limited importance in the Forest are Western White Pine, Grand Fir, Pacific Silver Fir, Yellow Cedar, Sitka Spruce, Red Alder and Bigleaf Maple.

Summaries of the logging and fire history in the area are presented in the U.B.C. Faculty of Forestry Bulletin (Anon. 1959) and by Walters and Tessier (1960). The oldest trees at 800 years are Coast Douglas Fir; the most common age of the old growth is 300-350 years. The oldest of the second-growth stands, located on the Pitt Lake slope, is 120 years and probably originated following a fire about the year 1840. Younger second-growth stands have been established on a fairly extensive area which was burned over in 1868.

In 1921 logging operations were started on the east side of the Research Forest by Abernethy and Lougheed Logging Company, and this became one of the largest railway logging operations in the province. In 1925 a fire started near Alouette Lake (east of the forest boundary) and burned 632 ha and in 1926 and 1931 additional fires did extensive damage between Marion and Mike lakes.

Brown and Kirkland Company logged timber berth 351, a part of which was located in the northwest corner of the present Research Forest, from 1926 to 1931.

Some of the plants commonly found in the Research Forest are listed in Appendix B.

Geomorphology

There are four major geomorphological land associations on the Research Forest (Figs. 10, 11). The material and diagrams have been extracted from Lacate (1965).

Land Association A Mountainous to strongly rolling, granitic-cored uplands (Fig. 10).

Characterized by rugged, mountainous topography and extensive areas of shallow soils. The granitic bedrock is generally overlain by dense, compact till which is nearly impervious despite relatively little clay and a high percentage of sand. This is partly a result of the weight of glacial ice beneath which the till was deposited and partly a result of mechanical composition: fine particles fill voids between coarse particles and bind them together to form a natural "concrete". Soils have been developed on a complex of ablation till and colluvial material which overlies the till. Colluvium is generally unsorted and of a gravelly loam texture. The forest and vegetation cover is extremely variable due to the range in land features and the sequence of logging and repeated fires. This land association occupies 42.5% of the research forest area.

Land Association B Hilly to gently rolling, granitic-cored uplands and valleys (Fig. 11).

Covering approximately the same total land area as land association A, this land association occurs throughout the research forest. Land association B is characterized by a higher proportion of deeper soils than is found in land association A, and by less rugged terrain. Gravelly sandy loam colluvium overlying

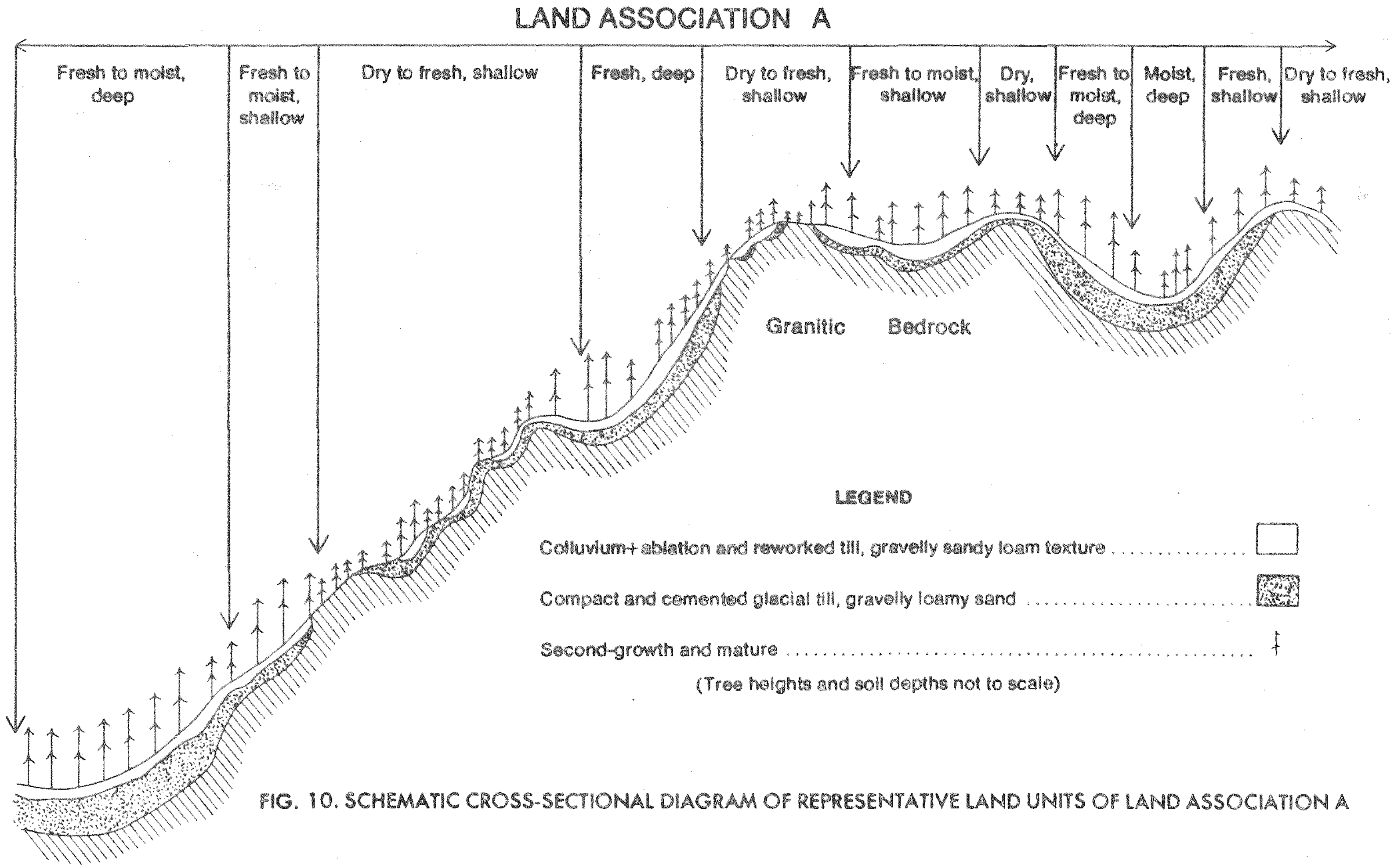


FIG. 10. SCHEMATIC CROSS-SECTIONAL DIAGRAM OF REPRESENTATIVE LAND UNITS OF LAND ASSOCIATION A

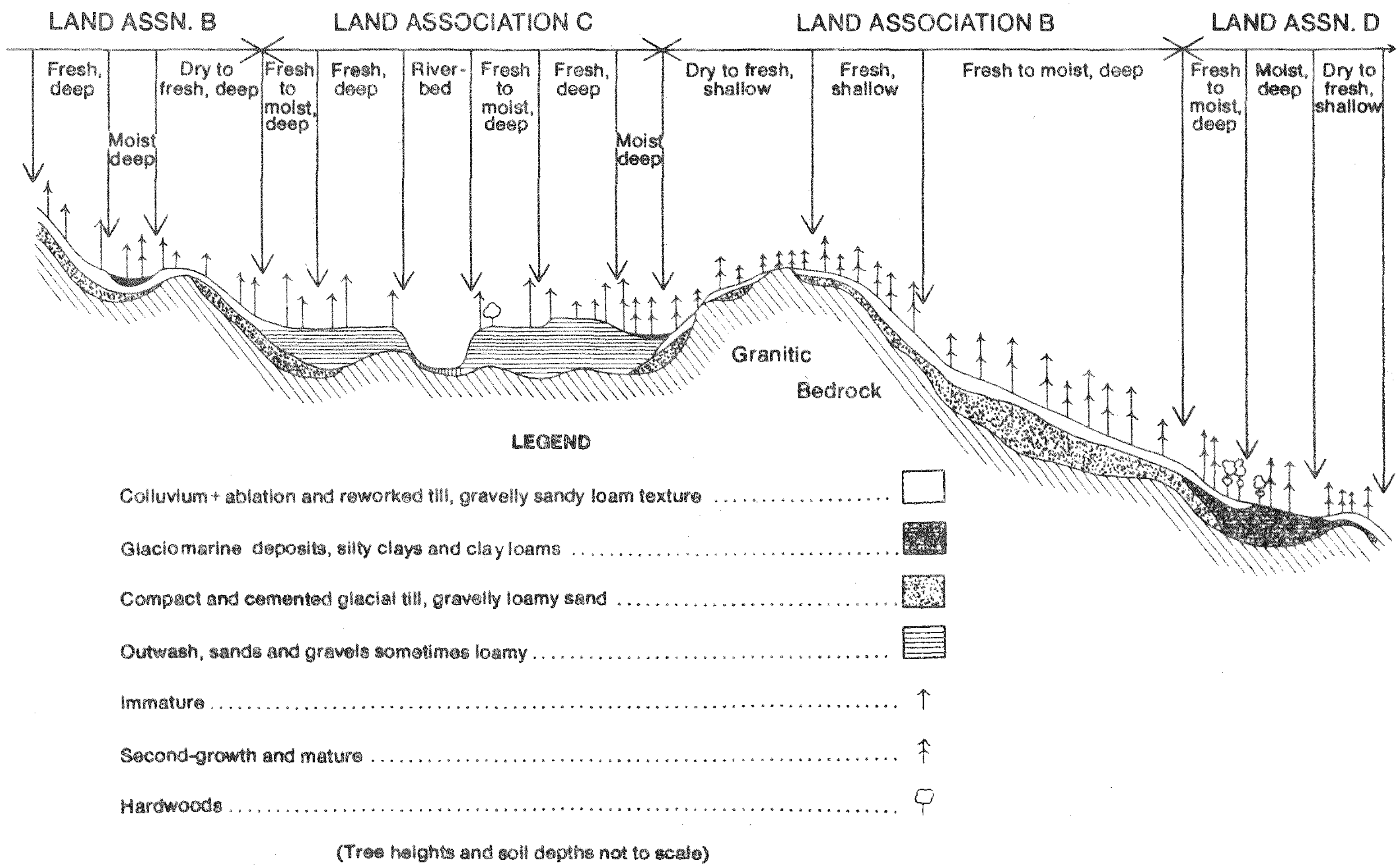


FIG. 11. SCHEMATIC CROSS-SECTIONAL DIAGRAM OF REPRESENTATIVE LAND UNITS OF LAND ASSOCIATION B, C, D

unweathered, compact, till or bedrock is the most common structural pattern of the terrain. In draws and low-lying areas reworked till and poorly sorted sands and gravels mantle the till. A small area of rich, loamy colluvium is situated near Loon Lake Camp. Patches of talus and varved lacustrine clays and silts are minor inclusions. This land association occupies 43.9% of the research forest.

Land Association C Flat to gently rolling, complex of glaciofluvial and substratified drift deposits (Fig. 11)

This land association is comprised of a strip of land between the lower parts of the North Alouette River and Blaney Creek valleys. Outwash sand and gravel terraces and deltas are the common landforms. The soil materials are quite deep. Although these sediments are generally permeable, tree rooting is restricted on some terraces by discontinuous iron pans and cemented layers. Temporary, perched water tables occur above these layers for short periods during the year. Except for terrace scarps and the occasional bedrock knolls, the topography is flat to gently sloping. This land association occupies 7.8% of the Research Forest.

Land Association D Flat to gently rolling, complex of glaciomarine deposits and substratified drift (Fig. 11)

Although limited to the southwest corner of the Research Forest and occupying only 2.2 percent of the total area, this land association contains some of the most productive land. Glaciomarine deposits cover rolling to flat topography. Some inclusions of bedrock knolls and islands of till occur. These glaciomarine drift deposits have a silt loam to silty clay texture. Stones and sand lenses are scattered throughout.

The remainder of the Research Forest is made up of water and streams (3.6%).

Soils

In the mountainous terrain that extends over much of the research forest geomorphological processes are significant for soil genesis. Many upland soil profiles show evidence of soil creep, slides, slumping or disruption by physical or faunal processes. Buried profiles, overlain by colluvial-alluvial caps varying in thickness from 12-75 cm occur on many lower slopes. On some upper slopes the surface horizons have been removed or disturbed by gravitational transfer in land associations A and B. Lithic Podzols occur on slopes and ridges where the soil is shallow to bedrock. With deeper soils, Podzols (Humo-Ferric and Ferro-Humic) are most common. In old growth stands, Orthic Podzols are common on the better drained conditions, Ortstein and Gleyed Podzols where drainage is imperfect, and Humic Gleysols where drainage is poor. In land association C Orthic Podzols are associated with well drained soils. Orthic Podzols predominate on moist but well drained sites within land association D. Gleysols and Gleyed Podzols are associated with poorly drained areas.

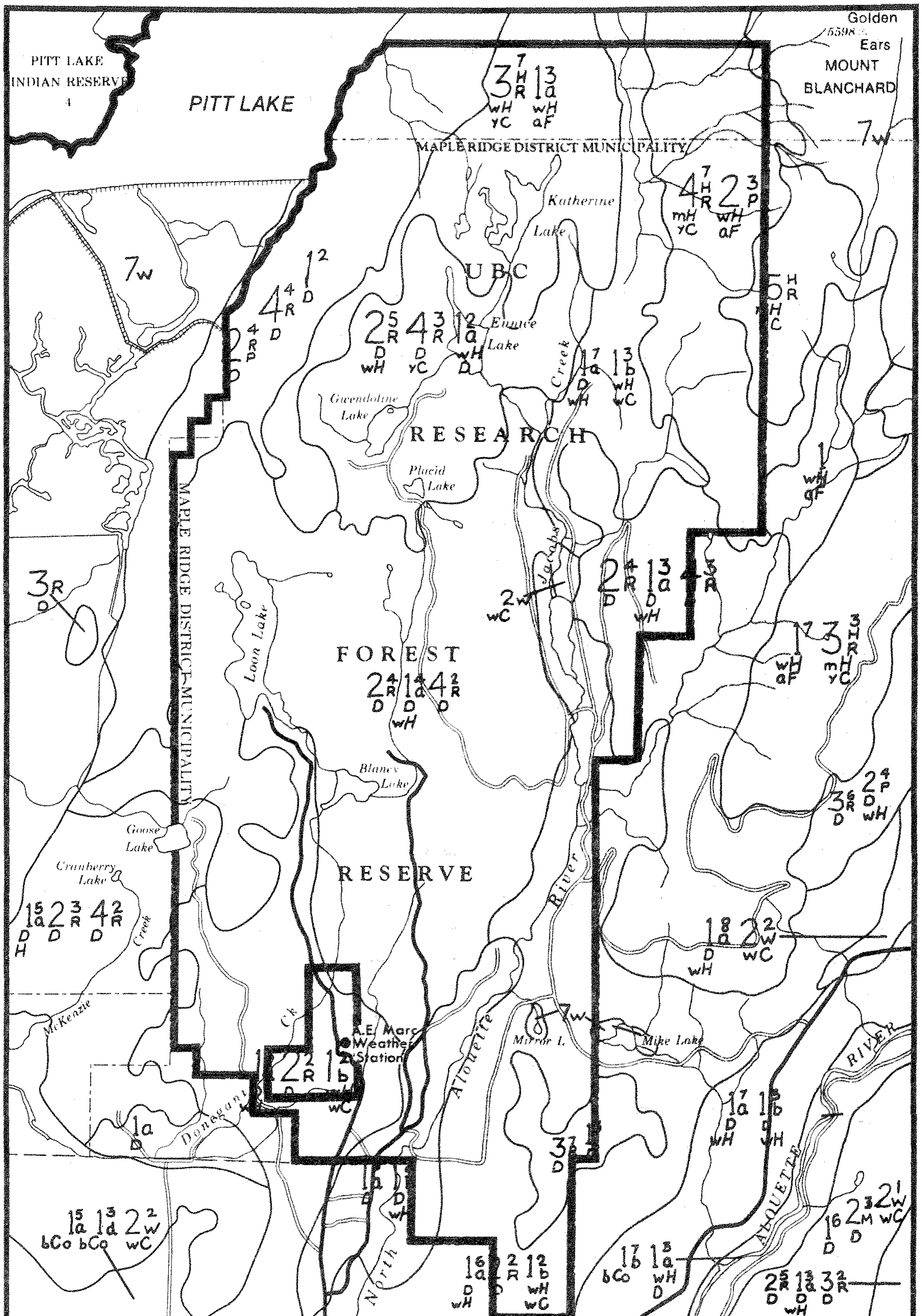


FIG. 12 MANUSCRIPT MAP SHOWING FOREST CAPABILITY MAPPING UNITS

FIGURE 12

LEGEND

Capability Classes

Class	Metric Units m³/ha./yr.	Class	Metric Units m³/ha./yr.
1h	30.1-33.0	1	7.8-9.1
1g	27.1-30.0	2	6.4-7.7
1f	24.1-27.0	3	5.0-6.3
1e	21.1-24.0	4	3.6-4.9
1d	18.1-21.0	5	2.2-3.5
1c	15.1-18.0	6	0.8-2.1
1b	12.1-15.0	7	0.0-0.7
1a	9.2-12.0		

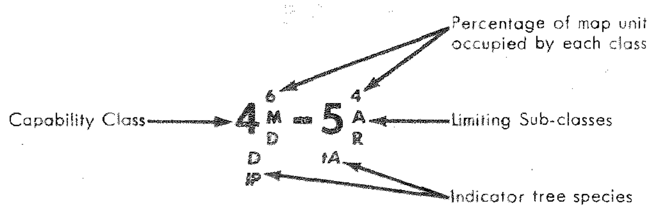
Limiting Sub-classes

A drought or aridity (low precipitation)
C adverse climate—usually high alpine areas
D rooting depth restricted by dense or compacted soil layer
E actively eroding soils
F low fertility
H low air and soil temperatures, short growing season
I periodic inundation (flooding)
L excess lime levels as it affects the uptake of other nutrients
M soil moisture deficiency
N excessive levels of toxic elements
P stoniness
R rooting depth restricted by bedrock
S combination of soil factors
U exposure (wind and atmosphere)
W soil moisture excess

Tree Species Indicators

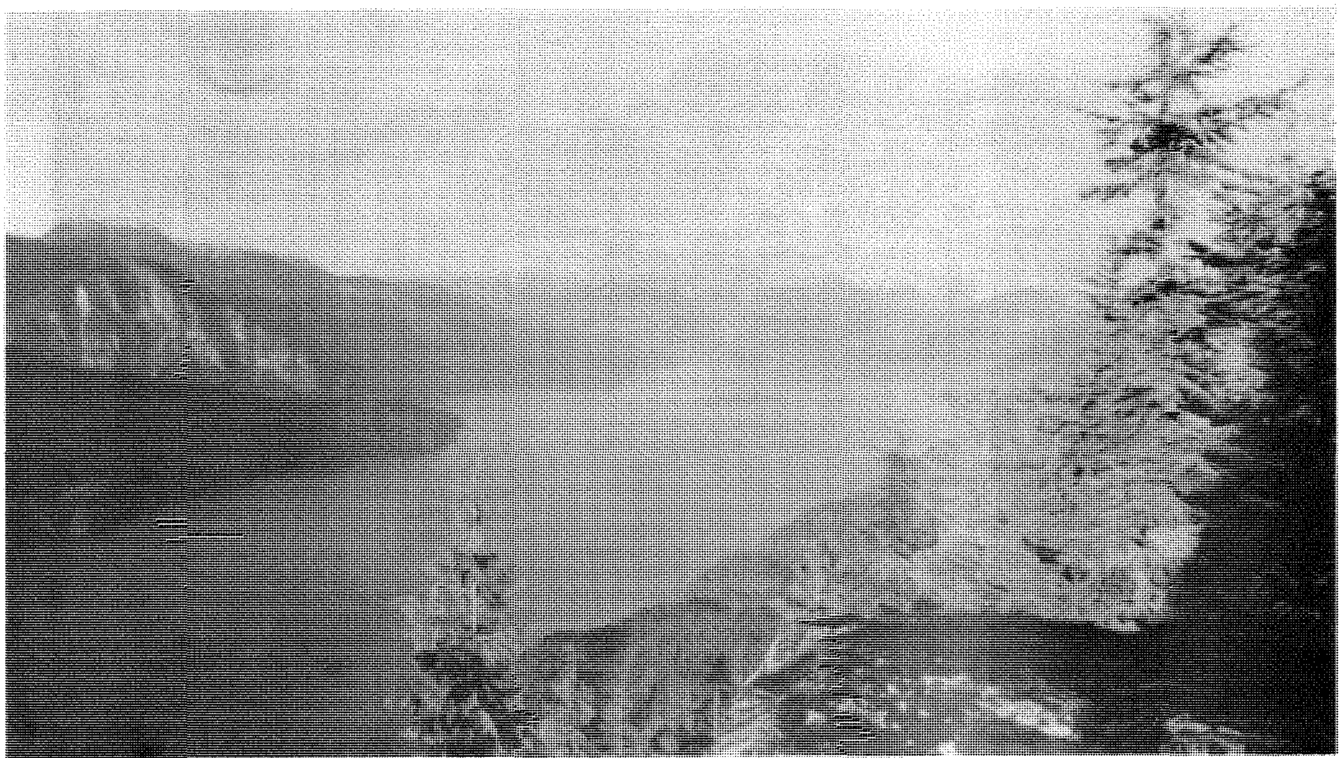
rAl	Red Alder	**gF**	Grand Fir	**SP**	Shore Pine
Ar	Arbutus	**mH**	Mountain Hemlock	**WP**	Western White Pine
tA	Trembling Aspen	**wH**	Western Hemlock	**whP**	White Park Pine
wB	Common Paper Birch	**aL**	Alpine Larch	**bPo**	Balsam Poplar
wC	Western Red Cedar	**wL**	Western Larch	**bS**	Black Spruce
yC	Yellow Cedar	**bM**	Bigleaf Maple	**eS**	Engelmann Spruce
bCo	Black Cottonwood	**gO**	Garry Oak	**sS**	Sitka Spruce
D	Coast Douglas Fir	**lP**	Lodgepole Pine	**wS**	White Spruce
aF	Pacific Silver Fir	**liP**	Limber Pine	**tL**	Tamarack
alF	Alpine Fir	**pP**	Ponderosa Pine		

Example Classification



NOTE: A more detailed 36 page manual entitled Land Capability Classification for Forestry, is available from the Lands Directorate, Lands, Forests and Wildlife Service, Department of the Environment, Ottawa, Ontario, K1A 0H3

SOURCE: Ministry of the Environment
Resource Analysis Branch
Victoria, B.C.

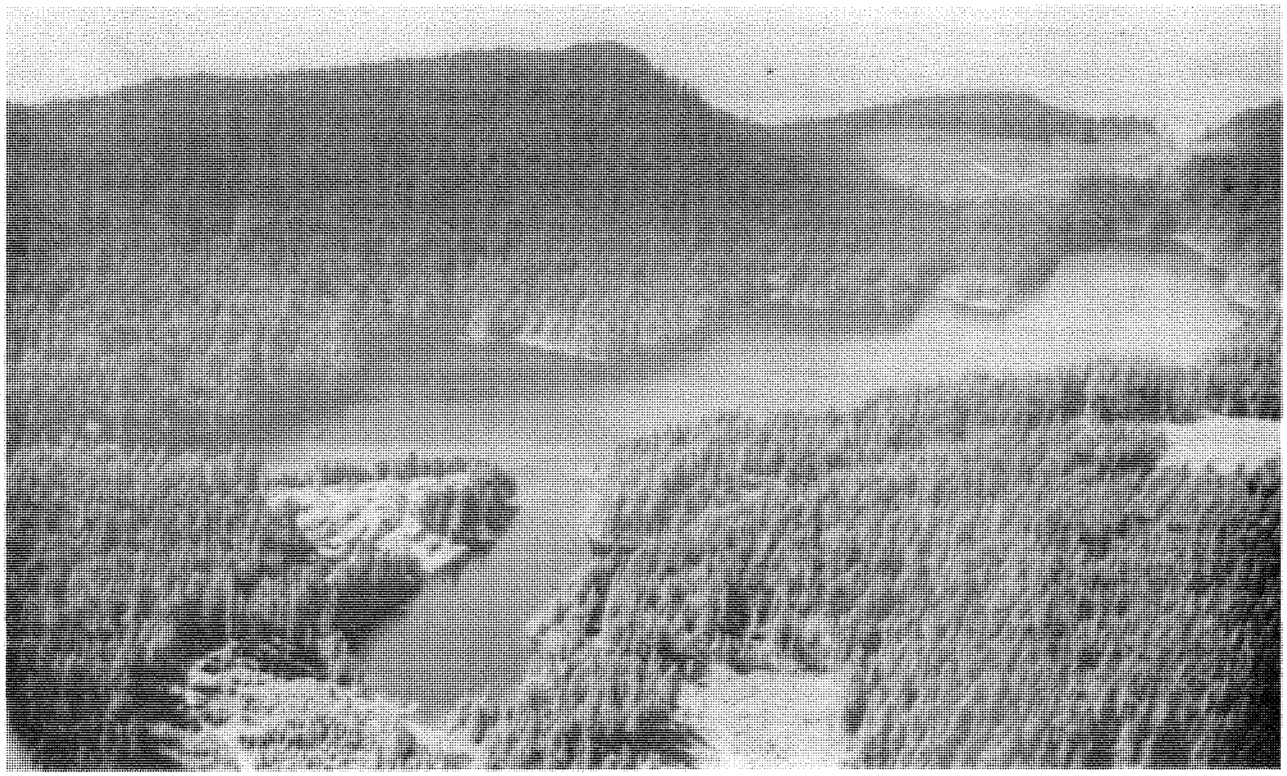


Photograph by J. Walters

FIG. 13 PITT LAKE AND PACIFIC RANGES FROM UNIVERSITY OF BRITISH COLUMBIA RESEARCH FOREST

Photograph by J. Walters

FIG. 14 SWORDFERN SITE, UNIVERSITY OF BRITISH COLUMBIA RESEARCH FOREST



Photograph by J. Walters

FIG. 15 LOON LAKE CAMP, UNIVERSITY OF BRITISH COLUMBIA RESEARCH FOREST

Photograph by D. Moon

FIG. 16 COASTAL FOREST, PACIFIC RANGES

Land Use

Agricultural Capability.

There is no farming on the Research Forest because much of the area is classified as agricultural land capability class 7. Some areas of Class 4 and 5 occur.

Forestry Capability.

The objective of the land capability inventory for forestry is to describe the potential capability of the land under indigenous tree species growing at full stocking and assuming good management. The classification serves to indicate the lands on which intensive management practices might be justified. The capability or production potential is in terms of mean annual increment expressed as m^3/ha. There are seven capability classes (plus an expanded class 1) based on their inherent ability to grow wood fibre. The forest capability classes are based on total tree volumes of all trees 7.75 cm or greater in diameter at breast height. Rotation ages are 100 years for conifers and 50 years for deciduous species. Application of the data can be used for regional planning, preliminary appraisals for designated timber land lease areas, a basis for land assessment purposes, wildlife and recreational land-use planning, and teaching of forest land management.

The very favourable climatic conditions on the Lower Mainland make the area one of the most productive in the province. The moist environment tends to overshadow soil properties affecting productivity, but, soil factors such as depth to bedrock, texture, and soil moisture regime can be used in designating and interpolating capability classes (Fig. 12). Mean annual increments (M.A.I.) range from less than 0.7 to over 14 m^3/ha for Coast Douglas Fir and Western Hemlock.

Tour Itinerary

On entering U.B.C. Research Forest the tour will proceed to

STOP 1 where Mr. J. Walters, Director, will outline the history and operation of the Research Forest. The tour will then go a short distance across the North Alouette River to

STOP 2. SITE 1 where an Orthic Ferro-Humic Podzol profile will be examined and discussed by K. Klinka. A number of detailed studies on soil-plant relationships and energy balance have been conducted on nearby sites (Ballard and Cole, 1975).

Figures 13, 14, 15, 16 illustrate typical vegetation and landscapes in the forest.

Site 1: Orthic Ferro-Humic Podzol

SOIL PROFILE: Orthic Ferro-Humic Podzol developed on stony littoral deposits.

LOCATION: In a forest stand north of the road A 56-2; 1.0 km east of the U.B.C. Research Forest administration building; $49^{o}15'50''$N, 122^{o} $33'40''$W; 180 m a.s.l.

LANDFORM, TOPOGRAPHY, DRAINAGE: The area of the Research Forest was subjected to several glaciations. Site 1 is located in an area of relatively complex surface deposits. South of the site there are clay loam glaciomarine deposits, and west of the site there are stratified loamy sand glaciofluvial deposits, frequently with compacted layers of fine sands. The loose (ablation) till on the site was likely reworked by water action during marine recession (Lacate, 1965) and acquired some characteristics of glaciofluvial deposits.

The site belongs to low to medium altitudinal areas designated as submontane. The general aspect is south. The submontane (southern) part of the Research Forest is flat to gently rolling landscape with a few hilly granitic-cored uplands. Within an area of relatively uniform microclimate (a biogeoclimatic subzone) and parent materials, relief controls soil moisture and nutrient regime. Therefore, similar soils are found to occur repeatedly at similar topographic positions.

CLIMATE: Climatic data for the Research Forest are given in the introductory section on climate and in Table 1.

VEGETATION: Using the system of synecological classification proposed by Krajina and his students (Krajina, 1965 and 1969), the submontane part of the Research Forest belongs to the Coastal Western Hemlock, drier (Douglas Fir-Western Hemlock) biogeoclimatic subzone (CWHa). Western Hemlock, favoured both climatically and to a certain degree also edaphically, is the most frequently occurring species in the forest cover. If undisturbed, it has the greatest potential among all the other tree species to dominate the vegetation composition, therefore, it was designated as the climatic climax species.

Predominance of several moss species (especially *Plagiothecium undulatum, Rhytidiadelphus loreus, Hylocomium splendens* and the scarcity of herbs, and the abundance of Western Hemlock in all strata, are characteristic floristic features of mesic (moderately well drained and medium base-saturated) ecosystems in the CWHa subzone. Accumulation of acid decomposition products on the forest floor, leaching and translocation of materials from the upper to the lower horizons are the prevailing pedogenic processes.

SOILS: The pedon described and sampled at Site 1 is classified as Orthic Ferro-Humic Podzol. The organic surface horizons (L, H-F) are moderately thick accumulations of fresh and partly decomposed, extremely acid forest litter. They overlie a thin light colored Ae horizon. Below the Ae horizon is a reddish brown Bfh1 horizon that is weakly structured, extremely acid and of a loam texture. At a depth of 9 to 52 cm the Bf horizons are yellowish brown, loamy, and weakly structured. Organic matter content increases and weak mottling occurs in the underlying Bhf horizons at depths of 52 to 89 cm. A transitional BCg horizon overlies stone-free, mottled IICg horizons to depths of 171 cm.

Pedological Discussion

Frequently in the environment of the Pacific coastal mesothermal forest (Krajina, 1969), as well as in any macroclimate in which annual total precipitation is higher than the corresponding evapotranspiration, conditions exist for the common occurrence of seepage (hygric) habitats, i.e. habitats in which the soils are temporarily or permanently affected by an underground flow of seepage water. These conditions are: a large amount of precipitation, a glaciated mountainous landscape with long slopes, and the presence of a restricting soil layer. Although the soils may be coarse textured and highly permeable, they can be designated as imperfectly or poorly drained due to influxes of water collected upslope.

It has been suggested, mainly on the basis of indirect evidence, that:

a) Seepage water supplies the soils not only with moisture but also with nutrients, permitting the development of highly productive ecosystems, even though the soils may be of a low base status.

b) Soil chemical analysis, which do not take into account any effect of seepage water, do not reveal any substantial difference between soils affected by seepage and those not affected by seepage. Very often chemical analysis suggests that a soil may be lacking in nutrients, although this may not be the case if the soil has an additional supply through seepage water flow.

Based on studies of Feller (1974) and Klinka (1976) in the U.B.C. Research Forest and research works elsewhere, the following can be concluded:

The flora of seepage habitats include species which require either a large supply of nutrients or water or both. If the seepage habitats provide more nutrients, then their flora can expect to be rich in all macronutrients as well, including nitrogen, and consequently, large quantities of nutrients will be returned to the soils. Results of foliar elemental analysis of lesser vegetation show that characteristic species for seepage habitats have the highest concentrations of the total nitrogen and mineral macronutrients. A great amount of nutrients particularly of Ca, K, and N may be stored in the plant foliage and thus prevented from leaching.

Observations of the thickness of humus layers, humus form, productivity of forest stands, and total concentrations of chemicals in humus layers, suggested that the decomposition rates and the concentrations increased with the increasing amounts of seepage water.

Pedogenic processes in the CWHa subzone attributed to the effects of seepage water can be summarized as follows:

1) Moder or mull humus formation. The presence of seepage water may not only increase chemical concentrations, but may also cause a qualitative improvement in the layers in terms of decreasing thickness and acidity and a narrowing of the C/N ratio.

2) Weak melanization. The occurrence of Ah (or Ahe) horizon and the absence of Ae horizon is characteristic of the soils on seepage habitats. This indicates that eluviation rates are somewhat reduced with an accumulation of bases in the surficial mineral horizon.

3) Weak gleyzation. Most of the soil horizons affected by seepage water flow are not colored or mottled sufficiently to be classified as proper gleyed horizons. Red colors are characteristic of most of the B horizons affected by seepage flow. The fast flowing seepage water with a high pH and dissolved oxygen content passing through coarse textured soils does not produce gray colors because the iron is maintained in the ferric form. Consequently, a typical gleyed horizon is not developed.

4) Enrichment of soils by seepage water. There is a distinct increase in exchangeable cation concentrations and base saturation in the horizon affected by seepage water. In contrast, the comparable horizons on sites not affected by seepage show the opposite trend. This increase may be attributed to loss of cations from seepage water to the soil exchange complex. However, this does not imply that nutrients in seepage water are obtained by plants solely via the soil exchange complex. Several studies suggested that plant roots may obtain nutrient chemicals quite readily from seepage water by a simple mass flow effect (Ballard and Cole, 1975). Nutrient uptake would then require little energy output on the part of the plant. Consequently, a simple, relatively unbranched root system may be adequate for a successful growth on seepage habitats. In this fashion a plant may accumulate large quantities of nutrients even from weak but permanent seepage flow as long as the root cells are not deprived of oxygen.

Additions of dissolved substances by seepage water to the soil tend to retard the expected trend of soil development under the macroclimate of the CHWa subzone. Although all ecosystems in this subzone develop under the same macroclimate, in those influenced by seepage water, moder or mull formation and weak melanization counteract the downward leaching of soluble soil constituents by percolating water. As a result weakly gleyed Sombric Humo-Ferric Podzols or Orthic Ferro-Humic Podzols develop on seepage habitats as compared to Orthic Humo-Ferric Podzols which develop on mesic habitats.

Land Use: Within the above described environmental setting, hygric (imperfectly and partly poorly drained) habitats support development of several highly productive ecosystems. This forest site was classified as a fully stocked, late immature Western Red Cedar - Western Hemlock variation of the *Tiarella (trif.)-Polystichum (mun.) - Thuja (plic.)* biogeocoenose on loamy sand, weakly gleyed Orthic and Sombric Humo-Ferric or Ferro-Humic Podzols with moder humus developed on reworked loose till over compacted (basal) till (Klinka, 1976). A relatively cool and moist microclimate, associated with the dense stocking and local accumulation of organic residues (decayed wood), is reflected in a special pattern of floristic composition and humus properties as compared to mature stands. The coverage of shrubs, herbs and partly moss layers in the immature variation is reduced.

These ecosystems are eminently suitable for wood production. Therefore, they should be managed intensively as commercial forest for wood production. Utilization of their production potential requires a thoughtful tree species selection and intensive application of a suitable silvicultural system. Preservation of values for other uses, which should not predominate, may require integration with the forestry use. Certain precautions are required to keep the ecosystems fully productive, one of them is the preservation of undisturbed subsurface seepage water flow by road lay out and road construction.

Douglas Fir should be the major component in the tree species composition of second growth (site index >50 m at 100 years). Minor variable proportion of Grand Fir and Western Red Cedar as co-dominant trees may be considered to fill the canopy openings as to increase volume yields and to improve the quality of Douglas Fir by self-pruning. These habitats, rich in moisture and nutrients, can support relatively high density stands and provide very high volume yields not attainable in unmanaged, naturally regenerated stands. The primary regeneration method could be moderate-sized clearcutting in order to ensure control and success in regeneration. Cutting sections should not include other ecosystems to facilitate the application of slash burning. Immediate regeneration by planting a well developed stock, to avoid a high hardwood and brush hazard, including primarily Vine Maple, Red Alder, and Salmonberry is desirable. These species may get established in such density that the shade intolerant Coast Douglas Fir cannot succeed, if not planted immediately after logging.

Early control of stocking and regulation of the tree species composition are needed. Crop tending measures may be required more frequently than in other ecosystems. Slash burning is not harmful and should be applied in site preparation for planting.

The tour proceeds northwest into the higher elevation of the Research Forest to

STOP 3. the site of hydrologic studies by soil hydrologists of the Department of Soil Science, University of British Columbia. The following section was contributed by J. de Vries.

a) Hydrology of a forested mountain slope soil.

The soil at this site is a Humo-Ferric Podzol, with a thick forest floor, a permeable B horizon, and compacted till at about 100 cm. The slope is 30%.

Experiments have shown that in response to a rainfall event a large proportion of infiltrated water is conducted through the aerated zone via a network of channels which are left behind by decayed roots. These channels form pathways of low resistance to water flow. Results indicate that their openings are located in the surface of the humified layer of the forest floor.

Piezometer data indicate that upon reaching the compacted till a considerable amount of water is temporarily stored in depressions within the till surface. Thus, the depressions play the role of subsurface storage elements. Upon filling up of these storages water finds its way to the streambank via a low resistance pathway provided by a permeable rootmat that is present on the surface of the compacted till, particularly in areas where the surface is concave.

A time of concentration analysis has indicated that both the shape of the hydrograph and the time lag between the start of the rainfall and start of rise of the hydrograph are dominated by rapid flow through the rootchannels and the rootmat.

A water balance analysis showed that 70% of the rainfall did not appear at the streambank due to leakage of the compacted till. Most of the water released to the stream after the end of the rain came from the saturated zone storage elements. Only a small proportion of the rain was stored in and subsequently released from the saturated zone.

b) Renovation of domestic wastewater by forest soil filtration.

Research entitled "Renovation of domestic wastewater by forest soil filtration" was started in June 1976 at the University of British Columbia research forest. Experiments are carried out on a forested mountain slope serviced by permanent set irrigation equipment. The vegetation is a fifteen year old stand of Western Red Cedar, Coast Douglas Fir and Western Hemlock.

The objective of the research is to determine the relative efficiency of the forest soil for removing nutrients from the wastewater. This efficiency is in part determined by the contact time between the infiltrated water and the soil. Soil hydrology studies have been in progress since 1974. Results indicate that a large proportion of infiltrated water is conducted to the streambank via rootchannels, which form pathways of low resistance to water flow. Movement of wastewater through these channels tends to reduce contact time, and therefore renovation efficiency.

STOP 4 Loon Lake Camp. Lunch

Following lunch the tour will proceed to an area of an active logging operation.

STOP 5 Observation of a study on the ecology of logging and slash burning.

Impact of Clearcutting and Slashburning
On Nutrient Movement Through and Out of a Forested Watershed
(contributed by J.P. Kimmins, Faculty of Forestry, U.B.C.)

Clearcutting and broadcast slashburning has been, and still is at many low elevation locations, the most common method of harvesting and site treatment in old growth forests on the B.C. coast. Concern has been expressed by some foresters, ecologists and environmentalists that these treatments may lead to loss of site productivity through loss of nutrients. Concern has also been expressed that these treatments will result in adverse effects on fish habitat through changes in water temperature and chemistry. This project was undertaken in response to these concerns. It has compared nutrient exports in streamwater before and after clearcutting and slashburning, and contrasted these exports with losses in harvested products and the emissions from the slashfire.

The project was initiated in 1971 when V-notch weirs were installed to monitor the outflow from two small forested watersheds (23 ha and 68 ha) at approximately 300 m elevation at the University of British Columbia Research Forest. The upper 44 ha of the larger area was separated from the lower portion by means of a third weir to act as an untreated control drainage. The lower 22 ha and the second watershed were both clearcut logged in 1973, and the lower portion of the larger watershed was slashburned in late August 1974.

Precipitation and streamwater were monitored weekly for 17 physical and chemical parameters. Streamflow and precipitation were monitored continuously and daily, respectively. A network of 19 soil pits distributed over the watersheds and equipped with throughfall (canopy drip) and surface runoff collectors, and LFH and mineral soil tension lysimeters was used to monitor water chemistry on a monthly basis as it passed vertically down through the forest ecosystem. Groundwater was monitored at three points.

The most notable changes in stream chemistry following clearcutting were immediate increases in dissolved potassium and an increase in dissolved nitrate after a delay of between 3 and 10 months. The most notable changes in soil water chemistry were increases in potassium and nitrate. Slashburning resulted in greater increases in bicarbonate, calcium and pH values in soil solution than did clearcutting. Losses of potassium in streamwater were increased about 10-fold while the net gains of 1-3 kg/ha/yr of nitrogen observed in undisturbed watersheds were converted to net losses of about 3-5 kg/ha/yr dissolved in streamwater. Sulphate, bicarbonate and nitrate anions were all involved in the leaching of cations from soils, although nitrate was probably less important than its concentration in streamwater suggests. Losses of nutrients to streamwater were much less than losses in logged materials and in smoke. Over two years the clearcut watershed lost about 128 kg/ha N, the logged and slashburned watershed lost about 670 kg/ha N, and the control watershed gained about 5 kg/ha N. Losses of other elements were smaller. Since slashburning, streamwater concentrations have tended to restabilize relatively rapidly. The regrowth of vegetation on the watersheds is being monitored and the watersheds will be the subject of a herbicide study in the early 1980s. More details of the results will be presented during the tour.

STOP 6 Observe logging operation (time permitting).

This will be the final stop on the tour before returning to Vancouver for dinner and hotel accommodation.

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APPENDIX A SITE 1

Field description of an Orthic Ferro-Humic Podzol on fluvial materials.

Classification:	Canada - Orthic Ferro-Humic Podzol, coarse loamy, mixed, acid, cold humid family U.S.A. - Typic Cryorthod, coarse loamy, mixed family F.A.O. - Orthic Podzol
Location:	Within U.B.C. Research Forest, Maple Ridge, B.C. in a forest stand north of road A 56-2; $49^{o}15'50''$N, $122^{o}33'40''$W.
Elevation:	180 m a.s.l.
Climate:	ref. U.B.C. Research Forest
Vegetation:	Plant list on site: Trees: *Alnus rubra, Thuja plicata, Tsuga heterophylla.* Shrubs: *Acer circinatum, Rubus parviflorum, Rubus spectabilis, Rubus ursinus, Thuja plicata, Vaccinium alaskaense, Vaccinium parvifolium.* Herbs: *Achlys triphylla, Athyrium filix-femina, Blechnum spicant* (excellent vigor), *Dryopteris austriaca, Polystichum munitum, Pteridium aquilinum, Tiarella trifoliata, Thuja plicata, Trientalis latifolia, Trillium ovatum.* Mosses: *Bazzania ambigua, Dicranum howellii, Isopterygium elegans, Hylocomium splendens, Pogonatam contortum, Plagiothecium undulatum, Rhizomnium glabrescens, Stokesiella oregana.*
Landform:	Hummocky fluvial veneer/silty material, stratified
Parent Material:	Fluvial deposit
Slope:	Midslope, 8%; aspect 225^{o}
Drainage:	Moderately well drained, rapid permeability, very slow runoff, seepage present
Land Use:	Forestry research

Horizon	Depth (cm)	Description
L	5-4	Litter, extremely acid; abrupt, irregular boundary to
H-F	4-0	Black (10YR 2/1 d); extremely acid; abundant, fine roots; abrupt broken boundary to
Ae	0-1	Dark grayish brown (10YR 4/2 m); and brown (7.5YR 5.5/2, d); loamy sand; very weak, fine subangular blocky; abundant, fine roots; nonsticky, loose; weakly cemented; abrupt, broken boundary to
Bhf	1-9	Dark reddish brown (5YR 3/4, m) with very dark gray and reddish brown (5YR 3/1 & 4/4, m) and brown with reddish yellow (7.5YR 5/4 with 6/6, d); loam; very weak, fine, subangular blocky; nonsticky, very friable, nonplastic; weakly cemented; abundant, fine and some coarse roots, inped, horizontally oriented; 5% stones and cobbles; extremely acid; clear, broken boundary to
Bf1	9-17	Reddish brown (5YR 4/4, m) and brownish yellow (10YR 6/5, d); loam; very weak, fine, subangular blocky; nonsticky, very

		friable, plastic; weakly cemented; abundant, fine and some coarse roots, inped, obliquely oriented; 5% stones and cobbles; very strongly acid; diffuse, broken boundary to
Bf2	17-35	Reddish brown (5YR 4/4, m) with some dark reddish brown (5YR 3/4, m) and reddish yellow (7.5YR 6/6, d) with some brown (7.5YR 5/4, d); loam; very weak, fine, subangular blocky; nonsticky, friable, plastic; weakly cemented; abundant, fine and some coarse roots; inped, obliquely oriented; 5% stones and cobbles; very strongly acid; diffuse, broken boundary to
Bf3	35-52	Reddish brown (5YR 4/4, m) and reddish yellow (7.5YR 6/6, d) with some brown (5YR 5/4, d); loam; very weak, fine, subangular blocky; nonsticky, friable, plastic; abundant, fine, and some coarse roots, inped, obliquely oriented; 5% stones and cobbles; very strongly acid; clear, broken boundary to
Bf4	52-67	Yellowish red (5YR 4/6, m) plus some dark reddish brown (5YR 3/4, m) and strong brown (7.5YR 5/5, d) loam; very weak, fine, subangular blocky; nonsticky, friable, plastic; abundant, fine and some coarse roots, inped, obliquely oriented; 5% stones and cobbles; very strongly acid; clear broken boundary to
Bhfgj	67-89	Dark reddish brown (5YR 3/3, m) and light gray (5Y 7/2, d); loam; weak, fine and medium subangular blocky; nonsticky, friable, plastic; abundant, fine and some coarse roots, inped, obliquely oriented; 5% stones and cobbles; very strongly acid; clear, broken boundary to
BCg	89-114	Olive gray (5Y 5/2, m) and light gray (5Y 7/2, d); gravelly sandy loam; yellowish red mottles; moderate to weak, medium subangular blocky breaking to single grain; nonsticky, friable, nonplastic; 60% gravel, a few cobbles and stones; few, mainly fine, inped roots, horizontally oriented; continuous weak cementation; strongly acid; abrupt, smooth boundary to
Cg1	114-134	Olive gray (5Y 5/2 & 4.5/2, m) and light gray (5Y 7/1.5, d); sandy loam; dark red mottles; strong, coarse platy; nonsticky, firm, plastic; weakly cemented; no roots; no stones, strongly acid; gradual, wavy boundary to
Cg2	134-171	Olive gray (5Y 5/2, m) matrix and brown (10YR 4/3, m) and light olive brown (2.5Y 5/4, m) exped; light gray (5Y 7/1, d) matrix and light yellowish brown (2.5Y 6/4, d) exped; loam; strong, coarse platy; dark red mottles; slightly sticky, firm, plastic; weakly cemented; no roots; no stones; strongly acid.

Clay Mineralogy

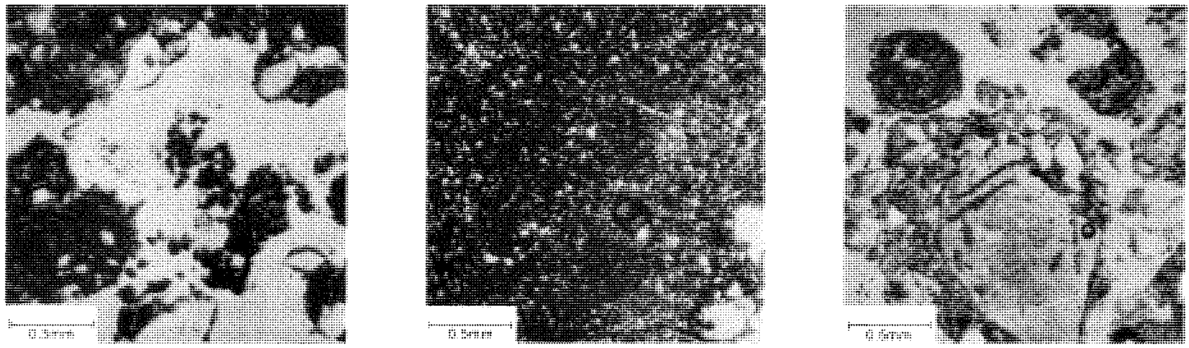
The Cg1 and Cg2 horizons contain very small amounts of amphibole and feldspar. Only the Cg1, Cg2, BCg and Bhfgj horizons contain chlorite which evidently altered to vermiculite in the Bf and Bhf horizons. Quartz is present in small amounts, and x-ray amorphous material is abundant, throughout the profile.

Table 2. Analytical data for the Orthic Ferro-Humic Podzol at site 1
Donneés analytiques du podzol ferro-Humique orthique à site 1

Horizon	Depth Profondeur cm	pH $CaCl_2$	 H_2O	Org. Mat. Mat. org. %	Nitrogen %	C/N	C.E.C. Cap. d'échange cationique me/100g	Base sat. Sat. de bases %	Exch. cat. Cations échang. Ca me/100g	 Mg	 K	 Na
L		4.12	4.35	89.75	1.324	39.32	119.05	50.96	55.73	3.31	1.39	0.24
H-F	4-0	3.33	4.19	78.70	1.814	25.20	125.72	21.03	23.63	2.14	0.47	0.20
Bhf	1-9	4.55	4.77	10.10	0.271	21.62	40.02	2.47	0.83	0.07	0.06	0.03
Bf1	9-17	4.86	5.13	6.57	0.188	20.27	34.33	0.67	0.15	0.02	0.04	0.02
Bf2	17-35	4.90	5.17	6.03	0.167	20.96	31.63	0.79	0.19	0.02	0.04	0.03
Bf3	35-52	4.77	5.15	6.05	0.176	19.94	34.09	0.97	0.25	0.02	0.03	0.03
Bf4	52-67	4.76	5.24	7.88	0.241	18.96	39.04	0.74	0.20	0.03	0.03	0.03
Bhfgj	67-59	4.77	5.04	9.10	0.275	19.20	45.17	0.69	0.20	0.03	0.04	0.04
BCg	89-114	5.15	5.58	2.98	0.081	21.36	19.91	1.26	0.19	0.01	0.02	0.03
Cg1	114-134	5.45	6.18	1.00	0.031	18.71	9.11	4.17	0.30	0.01	0.03	0.04
Cg2	134-171	5.64	6.10	0.43	0.013	19.23	6.74	9.50	0.52	0.02	0.03	0.07

Horizon	Sand Sable 2-0.05mm %	Silt Limon 0.05-0.002 %	Clay Argile <0.002mm %	Fine clay Argile fine <0.2μ %	P Bray 1 ppm	P Bray 2 ppm	Pyrophos Fe %	 Al %	Oxalate Fe %	 Al %	C %
L					55.5	61.1	0.01	0.09	0.06	0.13	52.06
H-F					15.9	43.9	0.13	0.27	0.14	0.32	45.71
Bhf	48.4	30.3	21.3	14.5	6.3	23.0	0.33	1.16	1.01	3.03	5.86
Bf1	49.1	35.8	15.2	9.5	8.3	14.3	0.19	0.77	0.85	1.73	3.81
Bf2	50.1	35.0	14.9	9.4	7.3	14.3	0.20	0.72	0.81	3.41	3.50
Bf3	45.7	36.1	18.2	14.1	14.4	21.0	0.23	0.74	0.78	1.03	3.51
Bf4	51.2	33.5	15.3	11.5	8.4	11.6	0.29	0.98	0.45	3.96	4.57
Bhfgj	46.5	28.4	25.0	20.9	12.4	24.8	0.34	1.03	0.75	4.54	5.28
BCg	63.9	24.1	12.0	8.1	7.3	11.5	0.15	0.50	0.61	1.03	1.73
Cg1	60.1	30.9	8.1	3.7	8.5	25.5	0.03	0.25	0.41	0.92	0.58
Cg2	45.6	46.3	8.2	2.3	22.7	64.8	0.02	0.17	0.67	0.97	0.25

Figure 17. Micromorphology of the Orthic Ferro-Humic Podzol of Soil Site 1 at Haney Forest



a. plane light b. plane light c. partly X

Bhf The highly porous reddish brown fabric (Fig.17a) consists of aggregates of ferruginous clay with black organic fragments and silt and sand grains. There are also larger rock fragments of igneous and metamorphic origin (R). There are matrans round rock fragments, sand grains and large organic matter fragments (C, up to 300μm thick). Ferruginous glaebules with silt-inclusions (up to 3mm, O) also exist.
-1- intertextic
-2- matrigranic to matrigranoidic

Bf2 The horizon has a moderately porous yellowish brown fabric. It consists of aggregates of clay, isotropic ferruginous deposits (C) and skeleton grains of silt, sand (C) and rock fragments (O) (Fig.17b). Organic matter remnants (O-C) occur throughout. Weakly oriented, thin ferriargillans (R) and matrans of variable thickness (C) occur around some rock fragments and sand grains.
-1- intertextic
-2- phyto-matrigranoidic

Cg2 The fabric consists of alternate lenses of silt and sand (Fig.17c). It is moderately porous. The grains are mainly quartz, feldspar, pyroxenes and amphiboles and are quite fresh. Within the silt lenses ferruginous zones and ferri-argillans exist. Plasma is absent.
-1- granular
-2- orthogranic

APPENDIX B Plants* commonly found in the Lower Fraser Valley area

Scientific Name	Common Name
Trees	**Trees**
Abies amabilis	Pacific Silver Fir
Abies grandis	Grand Fir
Acer circinatum	Vine Maple
Acer macrophyllum	Bigleaf Maple
Alnus rubra	Red Alder
Arbutus menziesii	Arbutus (Pacific Madrone)
Betula papyrifera var. *papyrifera*	Common Paper Birch
Betula papyrifera var. *subcordata*	Pacific Paper Birch
Cornus nuttallii	Western Flowering Dogwood
Chamaecyparis nootkatensis	Yellow Cedar
Picea sitchensis	Sitka Spruce
Pinus contorta var. *contorta*	Shore Pine
Pinus monticola	Western White Pine
Populus balsamifera subsp. *trichocarpa*	Black Cottonwood
Populus tremuloides var. *tremuloides*	Trembling Aspen
Populus tremuloides var. *vancouveriana*	Trembling Aspen
Pseudotsuga menziesii var. *menziesii*	Coast Douglas Fir
Taxus brevifolia	Western Yew
Thuja plicata	Western Red Cedar
Tsuga heterophylla	Western Hemlock
Tsuga mertensiana	Mountain Hemlock
Shrubs	**Shrubs**
Arctostaphylos uva-ursi subsp. *adenotricha*	Kinnikinnick
Cornus sericea subsp. *occidentalis*	Western Red Osier Dogwood
Cytisus scoparius	Scotch Broom
Gaultheria shallon	Salal
Holodiscus discolor subsp. *discolor*	Creambush, Oceanspray
Kalmia microphylla	Western Swamp Kalmia
Ledum groenlandicum	Common Labrador Tea
Lonicera involucrata	Twinberry Honeysuckle
Lonicera sp.	Honeysuckle
Mahonia aquifolium	Tall Oregon-Grape
Mahonia nervosa	Dull Oregon-Grape
Myrica gale	Sweet Gale
Oplopanax horridus	Devil's Club
Paxistima myrsinites	Oregon Boxwood
Rosa gymnocarpa	Baldhip Rose
Rosa spp.	Wild Roses
Rubus parviflorus subsp. *parviflorus*	Western Thimbleberry
Rubus spectabilis	Salmonberry
Rubus ursinus subsp. *macropetalus*	Pacific Trailing Blackberry
Salix spp.	Willows
Spiraea douglasii	Hardhack
Symphoricarpos albus var. *laevigatus*	Common Snowberry

* Nomenclature from Vascular Plants of British Columbia. Roy L. Taylor and B. MacBryde, 1977.

Scientific Name	Common Name
Symphoricarpos mollis var. *hesperius*	Trailing Snowberry
Vaccinium alaskaense	Alaskan Blueberry
Vaccinium ovalifolium	Oval-leaved Blueberry
Vaccinium oxycoccos	Bog Cranberry
Vaccinium parvifolium	Red Huckleberry
Vaccinium uliginosum subsp. *occidentale*	Bog Blueberry
Herbs	Herbs
Achillea millefolium var. *millefolium*	Common Yarrow
Achlys triphylla subsp. triphylla	American Vanilla leaf
Antennaria spp.	Pussytoes
Blechnum spicant	Deer Fern
Calamagrostis canadensis	Bluejoint Small Reed Grass
Calypso bulbosa subsp. occidentalis	Fairyslipper
Carex spp.	Sedges
Castilleja spp.	Indian Paintbrushes
Chimaphila umbellata subsp. *occidentalis*	Common Western Pipsissewa
Cornus canadensis	Canadian Bunchberry
Cornus unalaschkensis	Western Cordilleran Bunchberry
Dicentra formosa subsp. *formosa*	Pacific Bleedingheart
Empetrum nigrum subsp. *nigrum*	Black Crowberry
Festuca sp.	Fescue
Fragaria chiloensis subsp. *lucida*	Pacific Coast Strawberry
Fragaria virginiana subsp. *glauca*	Blue-leaved Wild Strawberry
Fragaria virginiana subsp. *platypetala*	Broad-petaled Wild Strawberry
Galium sp.	Bedstraw
Geum macrophyllum var. *macrophyllum*	Large-leaved Avens
Goodyera oblongifolia	Large-leaved Rattlesnake Orchid
Leucanthemum vulgare	Oxeye Daisy
Linnaea borealis	Northern Twinflower
Lupinus nootkatensis	Nootka Lupine
Lupinus spp.	Lupines
Lycopodium annotinum	Stiff Club-Moss
Lysichiton americanum	American Skunk-Cabbage
Osmorhiza chilensis	Mountain Sweetcicely
Polypodium glycyrrhiza	Licorice Fern
Polystichum munitum	Sword Fern
Pteridium aquilinum subsp. *aquilinum* var. *pubescens*	Western Bracken
Pyrola asarifolia	Common Pink Pyrola
Rubus pedatus	Five-leaved Creeping Raspberry
Streptopus roseus var. *curvipes*	Simple-stemmed Twisted Stalk
Tiarella trifoliata	Trifoliate-leaved Foamflower
Trientalis latifolia	Broad-leaved Starflower
Trillium ovatum hibbersonii	Hibberson's Western White Trillium
Trillium ovatum ovatum	Western White Trillium
Mosses	Mosses
Dicranum fuscescens	Crane's-Bill Moss
Dicranum sp.	Crane's-Bill Moss

Scientific Name	Common Name
Hylocomium splendens	
Isothecium stoloniferum	
Leucolepis menziesii	Palm-tree Moss
Mnium insigne	Badge Mnium
Plagiothecium undulatum	
Polytrichum juniperinum	
Rhacomitrium canescens	Grey-frayed Cap Moss
Rhizomnium glabrescens	
Rhytidiadelphus loreus	Little Shaggy Moss
Rhytidiadelphus triquetrus	
Rhytidiopsis robusta	Robust Moss
Sphagnum sp.	Peat Moss
Stokesiella oregana	Oregon Beaked Moss
Lichens	Lichens
Cladonia rangiferina	Reindeer Lichen
Peltigera apthosa	Dog Lichen

APPENDIX C   Format for Micromorphological descriptions

The descriptions of soil micromorphology begin with a brief paragraph sumarrizing the main features of the microfabric in general terms. The relative frequencies, sizes or areal extent of features such as voids and nodules are indicated in brackets following the feature described. The technical name of the fabric in (1) Brewer's (1964) and (2) Brewer's and Pawluk's (1975) terminology is given following the general paragraph. On some occasions only the terminology that is best suited or most descriptive is used.

Illumination In these descriptions the following abbreviations are used to correct the illumination used

plane light - light vibrating in one direction
X polarizers - with crossed polarizers
partly X - with partly crossed polarizers

Magnifications used for descriptions

a) 25x - for colour, and arrangement of large peds and/or aggregates
b) 63X - for arrangement of smaller units and more detailed description
c) 125X - for examination of specific features.

Guide to relative frequencies of pedological features - after Stace et al (1968)

a) cutans frequent (F) >5% of the area
common (C) 5-2%
occasional (O) 2-0.5%
rare (R) rare but easily located and identified
very rare (VR) section must be searched to positively identify them.

b) nodules (F) >20% of the area
(C) 10-20%
(O) 5-10%
(R) 2-5%
(VR) <2%

Description of overall porosity

Using only those voids greater than 25μm in diameter
<5% - very dense
5-10% - dense
10-25% - moderately porous or moderately packed
25-40% - highly porous or loosely packed
<40% - extremely porous or very loosely packed

Note: a horizon that consists of well packed fine sand and silt at low magnification is silasepic porphyroskelic while at higher magnification it is granular. On some occasions, both fabrics will be stated along with the applicable magnification.

Types of banded fabrics - after Dumanski and St. Arnaud (1966)

1. isoband
2. banded fabric type A
3. banded fabric type B
4. banded fabric type C

APPENDIX D: THE CANADIAN SYSTEM OF SOIL CLASSIFICATION

Soils are classified in Canada according to a hierarchical system developed by the Canada Soil Survey Committee. Classes in all of the five categories: order, great group, subgroup, family and series, are based upon observable or measurable soil properties. Diagnostic properties at high categorical levels reflect soil genesis and hence the environmental factors that influence soil genesis. The nine soil orders, arranged alphabetically, are defined in brief, general terms and the great groups are listed.

Brunisolic order.

Soils having genetic horizons but lacking the horizons diagnostic of other orders. They occur dominantly in subhumid to humid forested regions and they usually have brown B horizons. Great groups are: Melanic Brunisol - has a mineral-organic surface horizon (Ah) and is not strongly acid; Eutric Brunisol - lacks a well developed Ah and is not strongly acid; Sombric Brunisol - has an Ah and is strongly acid; Dystric Brunisol - lacks a well-developed Ah and is strongly acid.

Chernozemic order.

Soils of the grasslands; they have a well-developed base-rich, mineral-organic surface horizon (Ah). The four great groups are based upon color of the surface horizon which reflects soil climate: Brown, Dark Brown, Black and Dark Gray.

Cryosolic order.

Soils of the permafrost zone that includes about one third of Canada; they may be composed of either mineral or organic material having permafrost near the surface (1 to 2 m). There are three great groups: Turbic Cryosol - strongly cryoturbated mineral soils as indicated by microrelief or by mixed horizons; Static Cryosol - mineral soils that are not strongly cryoturbated; Organic Cryosol - organic material having permafrost within 1 m.

Gleysolic order.

Soils having drab colors, prominent mottling or other features resulting from periodic or permanent high water table and reduction. They occur commonly in depressions and level areas that either receive runoff water or are groundwater discharge areas. There are three great groups: Humic Gleysol - well-developed mineral-organic surface horizon (Ah); Gleysol - lacks a well-developed Ah; Luvic Gleysol - has a B horizon (Btg) of significant clay accumulation.

Luvisolic order.

Soils, usually in forested regions, in which leaching has resulted in significant translocation of clay from the A to the B horizon (Bt). Usually they have a light gray eluvial horizon (Ae). The great groups are: Gray Brown Luvisol - mild soil climate and forest mull Ah; Gray Luvisol - cold to cool soil climate with usually less than 5 cm Ah.

Organic order.

Soils composed dominantly of organic materials (more than 17% organic carbon) of the required thickness (usually 60 cm for fibric materials and 40 cm for others). Great groups are: Fibrisol - mainly fibres that are not decomposed; Mesisol - more decomposed than Fibrisol; Humisol - highly decomposed, few fibres; Folisol - composed mainly of thick leaf litter over rock.

Podzolic order.

Acid soils developed under forest and heath; they have a B horizon enriched in humified organic matter and Al and Fe weathering products, usually underlying a light gray, weathered Ae horizon. Great groups are: Humic Podzol - B depleted of Fe; Ferro-Humic Podzol - B rich in organic matter combined with Al and Fe; Humo-Ferric Podzol - B contains less organic matter than Ferro-Humic Podzol.

Regosolic order.

Development of genetic horizons is absent or very weakly expressed. Great groups are: Humic Regosol - has a dark, mineral-organic surface horizon (Ah); Regosol - either lacks or has a thin Ah.

Solonetzic order.

Soils associated with saline materials and having prismatic or columnar structured, Na-rich, B horizons that are hard when dry and nearly impermeable when wet. They occur mainly in the grasslands associated with Chernozemic soils. Great groups are: Solonetz - lacks a well-developed eluvial Ae; Solodized-Solonetz - has a well-developed Ae; Solod - has an Ae and an AB in which the structure of the former B has disintegrated.

Subgroups are formed by subdivisions of great groups according to kind and arrangement of horizons indicating conformity to the central concept of the great group, intergrading to other orders, or additional special horizons. Families are differentiated from subgroups on the basis of parent material characteristics, soil climate factors and soil reaction. Series are differentiated from families on the basis of detailed soil features.

Classification Correlation

Canadian	US	FAO
Brunisolic	Inceptisol	Cambisol
Chernozemic	Mollisol	Kastanozem, Chernozem, Rendzina
Cryosolic	Pergelic subgroups	Gelic subgroups
Gleysolic	Aquic suborders	Gleysol, Planosol
Luvisolic	Alfisol	Luvisol
Podzolic	Spodosol	Podzol
Organic	Histosol	Histosol
Solonetzic	Natric great groups	Solonetz

APPENDIX E: METHODS OF ANALYSIS

Soil descriptions - follow the standard conventions outlined in the Canadian System of Soil Classification (Canada Soil Survey Committee, 1977).

Analytical methods - are described in the Manual on Soil Sampling and Methods of Analysis (Canada Soil Survey Committee, 1976).

General procedures are as follows:

pH: saturated paste (H_2O) and neutral salt (0.01 M $CaCl_2$)
Total C: induction furnace method
$CaCO_3$ equiv: calcimeter method
Total N: semi-micro Kjeldahl
Exchangeable cations:
- a. neutral salt - extracting with 2N NaCl
- b. pH 7 - buffered ammonium acetate

Iron and aluminum:
- a. dithionite - citrate - bicarbonate
- b. acid ammonium oxalate (pH 3)
- c. sodium pyrophosphate (0.1M)

Water soluble salts: ions were determined on saturated extracts.
Available nutrients:
- a. N - modified P2 Bray (NH4F-H_2SO_4) extract
- b. P - modified P1 Bray (NH4F-H_2SO_4) extract
- c. K - ammonium acetate (1N)
- d. S - 0.1 M $CaCl_2$

Organic matter: classical $NaOH/Na_4P_2O_7$ extractions
Mineralogy: x-ray diffraction of the <2 μm soil fraction
Fibre content: syringe method for fibres retained on 100 mesh seive
Bulk density: saran-coated clod method, coarse fragments included
Water holding capacity: pressure plate method
Atterberg limits: standard procedure