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THE UNIVERSITY OF ALBERTA

TREE GROWTH PREDICTION AND PLANT COMMUNITY DISTRIBUTION IN RELATION TO ENVIRONMENTAL FACTORS IN LODGEPOLE PINE, WHITE SPRUCE, BLACK SPRUCE AND ASPEN FORESTS OF WESTERN ALBERTA FOOTHILLS.

BY

© IAN GEORGE WILLIAM CORNS

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

IN

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DEPARTMENT SOIL SCIENCE

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FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled "Tree growth prediction and plant community distribution in relation to environmental factors in lodgepole pine, white spruce, black spruce and aspen forests of western Alberta foothills" submitted by IAN GEORGE WILLIAM CORNS in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Forest Soils.

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ABSTRACT

The forests of the Wapiti map area, Alberta (NTS 83L) were studied in order to ascertain relationships between forest growth, plant community distribution and environmental factors within the western boreal and subalpine forest. Quantitative data on tree productivity, vegetation and soils were collected from 137 plots.

The 15 described forest vegetation types of predominantly fire origin were dominated by lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.), white spruce (*Picea glauca* (Moench) Voss) black spruce (*Picea mariana* (Mill.) BSP.) or aspen (*Populus tremuloides* Michx.), were floristically simple (111 vascular plants), had tree productivity ranging from 0.4 $m^3 ha^{-1} yr^{-1}$ in the *Picea mariana* / *Ledum groenlandicum* / *Rubus chamaemorus* type to 5.0 $m^3 ha^{-1} yr^{-1}$ in the *Populus balsamifera* / *Rosa acicularis* / *Thalictrum venulosum* type and occurred on soils representing Luvisolic, Brunisolic, Gleysolic, Regosolic, Podzolic and Organic Orders. Two major successional trends are apparent in the upland boreal forest: lodgepole pine, aspen and balsam poplar to *Picea glauca* / *Rubus pubescens* - *Maianthemum canadense* type on moist sites at low elevations and lodgepole pine and black spruce forests to *Picea* spp. - *Abies lasiocarpa* / *Hylocomium splendens* type on moist to well drained sites at higher elevations. *Pinus contorta* / *Menziesia glabella* / *Rubus pedatus* type succeeds to *Picea engelmannii* - *Abies lasiocarpa* / *Menziesia glabella* type in closed canopy subalpine forests.

Multiple linear regression equations were calculated for 83 lodgepole pine-, 30 white spruce-, 15 black spruce-, and 17 aspen - dominated plots using mean annual total volume increment, stem density, site index, periodic annual total volume increment per tree, age of maximum periodic

annual total volume increment and mean annual basal area increment as dependent variables. Forty-nine independent variables including five external site variables, 21 soil variables, five stand variables, and 18 vegetation variables accounted for large amounts of the variability in the dependent variables: lodgepole pine (44-66%), white spruce (70-94%), black spruce (98-99%) and aspen (94 to 99%). Testing the equations with an independent sample reinforced their validity. When vegetation variables were deleted from the regression, the equations ~~lost much of their predictive capability.~~

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I. INTRODUCTION

In recent years a greater appreciation of forested land as a valuable natural resource has intensified interest in the evaluation of variation in forest site productivity and in inventories of a rapidly changing landscape. Forest site classification originated several decades ago in Scandinavia (Cajander 1926, Ilvessalo 1954) and other parts of Europe. Thorough reviews of forest site classification work have been compiled for the United States by Ralston (1964), Jones (1969) and Carmean (1975). Carmean (1977) reviewed site classification research on northern forest species for the United States and Canada. Daubenmire (1976) comprehensively reviewed the use of vegetation in assessment of the productivity of forest lands. Only in the past 30 years has any intensive forest-site appraisal research been conducted in Canada, particularly in the provinces of Ontario (Hills 1952, 1958; Hills and Pierpoint 1960), Quebec (Heimburger 1941, Linteau 1955, Lafond 1964, Lemieux 1965), the Maritimes (Loucks 1962, Damman 1964) and in British Columbia (Illingworth and Arlidge 1960, Lacate 1965). Excellent reviews of forest site classification studies in Canada have been prepared by Rennie (1963) and Burger (1972).

The relatively recent interest in the Canadian forest resources is related to two factors. The first is Canada's youth in relation to forest resource development. The second is the country's immense area (9,964,000 km^2) of which over 3,222,700 km^2 is forested land (Forest Econ. Res. Inst. 1972). This latter factor has in the past lead to belief that there will always be enough forested land to provide Canada with lumber, pulp, paper and other forest products and benefits. Now there is realization that our forested land must be carefully managed if it is to remain productive.

Forest-site research in the western boreal forest (Alberta, and Mixedwood Section (B18a; Rowe 1972) of Saskatchewan and Manitoba has fallen behind other parts of Canada and the United States due primarily to the fact that only very recently (the last 20 years in Alberta) has any real utilization demand been put upon the western Boreal Forest Region. The growing concern that our forest resources are too rapidly being depleted is prompting here, as elsewhere, the search for means to most effectively utilize our forest resource while still maintaining its productivity.

Some of the earliest work in the western boreal forest was done by Brinkman (1931, 1936) in Alberta. Smithers (1956) assessed site productivity in dense lodgepole pine stands in the Kananaskis Forest Experiment Station, Alberta. Duffy (1964a) used multiple regression techniques to find relationships between site factors and growth of lodgepole pine in the Alberta foothills. Duffy (1965) developed a forest land classification for the Mixed wood section of central Alberta on the basis of differences in soil parent material and soil moisture status as they influence white spruce site index. Jameson (1963) compared tree growth on two sites in the Riding Mountain forest experimental area, Manitoba and in 1965 he related jack pine growth to site in the Mixedwood forest Section (B. 18a) of Saskatchewan. Dumanski et al. (1973) evaluated the productivity of lodgepole pine forests using soil survey maps for the Hinton - Edson area. Lesko and Lindsay (1973) related lodgepole pine and white spruce site index within 15 forest types to soils in the Chip Lake map area in west-central Alberta. Kabzems et al. (1976) described 23 forest ecosystems in the Saskatchewan Mixedwood Section (B. 18a) with respect to vegetation, forest productivity and soils. In addition, several descriptions of vegetation distribution in northern and north-western Alberta have been made by Lewis et al. (1928), Dowding (1929), Raup (1933, 1934, 1946), Moss (1953, 1955), Moss and Pegg (1963), LaRoi (1967) and most recently by Achuff and LaRoi (1977).

In recent years attempts have been made in Biophysical Land Classification (Jurdant et al. 1975) to differentiate and classify ecologically significant segments of the land surface, rapidly, on a small scale (reconnaissance survey), to satisfy the need for an initial overview and inventory of land and associated wildland resources (Lacate 1969). Biophysical inventories have been conducted in Quebec for several years (e.g. Jurdant 1969), and more recently in National Parks (Coen and Holland 1976, Wells et al. 1977).

Biophysical inventories or independent surveys of soils and vegetation in conjunction with aerial photography have been used as the basis for the production of small scale interpretive maps relative to forestry, agriculture, ungulates, waterfowl, sportfish and recreation in the Canada Land Inventory program (McCormack 1968).

Site Evaluation Methods

Site evaluation studies may take several approaches (Rennie 1963, Ralston 1964, Jones 1969, Brickell 1975). A determination of site quality may be made by direct methods (measurement) or by indirect methods (inference).

1. Direct methods

The direct methods of site evaluation usually involve establishing plots within mature forest stands in which plot maps may be prepared showing the species and position of every tree (Rennie 1963). Various mensurational data such as height, diameter and age for all trees of a stand or a representative sample of the population are taken. More precise estimates of increments in growth parameters might involve remeasurement of the same trees at five or ten-year intervals Productivity indices obtainable from these types of measurements may be expressed as total volume per unit area, basal area increment, annual or periodic volume and height increment or site index. Site index or total height at a specified convenient age has been the most widely used growth index in site evaluation.

In recent years refinements in direct forest productivity assessment have been made through the use of aerial photography. Continuing new development (Gimbarzevsky 1975) in false color infra-red remote sensing imagery and the assignment of spectral "signatures" that characterize the light reflectance of individual tree species will no doubt prove even more useful in this regard.

2. Indirect Methods

Indirect methods for estimating site productivity utilize a related attribute as a criterion. Five methods may be recognized: climate, ground vegetation, soil properties, foliar characteristics and site mapping (Rennie 1963). Site mapping tends to be an integration of the former approaches.

Classifications based substantially upon climatic criteria are by necessity of a very small scale, eg.Rowe's (1972) Forest Regions of Canada. Krajina's (1965) Biogeoclimatic Zonation of British Columbia is a similar approach though it gives more detailed climate, vegetation and soils descriptions of the zones than does Rowe's (1972) treatment.

Studies relating forest productivity to vegetation type have had varying degrees of success. Cajander's (1926) work in Finland is a classic example of demonstrated productivity-vegetation relationships. Daubenmire and his students (1942 et seq.) have successfully related forest productivity to habitat type. Canadian examples of studies where vegetation type-productivity relationships have been shown include those of Linteau (1955) in Quebec, Rowe (1956) for the prairie provinces, Illingworth and Arlidge (1960) in British Columbia and Lesko and Lindsay (1973) in Alberta. Duffy (1964b) has comprehensively reviewed concepts in plant sociology with respect to their use in forest site classification.

Ordination approaches to site or to vegetation classification treat the vegetation as a continuum which has developed in response to environmental gradients of climate, soil moisture, nutrients and other site attributes. An ordination technique often helps elucidate the factors responsible for the differences between stand species composition and productivity. Examples of ordination approaches include Maycock and Curtis (1960) and McIntosh (1967).

Site evaluation studies relating soil properties to productivity take one of two approaches (Ralston 1964): interpretation of forest productivity from conventional soil survey data, and derivation of field guides based on empirical correlations of site attributes and tree growth. The latter is analogous to what Jones (1969) refers to as the factorial approach. Forest soils display a whole gamut of characteristics which in general are difficult to measure and call for experimental skills in a number of disciplines (Rennie 1963). Numerous soil characteristics have been correlated with forest growth as noted in the literature. Specific examples are dealt with in the "discussion" section. More conventional criteria studied include pH, available nutrients, moisture regime, texture and soil depth. The quantitative effect of soil factors and their interaction in relation to tree growth (usually expressed as site index) was first tested statistically by Coile (1935) utilizing multiple regression analysis. Most studies of this type since that time have dealt with physical soil properties, though virtually any factor can be included as an independent variable.

Another indirect method of evaluating one aspect of site quality is foliar analysis. It is more useful on nursery stock or young trees, and tends to be a reliable criterion when particular nutrients become acutely deficient, rather than only slightly so (Rennie 1963).

Forest site mapping takes several approaches. The map units may be separated on the basis of a single attribute such as soil texture or more commonly are a synthesis of criteria which reflect differences in the main ecological features of the habitat, i.e. regional climate, topography, geology, soil properties and vegetation cover. The ways in which forest site mapping methods differ are in the interpretation of the environmental factors, the actual quantitative measurements made to specify them and in the emphasis given to different factors (Rennie 1963). The usefulness of a conventional soil survey for site evaluation depends upon whether the taxonomic units defined are sufficiently uniform ecologically, which in turn depends on the degree of coincidence of the classification criteria with the characteristics of greatest relevance to problems of forest management (Rennie 1963). Hills (1952 et seq.) has used a physiographic approach to site, with landform as the basic map unit, with subdivisions according to climate, moisture and nutrients.

The most useful forest productivity maps are likely to be a result of the consideration of as many ecologically significant factors as feasible.

The present study was initiated in 1972 in conjunction with a reconnaissance soil survey of the Wapiti map sheet area (NTS 83L) and had the following objectives: (1) To determine the effect of various vegetation and site factors upon several measures of forest productivity for the major tree species within the study area; (2) To compare the forest productivity of the soil mapping units; (3) To describe and classify the major forest vegetation types of the Wapiti map area in relation to the soils; (4) To describe and determine the successional relationships of the major forest vegetation types of the Wapiti map area.

It is hypothesized that: (1) the various vegetation and site factors are correlated with the forest productivity measures in such a way that they can be used in regression analyses for the purposes of tree growth prediction; (2) the productivity of the soil mapping units differs significantly among the units. In addition it is hypothesized that (3) vegetation types can be classified; (4) major successional trends are discernable.

II THE WAPITI MAP AREA

A. LOCATION

The Wapiti map area (NTS 83L) is located in western Alberta between 118° and 120° W longitude and between 54° and 55° N latitude covering an area of approximately 17,460 km^2 (5740 mi^2 ; Fig. 1). It is bordered to the west by the British Columbia boundary. The town of Grande Cache lies just below the south-western quarter and the city of Grande Prairie is just north of the area. The forestry trunk road closely parallels the eastern boundary.

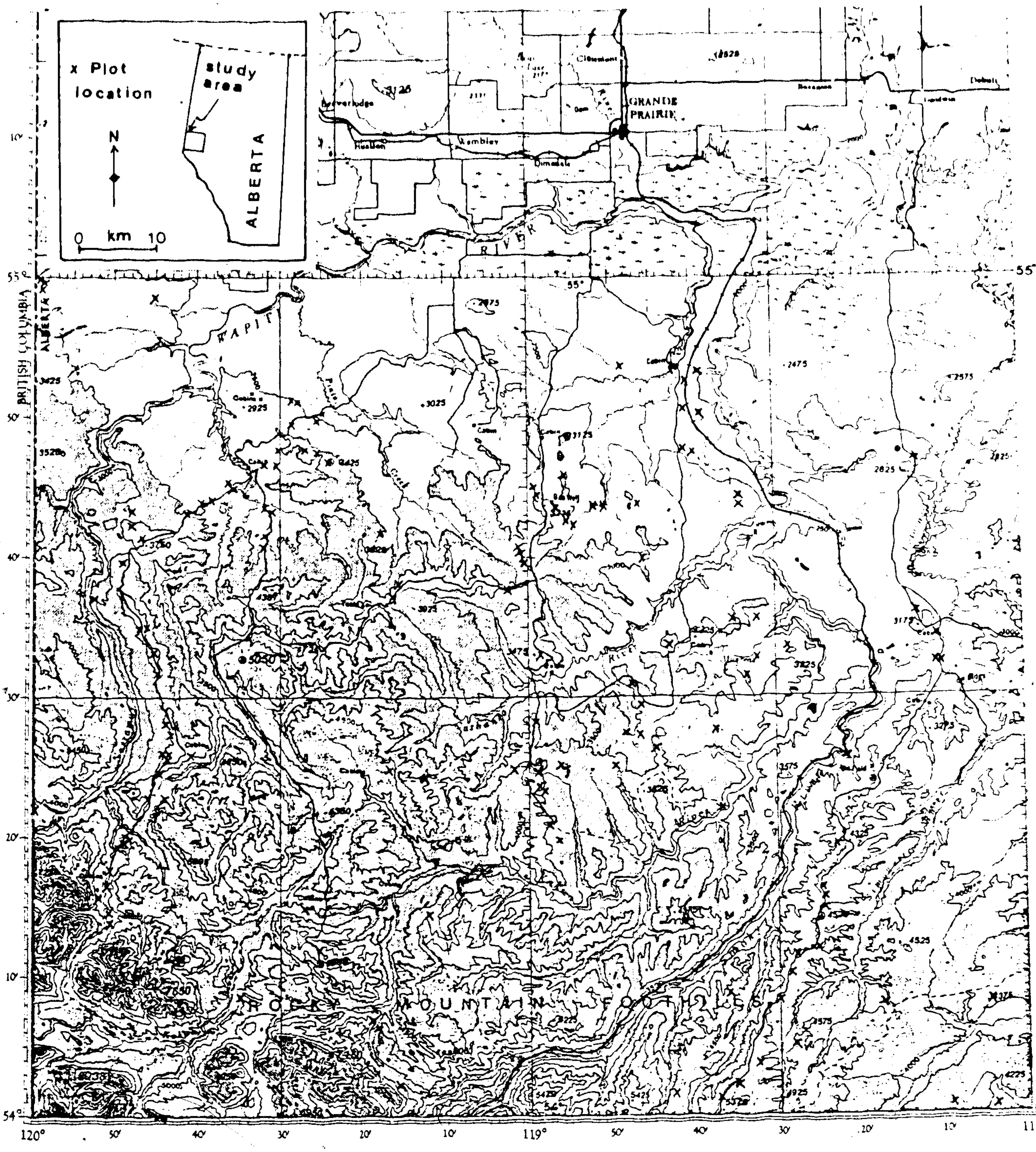
B. SURFICIAL GEOLOGY

Both Cordilleran and Keewatin ice sheets covered parts of 83L. The influence of the Cordilleran ice sheet is restricted to the hills and valleys in an area that includes between one-quarter and one-third of the map area in the south and west (Bayrock 1972). Virtually all of the remainder of the area was covered by the Keewatin (Continental) ice sheet. At least two glacial advances occurred.

Meltwaters flowing by the ice margin deposited thick beds of gravel of Pleistocene age. These gravels were subsequently resorted and redeposited in river valleys, especially those of the Smoky, Kakwa, Cutbank and Simonette rivers. These glaciofluvial deposits are in the form of river terraces of coarse gravel, outwash sand and gravel, the proportions of each varying locally, and ice-contact deposits such as kames and eskers. The latter account for a very small proportion of the Wapiti area.

A large proglacial lake of Pleistocene age formed in the north and

Figure 1: The Wapiti map sheet study area



x Plot location
study area
ALBERTA
N
0 km 10
GRANDE PRAIRIE
RIVER
WAPITI
BRITISH COLUMBIA
ALBERTA
ROCKY MOUNTAIN FOOTHILLS
55°
54°
120°
50'
40'
30'
20'
10'
119°

east of the area and gave rise to the large amount of glaciolacustrine delta sands, bedded silt and clay, and bedded sand and silt. Aeolian sand, derived from glaciolacustrine sand occurs near the glaciolacustrine deposits in sheet and dune form.

A thin deposit of calcareous till derived from the Cordilleran glaciers occurs in a fairly large area of ground moraine on both sides of the Narraway River; very stony (greater than 30%) cirque and valley glacier deposits in the higher foothills; stony till deposits within dissected lateral moraine of large valley glaciers, especially in the lower valley of the Smoky River; and small pockets of thin (less than 50 cm to bedrock), stony (15-30%) pre-Wisconsin Cordilleran till, in which carbonates are leached to a depth of 2m, on the level elevated benches.

Till derived from the Continental glacier includes a few small areas in the north and east of the area of hummocky moraine of clayey to sandy texture with numerous erratics from the Canadian Shield. Most of the Continental till which covers about one-third of 83L is ground moraine of clayey to sandy texture, contains numerous erratics of Canadian Shield origin, and is of gentle relief. A fairly large area of thin, very stony ground moraine of reworked Tertiary gravel on level topography is present on the high plateaus in the southeast corner of the Wapiti area. Large areas of this ground moraine of continental origin but lacking erratics from the Canadian Shield, are present to the west of the majority of the Continental till. This thin till is made almost entirely of local bedrock.

A few small areas of shale, sandstone, siltstone, coal and conglomerate outcrops are present in the high relief areas in the southwest corner of the map area. Shale and sandstone are the predominant bedrock types and in general it is these materials that give the topographic relief to the landscape to a much greater extent than the surficial deposits.

C. BEDROCK GEOLOGY

Information on bedrock geology in the Wapiti map sheet area is scarce. A report by Allan and Carr (1946) describes geology and coal occurrences of the Wapiti-Cutbank area. The following general account (1: 1,584,000 map) for Alberta is given by Jackson (1975). The Wapiti map area lies within two major physiographic regions; the Interior Plains and the Western Cordillera. The Rocky Mountain Foothills section of the Western Cordillera is represented in the southwest corner. It is characterized by shales, conglomerates, coal, chert and sandstone of Triassic to Lower Cretaceous age and Upper Cretaceous shales, concretionary shales and sandstones.

The Interior plains region is east of the Rocky Mountain Foothills and is represented to the south and west of the Wapiti map area by the Western Alberta Plains section. This section is characterized by Upper Cretaceous shale and Tertiary shales, siltstones and sandstones. The Interior Plains Region to the north of the Wapiti map area is represented by the Wapiti Plain which is characterized by light grey, Continental and deltaic siltstones and shales of Upper Cretaceous age.

D. SOILS

Representatives of the Luvisolic, Brunisolic, Gleysolic, Regosolic, Podzolic and Organic Orders occur within the Wapiti map area. The soils were separated on the basis of differences in parent material into 28 "soil groups" (Twardy 1978). These "soil groups" that form the basis for the soils map, were further separated into 66 "soil units" distinguished on the basis of internal drainage, soil subgroup classification and the proportion of other non-mappable inclusions within the units. The ten most important soil groups with their associated parent materials in parentheses, listed in order of decreasing area are: (1) Edson (Continental till less than 975 m ASL) (2) Donnelly (lacustro-till), (3) Mayberne (Continental till greater than 975 m ASL) (4) Copton (coarse residual), (5) Torrens (fine residual), (6) Marlboro (medium textured Cordilleran till), (7) Robb (moderately coarse to medium textured thin Cordilleran till and colluvium), (8) Lodge (thin glaciofluvial deposits or aeolian over lacustrine or till), (9) Blackmud (sandy alluvium), and (10) Heart (aeolian).

More detailed descriptions of the soils of the Wapiti map area and their extent are discussed by Twardy (1978).

E. STREAM CHARACTERISTICS

The main streams of the Wapiti map area are the Smoky, Wapiti, and Simonette Rivers that drain toward the north. The Wapiti and the Simonette join the Smoky east of Grande Prairie and the Smoky joins the Peace River near Peace River Townsite. Important tributaries of the Smoky are the Kakwa and Cutbank Rivers which lie almost wholly within the study area. The Narraway River is a major tributary of the Wapiti and has its origin just to the west of the study area. The Latornell River, a major tributary of the Simonette lies wholly within the area.

With the exception of the larger rivers, most of the tributaries flow in steep-sided, narrow valleys and are still down-cutting, indicated by the absence of floodplains. The Smoky and Wapiti Rivers have developed flood plains at their northerly extent. Several other tributaries in the region have developed narrow floodplains but very little deposition has occurred elsewhere. Surface water and groundwater is abundant in the

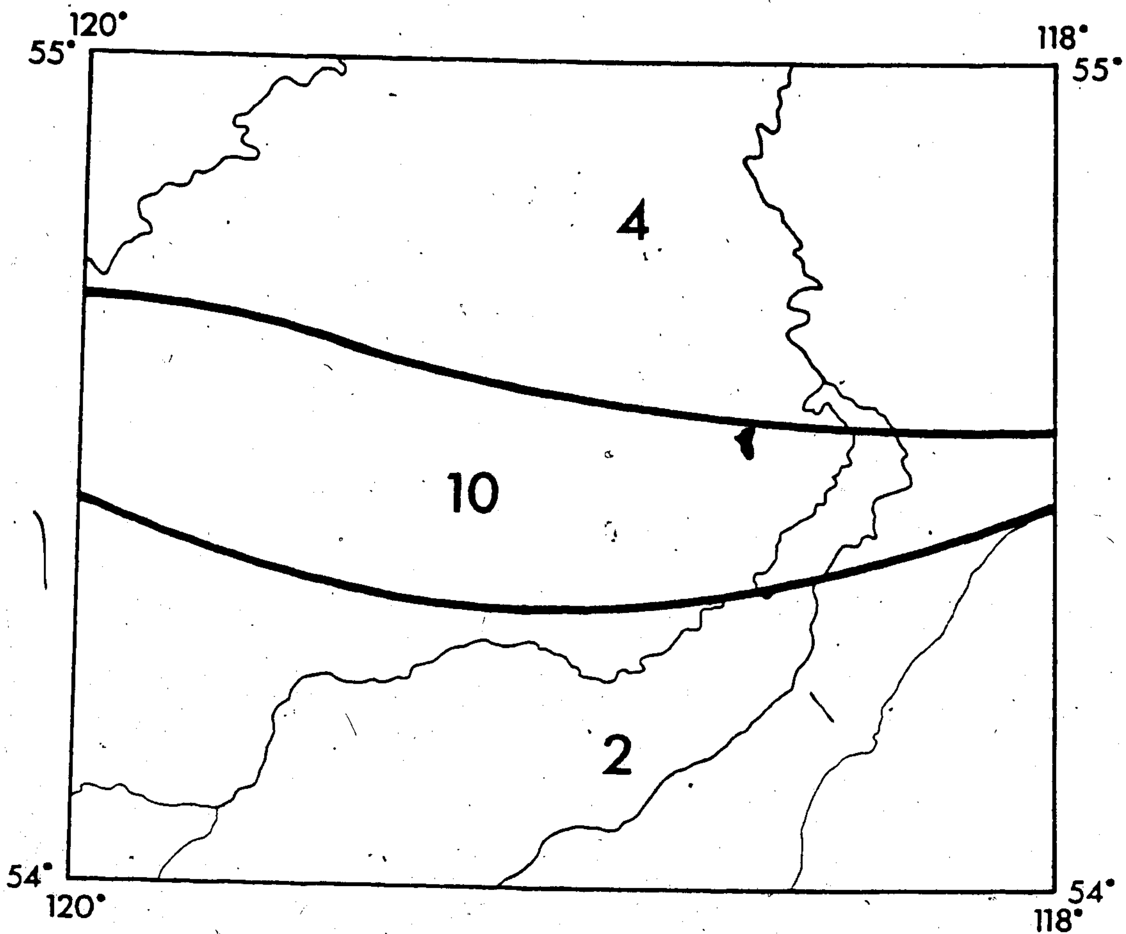
Wapiti area as shown by the innumerable perennial streams. The stream pattern is dendritic. Floods are common during the mountain snowpack melt and flood-related damage can be extensive in terms of washed-out roads, bridges and railroads, and severe soil erosion on exposed slopes. The heavy rainfall of June 1972, coinciding with peak snowmelt from the Rocky Mountains provided many examples of such damage. The higher elevations of the Wapiti map area to the south and west yield most of the water with less fluctuation than the lower areas as indicated by the greater stream density in the south and west.

Sediment loads in the streams during early summer are large and indicate excessive erosional losses on the watersheds. Unfortunately, few quantitative data are available, but most of the larger rivers remain clouded by suspended sediment until at least mid-August.

F. CLIMATE

The climate of the Wapiti map area is characterized by cool to warm summers and cold winters. The area lies within three summer climatic zones (MacIver et al. 1972; Fig. 2). The northern third of 83L (Fig. 2) is characterized for the period including the growing season between May 1 and September 30 by a mean air temperature of 10-11^{O}C, an average precipitation of 30-41 cm, a potential evapotranspiration of 43-46 cm and a frost-free period (greater than 0^{O} C) of 100-120 days (zone 4, MacIver et al. 1972). A belt running from west to east through the Wapiti sheet and representing approximately one-fourth of the area is characterized for the May 1 to September 30 period by a mean air temperature of 10-11^{O}C, precipitation of 36-46 cm, a potential evapotranspiration of 41-43 cm (i.e. a net water surplus), and a frost-free period of 100 to 120 days

Figure 2: Climatological zonation of the Wapiti map area



SMOOTHED STATISTICAL CLIMATIC ZONES (redrawn from MacIver et al. 1972)

Selected Seasonal Normals (1 May - 30 September)

1954 - 1968

Group Number	Temperature (°C) Mean	Maximum	Minimum	Precipitation cm	Degree - Days (°C) >-2	0	6
2	10-11	14-17	4-6	41-46	32-36	24-28	10-14
4	11-12	17-19	4-7	30-41	30-40	32-34	16-20
10	10-11	16-17	6-7	36-46	30-38	26-32	12-18

	Potential Evapotranspiration cm	Day Length Hours	Frost-Free Period Days	Killing Frost Free Period Days (>-2°C)
2	38-43	15.1-15.4	80-100	100-140
4	43-46	15.3-15.4	100-120	140-160
10	41-43	15.2-15.4	100-120	140-160

(zone 10, MacIver et al. 1972). Approximately the bottom one-third of the Wapiti map area has for the same months, a mean air temperature of 10-11°C, precipitation of 41-46 cm, a potential evapotranspiration of 38-43 cm and a frost-free period of 80-100 days (zone 2, MacIver et al. 1972). It thus becomes apparent that as elevation increases from the NE to the SW, precipitation increases and potential evapotranspiration and air temperature decrease (Fig. 2). We thus might expect the most favorable climates for tree growth to be in the northeast where temperatures are warmer and precipitation is adequate.

The nearest, full-time weather station is at Grande Prairie to the north (55° 11' lat. 118° 53' long.). Year-round temperature records are made at only one location in the Wapiti map area, The South Wapiti ranger station in the north of 83L. The year-round temperature records at the Muskeg ranger station below the southeast corner of the area are probably representative of much of the southern portion. Weather records from May to September inclusive are available for eight forestry fire towers within the Wapiti area. The extrapolations made by MacIver et al. (1972) were from these data.

Winters in the Wapiti map area are cold, with January (the coldest month) mean air temperatures (mean of daily maximum and minimum) of -17.3° C at Grande Prairie airport, -16.0° C at Muskeg and -15.4° C at South Wapiti. Mean monthly air temperatures are below freezing between November and March inclusive (Environment Canada 1975). Winter precipitation data are available only from the Grande Prairie station. Total precipitation for the November to March period is 18.5 cm (mostly snow) of which 3.4 cm fell in January and 3.1 cm each for November and December (Environment Canada 1975). The November to March precipitation total represents 42% of the total annual precipitation at Grande Prairie. In the predominantly higher elevations of the study area south of Grande Prairie, winter temperatures would probably be slightly lower and precipitation slightly higher, depending upon location.

III METHODS

A. FIELD SAMPLING

1. Plot Selection

From an examination of Alberta Forest Service (1: 126,720) forest cover maps and aerial photographs supplied by government (Alberta Forest Service) and industry (Proctor and Gamble Cellulose Ltd.), plot areas were chosen to encompass a wide variety of vegetation, soil and landform types, within uniform, even-aged and normally-stocked stands ranging from 45 to over 200 year old. Sampling was concentrated within 70-100 year old stands of the various forest types. Most plots were readily accessible by road, though four-wheel drive and the Cramer "swamp buggy" were used to get to less accessible areas via seismic lines and rough trails. Sampling was done primarily within the Upper Foothills (B. 19c) and Lower Foothills (B. 19a) Sections of the Boreal Forest Region (Rowe 1972) and to a lesser extent in the East Slope Rockies Section (SA. 1) of the Subalpine Forest Region. Treeless and alpine areas of 83L were sampled with much less intensity than the remainder of the area, and ground work was largely of a descriptive nature. **Sampled plots totaled 137.**

2. Plot Sampling

2.1 Soils

In each plot a soil pit was dug in a position with a soil profile representative of the plot area. The soil profile was examined and described noting structure, texture, color, thickness of horizons, pH (Lamotte-Morgan field kit) as well as plant rooting characteristics and internal drainage according to CSSC (1970). Prevalent slope gradient and aspect were also recorded.

2.2 Vegetation

Within the circular (0.405 ha) plots, the diameters and heights of all trees over 1.3 cm diameter at breast height (1.5m) were tallied by species. When the tree tally was completed, five to seven healthy dominant and co-dominant trees were selected and felled, measured for height, and sections removed at 0.3m, 1.5m, and 1.8 or 3.7m intervals thereafter for stem analysis. In uneven-aged stands (dominant trees differed by more than 20 years) additional discs or increment cores were taken from the largest trees in the plot for determination of maximum stand age and evidence of stand history (fire, climate, disease, anomalies in growth patterns, etc.). Tree canopy cover was visually estimated at 12 random points in the center of the quadrats used for the subsidiary vegetation.

Subsidiary vegetation includes plants other than trees greater than 1.3 cm DBH, and was sampled by height strata. Estimates of per cent cover by species, using a modified Braun-Blanquet scale (Appendix 1), were made in 12 randomly placed 1x1m quadrats for terrestrial bryophytes, herbs and dwarf shrub species (up to 0.5 m tall). Shrub cover (over 0.5 m tall) estimates were made by species within 5x5m quadrats centered around the 1x1m quadrats. Tree regeneration density was tallied by species and height class within the 5x5m quadrats for individuals less than 1.5m tall.

A species list for the plot area as a whole was compiled. Unidentified specimens were collected for determination in the laboratory. The predominant height, vitality and phenology were noted for each species on the list. Additional notes were made of predominant plot aspect, slope relief, deadfall cover, evidence of disease, animal activity, fire history and of any features that would make the area particularly attractive for recreational or natural area uses.

B. DATA ANALYSIS

1. Stem Analysis

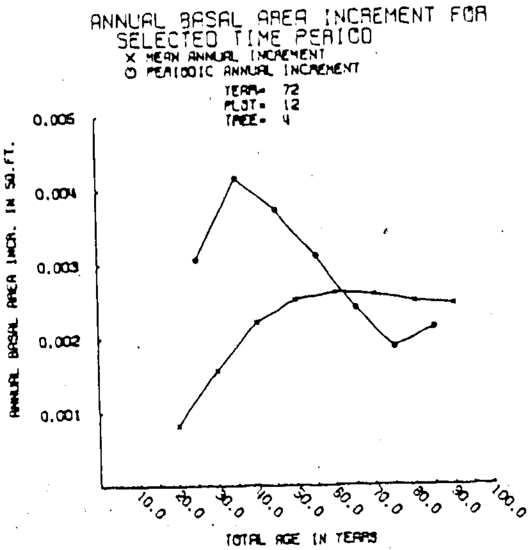
Stem growth data were computed using the stem analysis program of Pluth and Cameron (1971). Growth measurements were made at 10-year increments (20 years for very suppressed trees) from the outside of the stem toward the center on the maximum diameter and at 90° to the maximum. The program took the mean diameter as a basis for computation. A tree age adjustment was made to account for a one-foot stump height, using 10 years for the three *Picea* species, five for lodgepole pine and one year or no correction for aspen. Stem section volumes were calculated as right circular cylinders except for the uppermost section or terminus which was always calculated as a right circular cone. Computations for the height-diameter and height-age curves are derived from procedures outlined for stem analysis by Avery (1967). The program calculates periodic annual increments for the ten-or 20-year time periods from the most recent period backwards in time. Basal areas are calculated as the cross-sectional areas at 1.5m from diameters measured inside bark. Using a CalComp plotter, the program plotted curves of height-diameter, height-age, volume incrementage and basal area increment versus age for each tree (Fig. 3).

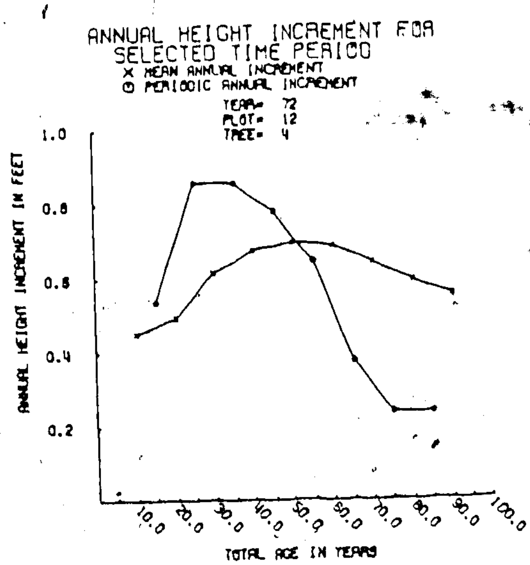
Means and standard error of the mean were calculated for the following statistics taken from the individual tree stem analysis data for each species sampled in each plot: (1) site index (at 70 years) (2) total volume per tree (3) periodic volume increment (70 to 80 years) (4) maximum periodic volume increment and (5) age of maximum periodic volume increment. For sample trees with ages less than 80 years, linear extrapolations were made for site index and periodic volume increment from the previous height and volume growth increments.

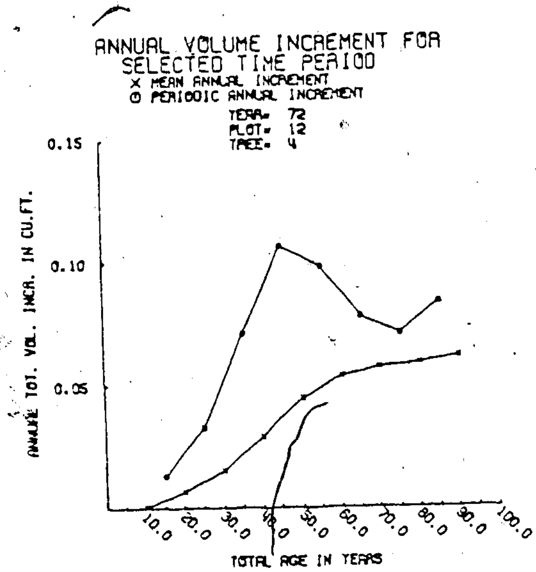
2. Plot tally

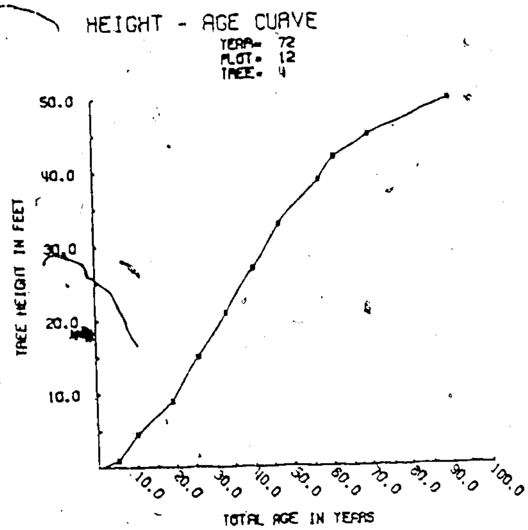
A simple computer program facilitated computation of forest stand statistics

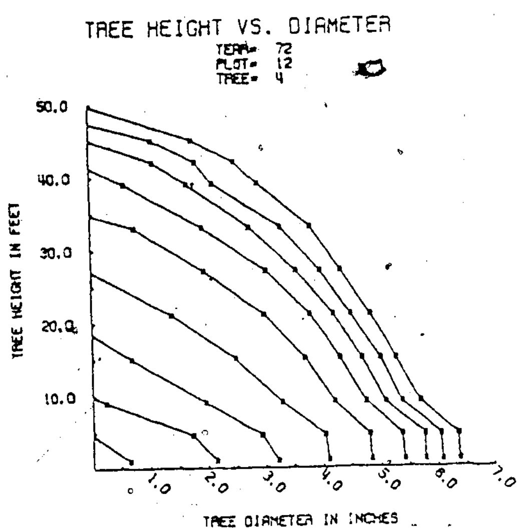
Figure 3: Calcomp plots of stem analysis data for one tree showing mean annual basal area increment vs. age, annual height increment vs. age, mean annual total volume increment vs. age, height vs. age and height vs. diameter relationships.


ANNUAL BASAL AREA INCREMENT FOR
SELECTED TIME PERIOD
X MEAN ANNUAL INCREMENT
⊙ PERIODIC ANNUAL INCREMENT
YEAR= 72
PLOT= 12
TREE= 4
ANNUAL BASAL AREA INCR. IN SQ.FT.
0.005
0.004
0.003
0.002
0.001
10.0 20.0 30.0 40.0 50.0 60.0 70.0 80.0 90.0 100.0
TOTAL AGE IN YEARS


ANNUAL HEIGHT INCREMENT FOR
SELECTED TIME PERIOD
X MEAN ANNUAL INCREMENT
⊙ PERIODIC ANNUAL INCREMENT
YEAR= 72
PLOT= 12
TREE= 4
ANNUAL HEIGHT INCREMENT IN FEET
1.0
0.8
0.6
0.4
0.2
10.0 20.0 30.0 40.0 50.0 60.0 70.0 80.0 90.0 100.0
TOTAL AGE IN YEARS


ANNUAL VOLUME INCREMENT FOR
SELECTED TIME PERIOD
X MEAN ANNUAL INCREMENT
⊙ PERIODIC ANNUAL INCREMENT
YEAR= 72
PLOT= 12
TREE= 4
ANNUAL TOT. VOL. INCR. IN CU.FT.
0.15
0.10
0.05
10.0 20.0 30.0 40.0 50.0 60.0 70.0 80.0 90.0 100.0
TOTAL AGE IN YEARS


HEIGHT - AGE CURVE
YEAR= 72
PLOT= 12
TREE= 4
TREE HEIGHT IN FEET
50.0
40.0
30.0
20.0
10.0
10.0 20.0 30.0 40.0 50.0 60.0 70.0 80.0 90.0 100.0
TOTAL AGE IN YEARS


TREE HEIGHT VS. DIAMETER
YEAR= 72
PLOT= 12
TREE= 4
TREE HEIGHT IN FEET
50.0
40.0
30.0
20.0
10.0
1.0 2.0 3.0 4.0 5.0 6.0 7.0
TREE DIAMETER IN INCHES

from the plot tally data. Gross volume of trees greater than 1.3 cm DBH was computed for each species separately and then summed. Merchantable volume of trees with a minimum 7.6 cm diameter top was computed for each species separately and then summed. Gross mean annual total volume increment (MAI) was determined by dividing the total gross volume by the average age of the dominant trees sampled. This tends to give conservative MAI values in uneven-aged stands because the volumes of the smaller, younger trees are divided by the same age as the larger and older dominants and co-dominants. The coefficients used for the volume computations are those determined by the Canadian Forestry Service and used by Alberta Forest Service. Basal area at 1.5 m was computed by species then summed. Tree density (stems/ha) was determined. The program tallied the density of dominant, co-dominant, overtopped and suppressed trees when this information was recorded with the tree height and diameter.

3. Vegetation-Environment Relationships

A two-dimensional ordination was constructed using the method of Beals (1960) and an index of vegetational similarity (Bray and Curtis 1957): I=2W/a+b, where a= sum of quantitative values of all species in stand A, b= the same for stand B, and W= sum of quantitative values the two stands have in common. Prominence value (Beals 1960) data for all vascular species were used in calculating disimilarity indices (I-1), where PV= mean cover % X quadrat frequency %.

A vegetation synthesis table was constructed with the plot numbers arranged horizontally and the species listed vertically in order of decreasing constancy (no. of stands in which species occurred) from top to bottom. Plots were arrayed according to floristic similarity using the

Braun-Blanquet method (Mueller-Dombois and Ellenberg 1974 p. 177). Similarity of soils and other environmental factors were also considered in making the stand groupings (vegetation types).

4. Stepwise Multiple Regression

A stepwise multiple linear regression of the abbreviated Doolittle method (Steele and Torrie 1960 p. 289) was computed to relate several measures of forest productivity to soil, site and vegetation data taken from the stem analysis plots. By definition, a regression equation supplies estimates of population means. In practice it may also be used to predict events (Steele and Torrie 1960). The multiple regression equation is expressed in the form $Y = a+b_1x_1+b_2x_2+...b_nx_n$ where Y is the predicted value of the dependent variable; a is the intercept of the regression line on the vertical axis; b_1, b_2....b_n are the partial regression coefficients of Y on X; X_1, X_2, ...X_n are the observed values of the independent variables. The program enabled one to select the dependent and forced independent variables and to specify which variables are to be omitted from the regression. Prior to running the regression the various independent variables were plotted against the dependent variables using a computerized bivariate plotting program. Where nonlinear relationships between one of the independent variables and a dependent variable were apparent, the appropriate transformation, linear or nonlinear was applied to the independent variable to best approximate a linear relationship between the dependent and independent variables after the transformation. The sequence addition of the independent variables in the regression is dependent upon how much the independent variable contributes to the R^2 value; the greater the contribution, the greater the importance that variable has in accounting for the variation within the data supplied for the dependent variable R^2 (the proportion of the variation in the dependent variable that is accounted for by the regression). The regression equations presented for lodgepole pine-, white spruce-, black spruce-, and aspen-dominated (according to basal area), plots give the dependent variable as a function of the nine independent variables accounting for the greatest proportion of the R^2 value.

The level of significance of the regression was determined from the F ratio calculated by the program.

5. Duncan's Multiple Range Tests

Initially, soil associations, vegetation type productivity (MAI and SI), elevation (nearest 150 m), slope class, soil subgroup and slope aspect were cross-stratified against mean annual increment (rotation age) and density. Because of the relatively small sample (137 plots), and because some tree species are not found on certain soil associations, it was not possible to evaluate productivity for all classes listed above using Duncan's New Multiple Range test (Duncan 1955). The growth prediction equations thus serve as a better means of evaluation in these cases. The stratification using Duncan's tests to compare mean annual increment by vegetation type proved more satisfactory.

IV RESULTS AND DISCUSSION

A. VEGETATION ZONATION

The forest vegetation of the Wapiti map area lies within two Forest Regions and four Forest Sections (Rowe 1972). Most of the area lies within the Mixedwood (B 18a), Lower Foothills (B 19a) and Upper Foothills (B 19c) Sections of the Boreal Forest Region. The remainder of the forest vegetation lies within the East Slope Rockies (SA1) section of the Subalpine Forest Region. A small portion of the area is alpine tundra.

Rowe's (1972) forest regions are mapped on a very small scale (1: 6,336,000) and are delineated primarily by the distribution of the major tree species. The descriptions provided for the forest regions, especially the elevation criterion, have enabled an estimation of the extent of the component forest sections within the Wapiti map area.

1. Mixedwood (B. 18a)

The Mixedwood Section of the Boreal Forest Region accounts for approximately 34% (5100 km^2) of the Wapiti map area, primarily in the North at elevations less than 900 m and upon predominantly glaciolacustrine parent materials. The characteristic forest vegetation of the well drained uplands is a mixture of aspen and balsam poplar, white birch, white spruce and balsam fir, the last two species most common in old stands (Rowe 1972). The mixedwood in the Wapiti map area is broken up by lodgepole pine stand outliers of the Lower Foothills Section (B. 19a), though aspen-dominated forest is most prevalent.

2. Lower Foothills (B. 19a)

The Lower Foothills Section of the Boreal Forest Region accounts for approximately 38% (5700 m^2) of the Wapiti map area primarily in a band running across the centre of the area at elevations from 900 to 1200 m and within predominantly ground moraine of Continental origin. The characteristic forest vegetation is dominated by lodgepole pine with lesser amounts of aspen and balsam poplar in the wake of fire (Rowe 1972). In older stands the white spruce and black spruce are very often present. Balsam and subalpine fir show scattered distributions in the upland forest.

3. Upper Foothills (B. 19c).

The Upper Foothills Section of the Boreal Forest Region represents approximately 21% or 3200 km^2 of the Wapiti map area primarily in the south and south-west portions at elevations from 1200 to 1800 m and commonly upon colluviated till of both Continental and Cordilleran origin. The characteristic forest vegetation is dominated by lodgepole pine with black spruce, subalpine fir and white spruce-Engelmann spruce hybrids commonly present. The Upper Foothills Section is a transition between the Lower Foothills Section and the Subalpine Forest Region. The Upper Foothills is characterized by rolling topography and deep valleys.

4. East Slope Rockies (SA. 1)

The East Slope Rockies Section of the Subalpine Forest Region represents approximately 6% or 825 km^2 of the Wapiti map area primarily in the south-west portion at elevations from 1800 to 2000 m (Plate 1) and on the steep slope of uplifted Mesozoic shales and sandstones. A thin veneer of Cordilleran till is often present. The characteristic forest vegetation is dominated by Engelmann spruce and subalpine fir. Lodgepole pine dominates younger stands especially after fire (Rowe 1972). The East slope Rockies

Plate 1 Upper subalpine landscape in vicinity of Kakwa Falls.

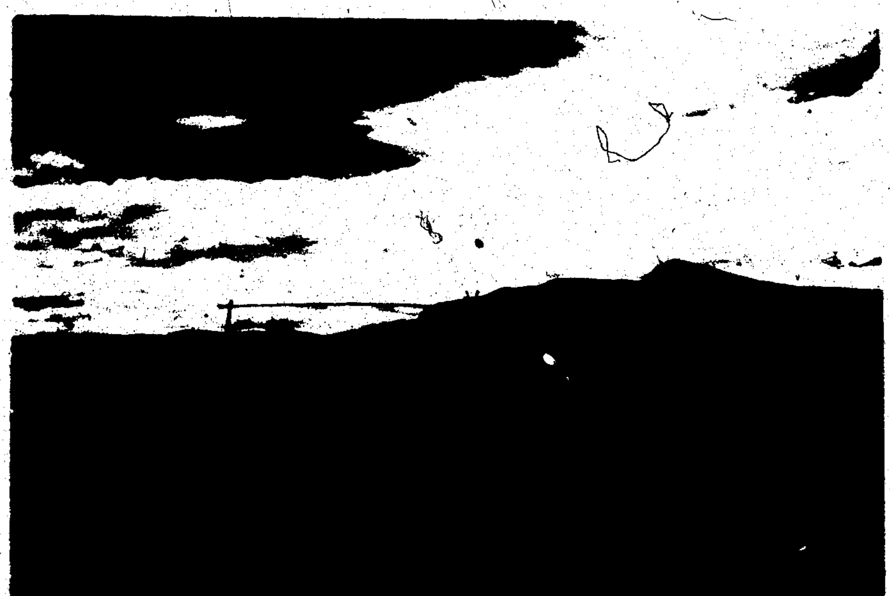


Plate 2 Alpine tundra in southwest corner of Wapiti map area.

Section grades into alpine tundra in a few localities.

5. Alpine Tundra

Alpine tundra occurs above timberline on the higher mountains at elevations above 2000 m in the south-west of the Wapiti map area (Plate 2) representing approximately 1% or 90 km^2. Parent materials of the predominantly Regosolic soils are Mesozoic shales and sandstones. A thin till veneer is sometimes present. Forest vegetation is absent, and consequently plots were not established in this zone. Characteristic species of the alpine tundra include *Dryas hookeriana, Carex nardina, Cassiope tetragona, Kobresia bellardii* and *Silene acaulis*.

B. CLASSIFICATION OF THE FOREST VEGETATION

The forest vegetation of 83L was classified into 15 forest types on the basis of the dominant tree species, floristic composition and by environment as inferred from soils. The floristic classification was patterned after Braun-Blanquet's methods as described by Mueller-Dombois and Ellenberg (1974) and after a Bray and Curtis (1957) ordination. The concepts of the forest types were developed both during field investigations and after the plots were sampled and the data analyzed. No attempt was made to restrict sampling to certain forest types nor to exclude certain forest types from sampling, though certain forest types are not well represented, particularly those at high elevations. Table 1 represents 15 concepts of forest ecosystems for the Wapiti map area.

In order to keep a conceptual grouping useful, it should not include excessive variability but also should not be so restricted that stands

Table 1: Percent cover values of plant species with greater than 20% presence, arranged in order of decreasing presence. Vegetation type number is in parentheses.

	Populus tremuloides/Viburnum edule /Rubus pubescens (1)															PB/Ra/Tv (2)	Picea glauca/Rubus pubescens -Maianthemum canadense (3)												/Hyloc[...]	
Plot Number	86	26	19	87	85	100	122	90	45	46	23	27	123	106	x̄	18	48	94	25	91	24	118	117	44	95	47	124	x̄	101	57
Shrub Layer cover	6	14	8	6	7	34	4	32	17	13	5	4	14	22	14	7	8	52	12	13	3	5	8	2	22	9	4	13	12	3
Rosa acicularis	1	3	3	3	1	2	1	14	5	4	2	2	3	.	3	3	2	8	2	3	2	2	T	1	1	2	T	2	3	1
Sedum groenlandicum	.	.	1	.	.	.	T	.	.	.	.	.	.	.	T	.	.	.	.	.	.	.	.	T	.	.	.	T	.	1
Lonicera involucrata	1	4	1	T	.	2	T	T	3	T	T	1	2	1	1	1	1	9	4	1	1	1	4	1	4	5	1	3	2	T
Viburnum edule	3	6	1	T	5	10	1	17	6	9	1	1	9	2	5	1	2	30	2	8	1	1	3	.	15	2	3	6	4	1
Spiraea lucida	.	T	.	.	.	19	2	1	3	T	T	T	.	2	2	T	1	5	1	.	.	.	.	T	.	.	.	1	.	.
Alnus crispa	.	.	.	.	.	.	1	.	.	.	.	.	.	.	T	.	.	.	T	1	.	.	1	.	1	.	T	T	.	.
Sorbus scopulina	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	T	.	T	T	.	T	.	T	.	.	T	.	.
Salix spp.	.	T	T	.	.	.	.	.	.	T	1	.	.	.	T	T	.	.	.	.	.	.	.	.	T	.	.	T	.	.
Ribes lacustre	T	.	.	.	.	.	.	.	.	.	.	.	.	.	T	.	.	T	1	.	T	T	T	.	T	T	.	T	.	.
Amelanchier alnifolia	.	T	.	.	T	T	.	T	.	T	T	T	.	T	T	T	1	T	T	T	.	T	.	.	.	T	.	T	.	.
Shepherdia canadensis	.	T	2	1	T	1	T	T	T	.	1	.	.	.	T	1	1	.	.	.	.	1	.	.	.	.	.	T	.	.
Salix bebbiana	.	.	.	2	1	T	T	.	.	.	.	.	.	17	1	.	T	.	.	.	.	.	.	.	.	.	.	T	.	.
Menziesia glabella	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Rhododendron albiflorum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.
Cornus stolonifera	1	1	.	.	T	.	.	.	.	T	T	.	.	T	T	1	.	.	2	.	T	.	T	.	1	.	.	T	T	.
Ribes hirtellum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	T	.	.	.	.	T	.	
Herb-Dwarf shrub Layer cover	22	19	24	27	33	27	31	43	22	31	15	27	19	60	29	20	22	35	13	30	12	17	20	9	21	23	20	20	59	39
Cornus canadensis	8	3	4	1	3	11	9	1	10	10	5	9	4	13	7	.	8	9	4	5	4	3	9	3	6	10	11	7	17	18
Linnaea borealis	T	.	2	T	1	2	2	T	3	1	2	2	T	5	1	T	6	1	.	3	3	3	4	3	4	4	4	3	20	6
Petasites palmatus	T	3	2	1	T	1	1	T	1	1	T	1	T	2	1	2	T	1	T	T	T	2	T	T	T	T	1	T	4	1
Equisetum arvense	T	T	T	T	T	T	T	1	.	T	T	.	T	T	T	4	T	T	T	T	T	1	.	T	T	.	T	T	T	3
Epilobium angustifolium	2	3	3	2	7	4	6	6	T	1	T	.	9	7	4	4	1	.	.	1	T	2	T	T	T	.	T	T	.	T
Pyrola secunda	T	.	.	.	.	T	.	.	.	T	.	.	.	T	T	.	T	T	T	.	.	1	T	.	T	T	.	T	.	.
Vaccinium vitis-idaea	.	.	.	T	.	.	2	T	.	.	T	.	.	.	T	.	.	.	.	.	.	.	.	T	.	.	T	T	.	1
Calamagrostis canadensis	T	T	3	T	1	T	T	1	T	.	.	1	T	T	T	1	T	.	T	T	T	.	.	T	.	.	.	T	.	T
Arnica cordifolia	T	.	.	.	5	T	T	1	T	.	.	.	.	6	T	.	T	.	.	3	.	.	.	.	.	.	.	T	.	.
Pyrola asarifolia	T	T	T	T	T	2	2	T	1	.	T	1	1	2	1	.	.	1	T	7	.	T	1	T	.	T	.	1	.	T
Vaccinium membranaceum	.	.	.	.	.	.	.	.	.	.	.	.	.	T	T	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
Lycopodium annotinum	.	.	.	.	.	.	.	.	1	.	1	T	.	T	T	.	.	.	.	.	.	.	.	.	.	.	T	T	.	
Rubus pubescens	4	4	2	2	1	1	1	3	1	3	T	3	3	3	2	T	T	2	5	2	1	2	3	T	3	3	1	2	4	
Mertensia paniculata	2	2	T	.	T	T	T	4	1	2	T	1	.	.	1	3	.	1	2	2	2	2	.	T	2	T	1	1	3	
Mitella nuda	T	T	.	T	.	T	T	T	T	2	.	T	T	.	T	.	.	1	T	1	1	.	1	1	2	2	1	1	2	
Vaccinium myrtilloides	.	.	.	.	.	.	.	.	.	.	.	.	.	7	T	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
Vaccinium caespitosum	1	.	.	5	3	1	T	13	.	.	T	.	.	3	2	.	1	.	.	.	.	.	.	1	.	.	T	T	.	
Maianthemum canadense	.	.	T	T	T	3	1	1	2	2	T	T	T	2	1	.	2	T	T	2	T	T	1	T	.	2	T	1	.	
Elymus innovatus	1	.	T	4	3	T	T	1	T	T	1	.	.	.	1	.	T	.	.	T	.	1	.	T	.	.	.	T	.	
Lathyrus ochroleucus	3	1	1	5	5	T	1	3	1	T	T	T	.	7	2	2	1	.	T	2	T	T	.	T	.	T	T	T	.	
Rubus pedatus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	T	T	.	.	.	.	T	.	
Viola renifolia	T	.	.	.	T	T	.	T	T	1	.	T	T	T	T	T	T	T	T	T	T	.	.	T	T	2	T	T	T	
Streptopus amplexifolius	.	.	.	.	.	.	.	T	.	T	.	1	1	1	T	.	.	.	.	.	.	.	.	.	T	.	.	T	.	
Fragaria virginiana	1	1	3	5	1	1	T	.	T	T	2	.	.	T	1	T	.	.	T	.	T	T	T	1	T	T	1	T	.	
Aster conspicuus	T	2	3	[illegible]	3	1	6	1	.	1	2	T	T	1	2	4	.	3	T	T	.	T	.	.	.	.	.	T	T	
Galium boreale	T	T	1	1	T	T	.	T	1	T	T	.	.	.	T	T	T	T	T	T	.	T	.	T	T	T	.	T	.	
Equisetum scirpoides	.	.	.	.	.	T	.	.	.	.	.	.	.	.	T	.	.	.	.	.	.	.	.	T	T	T	T	T	5	
Gaultheria hispidula	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
[illegible]		T	[illegible]	[illegible]	[illegible]	[illegible]	T	7	T	7	2	8	1	.	1	.	2	15	1	2	1	.	.	.	.	.	.	2	3	

Linnaea borealis	T	.	2	T	1	2	2	T	3	1	2	2	1	3	1	.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Petasites palmatus	T	3	2	1	T	1	1	T	1	1	T	1	T	2	1	2	T	1	T	T	T	2	T	T	T	T	1	T	4	1
Equisetum arvense	T	T	T	T	T	T	T	1	.	T	T	.	T	T	T	4	T	T	T	T	T	1	.	T	T	.	T	T	T	3
Epilobium angustifolium	2	3	3	2	7	4	6	6	T	1	T	.	9	7	4	4	1	[illegible]	.	1	T	2	T	T	T	.	T	T	.	T
Pyrola secunda	T	.	.	.	.	T	.	.	.	T	.	.	.	T	T	.	T	T	T	.	.	1	T	.	T	T	.	T	.	.
Vaccinium vitis-idaea	.	.	.	T	.	.	2	T	.	.	T	.	.	.	T	.	.	.	.	.	.	.	.	T	.	.	T	T	.	1
Calamagrostis canadensis	T	T	3	T	1	T	T	1	T	.	.	1	T	T	T	1	T	.	T	T	T	.	.	T	.	.	.	T	.	T
Arnica cordifolia	T	.	.	.	5	T	T	1	T	.	.	.	.	6	T	.	T	.	.	3	.	.	.	.	.	.	.	T	.	.
Pyrola asarifolia	T	T	T	T	T	2	2	T	1	.	T	1	1	2	1	.	.	1	T	7	.	T	1	T	.	T	.	1	.	T
Vaccinium membranaceum	.	.	.	.	.	.	.	.	.	.	.	.	.	T	T	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lycopodium annotinum	.	.	.	.	.	.	.	.	1	.	1	T	.	T	T	.	.	.	.	.	.	.	.	.	.	.	T	T	.	.
Rubus pubescens	4	4	2	2	1	1	1	3	1	3	T	3	3	3	2	T	T	2	5	2	1	2	3	T	3	3	1	2	4	6
Mertensia paniculata	2	2	T	.	T	T	T	4	1	2	T	1	.	.	1	3	.	1	2	2	2	2	.	T	2	T	1	1	3	1
Mitella nuda	T	T	.	T	.	T	T	T	T	2	.	T	T	.	T	.	.	1	T	1	1	.	1	1	2	2	1	1	2	2
Vaccinium myrtilloides	.	.	.	.	.	.	.	.	.	.	.	.	.	7	T	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Vaccinium caespitosum	1	.	.	5	3	1	T	13	.	.	T	.	.	3	2	.	1	.	.	.	.	.	.	1	.	.	T	T	.	.
Maianthemum canadense	.	.	T	T	T	3	1	1	2	2	T	T	T	2	1	.	2	T	T	2	T	T	1	T	.	2	T	1	.	.
Elymus innovatus	1	.	T	4	3	T	T	1	T	T	1	.	.	.	1	.	T	.	.	T	.	1	.	T	.	.	.	T	.	.
Lathyrus ochroleucus	3	1	1	5	5	T	1	3	1	T	T	T	.	7	2	2	1	.	T	2	T	T	.	T	.	T	T	T	.	T
Rubus pedatus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	T	T	.	.	.	.	T	.	.
Viola renifolia	T	.	.	.	T	T	.	T	T	1	.	T	T	T	T	T	T	T	T	T	T	.	.	T	T	2	T	T	T	1
Streptopus amplexifolius	.	.	.	.	.	.	.	T	.	T	.	1	1	1	T	.	.	.	.	.	.	.	.	.	T	.	.	T	.	.
Fragaria virginiana	1	1	3	5	1	1	T	.	T	T	2	.	.	T	1	T	.	.	T	.	T	T	T	1	T	T	1	T	.	.
Aster conspicuus	T	2	3	.	3	1	6	1	.	1	2	T	T	1	2	4	.	3	T	T	.	T	.	.	.	.	.	T	T	T
Galium boreale	T	T	1	1	T	T	.	T	1	T	T	.	.	.	T	T	T	T	T	T	.	T	.	T	T	T	.	T	.	T
Equisetum scirpoides	.	.	.	.	.	T	.	.	.	.	.	.	.	.	T	:	.	.	.	.	.	.	.	T	T	T	T	T	5	T
Gaultheria hispidula	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	T
Aralia nudicaulis	.	T	.	.	.	.	T	7	T	7	2	8	1	.	1	.	2	15	1	2	1	.	.	.	.	.	.	2	3	.
Lycopodium complanatum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Galium triflorum	.	T	T	.	.	.	.	.	.	T	.	T	.	.	T	T	T	T	T	.	.	.	.	.	T	T	.	T	.	T
Aster ciliolatus	.	T	.	1	T	.	.	T	T	1	.	.	.	1	T	.	1	1	T	1	T	.	.	T	4	.	.	1	.	.
Achillea millefolium	T	.	T	T	T	.	.	.	T	.	.	.	.	.	T	.	.	.	.	.	.	.	.	T	.	.	.	T	.	.
Habenaria hyperborea	.	.	.	T	T	T	.	T	.	.	.	.	.	.	T	.	.	.	T	.	.	.	.	.	.	T	T	T	.	.
Carex capillaris	.	.	.	.	.	.	.	.	T	.	.	.	.	.	T	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Actaea rubra	T	T	.	.	.	.	.	.	.	.	.	T	.	.	T	T	.	T	T	T	.	.	T	.	T	.	.	T	.	.
Empetrum nigrum	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Osmorhiza depauperata	.	T	.	.	.	.	.	.	.	.	.	.	.	.	T	.	.	.	1	.	.	.	1	.	.	.	T	T	1	T
Bryoid Layer cover	37	5	10	T	T	3	2	.	1	2	25	8	T	13	8	T	56	1	10	39	10	57	49	46	22	34	32	32	12	69
Pleurozium schreberi	10	2	5	.	.	3	.	.	T	.	14	4	.	5	3	.	21	T	2	[illegible]	3	1	2	13	13	T	3	6	3	8
Ptilium crista-castrensis	T	2	.	.	T	T	T	.	T	2	2	2	.	1	1	.	2	1	3	2	1	T	4	.	2	7	1	1	1	5
Hylocomium splendens	27	1	5	T	.	.	2	.	1	.	9	2	.	3	6	.	35	T	4	33	6	56	43	32	7	34	28	25	8	56
Polytrichum commune	.	.	.	.	.	.	.	.	.	.	T	.	.	2	T	.	.	.	T	.	.	.	.	.	.	.	T	.	.	.
Dicranum spp.	.	.	T	.	.	.	.	.	.	.	.	.	.	.	T	T	.	.	1	T	1	T	.	.	.	.	.	T	.	.
Sphagnum spp.	.	.	.	.	.	.	.	.	.	[illegible]	.	.	.	.		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Mnium spp.	T	.	.	.	.	.	.	.	T	.	T	.	.	.	T	. .	.	T	T	.	.	T	1	1	.	.	.	T	.	T
other mosses	T	.	.	.	.	.	.	.	.	.	.	.	.	2	T	T	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Peltigera spp.	T	T	T	T	T	T	T	[illegible]	.	T	1	T	.	T	T	.	T	.	1	.	1	T	T	2	T	T	.	T	T	4
other lichens	T	.	.	.	.	.	T	T	T	1	T	T	T	T	T	T	1	.	T	T	2	1	T	T	.	T	T	T	T	T

um splendens (4)									splendens (5)								/Equisetum arvense (6)								Rub.ch.(7)			/Rubus pubescens (8)										
9	121	78	49	61	5	136	50	X̄	128	127	129	133	7	126	10	X̄	65	15	135	73	31	67	63	X̄	29	14	X̄	93	58	108	120	99	105	107	97	92	116	71
T	9	3	6	32	T	7	T	6	2	3	3	3	22	1	T	5	4	13	14	14	8	14	5	10	12	15	14	6	T	2	7	21	2	17	4	36	3	18
T	1	1	1	1	T	1	T	1	T	T	T	2	T	.	.	7	1	3	8	1	T	1	.	2	.	.	.	T	T	T	1	1	.	1	1	1	T	2
.	T	1	T	.	.	1	T	T	1	.	.	.	22	T	.	T	1	1	2	7	7	13	5	5	11	15	13	T	T	T	.	.	T	.	.	T	T	.
T	4	1	4	18	T	3	.	3	.	1	.	T	T	1	.	T	2	7	2	T	T	T	.	11	.	.	.	2	T	2	2	6	.	1	.	1	T	1
T	3	.	.	12	.	.	.	2	.	.	T	1	T	.	.	T	.	.	.	.	T	.	.	T	.	.	.	2	T	7	1	12	1	10	1	30	T	8
.	.	.	.	1	.	.	.	T	1	2	3	.	.	.	.	1	T	2	.	.	.	.	.	T	.	.	.	.	.	.	.	1	1	5	2	4	3	2
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0	22	50	13	52	1	36	14	29	16	55	32	35	29	42	2	30	43	24	41	28	9	23	27	28	6	3	5	17	8	49	33	14	59	41	59	42	21	36
9	11	16	1	25	.	12	6	11	8	16	15	11	15	15	.	11	20	2	12	7	4	5	2	7	.	.	.	2	6	21	6	T	19	9	12	5	9	9
2	3	3	3	3	T	6	1	5	2	19	4	3	5	7	.	6	2	4	3	2	.	.	.	2	.	.	.	T	1	10	7	4	8	3	5	2	4	6
4	T	3	.	T	T	3	.	2	.	1	T	1	.	6	T	1	1	5	2	2	T	2	1	2	T	.	T	T	T	2	T	T	.	T	T	.	T	T
T	T	12	2	T	T	1	T	2	.	T	T	T	T	T	T	T	8	1	4	2	1	9	1	5	T	.	T	2	T	T	T	.	.	T	T	T	.	T
.	3	.	.	T	.	1	.	1	.	T	T	2	.	.	T	T	.	T	1	T	T	.	T	T	.	.	.	T	.	5	3	T	5	.	2	3	T	1
T	.	T	T	.	T	T	T	T	2	1	1	T	.	T	T	T	.	.	.	.	.	.	T	T	T	.	T	T	T	T	T	T	T	T	T	.	T	T
.	T	4	.	T	.	5	2	1	T	T	1	9	T	.	.	1	3	1	3	6	3	3	4	3	2	3	2	.	T	.	.	.	.	.	.	.	T	.
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T	T	.	.	1	.	T	1	T	1	.	2	1	.	.	T	1	.	.	[illegible]	T	.	.	.	T	.	.	.	.	T	T	T	T	1	2	1	1	T	1
.	.	.	.	.	.	.	1	T	7	2	2	.	.	2	.	1	.	.	.	.	T	.	.	T	.	.	.	T	.	.	.	.	T	.	22	3	1	T
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2	1	1	2	5	.	1	T	2	.	.	.	.	T	.	.	T	2	.	T	.	T	.	2	1	.	.	.	T	.	4	2	1	1	1	3	2	1	2
.	T	1	T	4	T	1	T	1	.	2	T	T	T	5	T	1	1	5	2	2	T	.	.	1	.	.	.	.	.	1	2	4	.	T	.	.	.	.
3	1	1	3	3	.	1	2	2	T	T	.	T	T	1	.	T	1	1	T	T	.	.	1	T	.	.	.	.	T	T	T	1	.	.	.	T	.	T
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2	2	T	T	1	T	2	.	T	T	T	T	T	T	T	8	1	4	2	1	9	11	5	T	.	T	2	T	T	T	.	.	T	T	T	.	T	.	T
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4	.	T	.	5	2	1	T	T	1	9	T	.	.	1	3	1	3	6	3	3	4	3	2	3	2	.	T	.	.	.	.	.	.	.	T	.	T	
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1	2	5	.	1	T	2	.	.	.	.	T	.	.	T	2	.	T	.	T	.	2	1	.	.	.	T	.	4	2	1	1	1	3	2	1	2	2	1
1	T	4	T	1	T	1	.	2	T	T	T	5	T	1	1	5	2	2	T	.	.	1	.	.	.	.	.	1	2	4	.	T	.	.	.	.	.	T
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77	46	41	10	57	65	49	59	60	53	35	75	22	7	44	48	45	39	66	66	76	74	59	59	70	65	52	73	28	28	68	19	10	30	21	37	6	24	41
5	3	19	T	15	16	9	25	30	37	20	39	6	.	22	7	7	4	10	42	1	28	14	17	.	8	35	50	17	17	32	9	2	19	17	32	4	24	2
31	21	10	1	6	29	10	22	6	6	3	5	3	.	6	4	T	2	21	.	27	5	8	5	.	2	4	15	1	1	5	6	2	2	2	5	1	T	T
41	20	8	9	36	20	28	9	24	10	12	30	9	7	14	36	32	32	32	1	18	39	27	9	.	4	.	8	9	7	31	2	6	9	2	T	.	T	39
.	.	.	.	.	.	.	.	.	T	T	1	T	.	.	.	1	.	T	T	1	.	1	.	T	T	7	T	T	T	.	T	T	.	T	T	.	.	.
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T	T	1	1	1	T	T	T	T	T	T	1	T	T	T	T	.	T	T	.	T	T	T	1	3	2	T	T	.	1	.	1	T	T	T	1	1	T	T

4of

Table 1: Percent cover values of plant species with greater than 20% presence, arranged in order of decreasing presence. Vegetation type number is in parentheses

.cont./Spic. ./Cor.can.(2)

119	131	43	X
15	2	8	8
2	1	4	2
T	.	.	T
T	.	.	T
T	T	.	T
13	1	4	6
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Pinus contorta/Alnus crispa /Cornus canadensis (10)

37	28	68	83	62	77	21	130	109	113	114	9	22	$\bar{X}$
12	6	16	24	26	15	9	3	4	29	9	10	1	13
3	T	1	1	1	1	T	2	2	.	T	T	.	1
6	4	.	T	1	T	1	.	1	T	1	1	.	1
.	.	2	5	T	1	.	1	1	.	.	1	.	1
T	.	9	5	T	7	.	.	T	.	.	.	.	2
2	1	2	4	T	T	.	.	.	.	.	.	T	1
1	1	2	8	24	5	8	1	T	29	8	8	1	8
.	T	T	T	.	.	T	.	.	.	.	.	T	T
.	T	1	.	.	.	T	.	.	.	.	T	.	T
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Pinus contorta/Picea mariana/ Ledum groenlandicum/ Vaccinium membranac

76	17	51	36	34	52	137	74	82	66	72	69	64	6	8	111	3	39	11	80	81	4
2	1	T	T	4	T	2	T	7	25	10	17	3	22	9	6	18	11	7	9	12	7
.	T	.	.	T	T	.	.	4	1	.	T	T	T	.	1	.	1	.	.	.	T
2	.	T	T	1	.	2	T	3	24	10	17	3	22	9	5	16	10	7	7	8	7
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4	29	12	35	30
7	9	T	13	10
9	5	7	4	6
1	1	.	2	1
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4	4	T	2	2
T	.	1	T	T
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.	T	T	T	T
1	1	T	1	1
4	T	4	T	2
.	T	T	.	2
4	2	.	T	2
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27	12	26	28	32	35	49	23	57	79	11	32	17	33
7	3	7	9	10	11	10	11	11	22	1	5	8	10
3	1	3	2	5	6	7	3	5	3	4	2	3	4
1	.	T	2	1	4	2	2	.	3	1	1	1	1
T	T	1	T	T	T	T	.	8	T	.	T	T	1
3	1	T	2	T	1	T	T	7	8	.	T	.	2
.	.	T	T	.	T	.	T	T	T	T	1	T	T
6	2	.	.	T	T	.	1	.	.	T	.	.	1
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T	.	2	T	T	T	T	T	2	.	2	T	.	1
T	.	.	3	.	8	19	.	5	4	1	6	3	4
.	1	T	.	1	T	T	.	.	11	.	T	.	1
.	.	2	3	1	3	.	.	T	.	T	.	1	1
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4	1	T	T	5	1	10	.	.	.	.	.	.	2
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42	26	37	30	29	22	41	40	19	28	32	26	14	16	22	24	25	21	25	24	31	19
7	3	8	9	7	4	12	9	7	12	17	10	2	6	5	6	6	8	10	4	6	6
30	7	T	1	2	1	5	7	3	2	4	2	T	1	1	2	1	1	5	1	T	1
.	1	T	.	1	T	2	1	1	T	T	.	.	T	.	T	.	1	.	T	T	1
T	T	.	T	1	.	T	T	T	2	.	T	.	.	.	.	T	T	T	.	T	T
T	4	3	T	4	1	T	T	.	.	T	.	.	.	.	T	.	1	.	T	T	T
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.	.	.	T	1	2	1	4	5	6	1	9	4	T	2	6	1	7	2	3	2	6
.	T	T	T	1	.	T	T	.	T	T	T	.	.	.	T	.	T	.	T	T	.
.	3	8	T	T	1	T	T	.	T	.	.	.	T	.	.	T	1	T	T	T	1
.	1	3	.	.	.	T	.	.	.	.	.	.	.	.	.	.	.	T	.	.	.
5	T	12	14	7	6	10	5	1	3	4	T	2	5	10	2	15	T	2	10	12	2
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T	T	1	T	T	T	T	.	8
3	1	T	2	T	1	T	T	7
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6	2	.	.	T	T	.	1	.
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T	.	2	T	T	T	T	T	2
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.	1	T	.	1	T	T	.	.
.	.	2	3	1	3	.	.	T
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4	1	T	T	5	1	10	.	.
T	.	.	T	4	1	.	T	T
1	T	T	T	.	T	.	2	.
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5	74	35	28	35	63	31	32	27
3	63	29	10	28	57	25	11	18
1	11	4	5	5	4	3	6	7
1	.	2	9	1	2	.	7	2
T	T	.	4	1	.	2	.	T
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.	.	.	.	.	.	.	6	.
3	T	.	1	1	1	.	3	.
T	2	1	T	1	T	T	2	T

3	1	1	1	1
T	.	T	T	1
8	.	T	.	2
T	T	1	T	T
.	T	.	.	1
3	T	T	T	T
21	T	14	1	4
.	2	T	.	1
4	1	6	3	4
11	.	T	.	1
.	T	.	1	1
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6	56	34	74	38
T	47	24	44	28
4	7	2	6	5
1	2	1	8	3
T	T	1	T	1
T	T	6	2	1
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30	7	T	1	2	1	5	7	1	2	4	2	T	1	1	2
.	1	T	.	1	T	2	1	1	T	T	.	.	T	.	T
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.	T	T	T	.	T	T	T	T	T	T	.	.	T	.	T
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.	1	3	.	.	T	.	.	.	.	.	.	.	.	.	.
5	T	12	14	7	6	10	5	1	3	4	T	2	5	10	2
.	.	T	1	1	1	T	1	.	T	T	T	.	1	2	3
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52	8	30	82	54	36	64	90	53	36	86	78	52	45	76	72
48	T	20	76	49	14	49	47	20	6	69	1	23	38	59	64
3	4	10	5	5	10	3	17	6	14	11	68	16	6	16	7
1	4	T	T	.	11	1	26	22	10	6	6	12	1	1	1
.	T	T	1	1	1	1	.	T	1	.	1	.	T	T	T
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6	1	.	1	1	1	T	2	2	T	1	1	4	4	3	3
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1	7	2	3	2	6	
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15	T	2	10	12	2	
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56	15	53	65	59	39	7
47	11	50	47	48	26	2
4	T	3	2	6	2	1
2	4	.	15	5	8	3
1	T	1	1	T	2	
T	T	.	.	.	1	
2	.	.	T	.	.	
4	3	8	7	T	11	
2	3	3	2	T	5	

12)

10	112	79	75	30	38	98	$\bar{X}$
.	T	33	7	3	13	10	8
.	T	.	.	T	.	1	T
.	T	30	7	3	13	10	7
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[illegible]	43	26	17	12	15	43	27
[illegible]	25	8	3	1	4	8	8
[illegible]	10	2	.	T	.	1	4
	2	T	.	.	.	.	T
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Pinus contorta/Ledum groen. /Pleurozium schreberi (11)

84	70	89	12	96	13	60	88	55	$\bar{X}$
3	9	6	6	26	12	4	7	T	8
.	.	T	2	1	3	T	.	T	1
.	7	4	3	20	9	4	5	T	6
2	1	.	T	1	.	.	T	.	T
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16	20	22	24	31	30	33	23	5	23
7	12	1	7	10	4	19	2	T	7
6	1	.	4	4	2	2	12	T	3
T	T	T	.	T	T	T	T	.	T
.	.	T	.	1	.	T	T	.	T
T	.	T	T	4	T	T	2	.	1
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.	3	9	6	1	6	1	4	5	4
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Pinus contorta/ Menziesia glabella /Rubus pedatus (13)

54	32	42	40	33	125	41	35	53	132	134	$\bar{X}$
45	25	6	30	4	2	2	6	14	5	5	13
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4	1	.	10	T	T	T	6	14	3	5	3
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2	6	6	2	4	1	.	.	.	.	.	2
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14	11	34	17	27	27	32	22	36	46	12	25
3	2	8	4	7	9	10	6	3	9	1	6
T	T	T	1	T	3	1	T	T	4	6	1
.	.	.	T	.	.	T	.	.	3	.	T
.	.	.	T	.	.	T	T	.	.	.	T
.	.	.	.	.	.	2	.	.	8	.	1
T	T	1	T	T	1	.	T	T	T	T	T
1	1	T	3	.	.	1	2	2	4	1	1
.	.	.	.	.	T	1	T	T	.	.	T
.	T	T	T	T	3	3	.	.	2	.	1
.	.	.	.	.	T	T	.	.	T	.	T
9	5	10	8	10	7	6	6	24	6	3	9
T	2	T	T	1	T	T	1	4	.	T	1
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Pc/Vm/1 (14)

56	16	$\bar{X}$
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Pe-Al/[illegible] (15)

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5	3	9	2	3	.	3	9	6	1	6	1	4	5	4	1	1	T	1	.	.	1	2	2	4	1	1	4	2	1	.
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6	7	.	24	2	.	4	12	2	.	16	6	3	.	5	.	.	.	T	.	.	.	7	.	2	1	1	4	21	12	.
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74	77	28	56	53	43	85	58	71	58	69	73	29	80	63	41	77	59	23	37	73	41	68	57	12	38	48	26	10	18	35
47	75	27	43	37	12	1	56	64	36	68	66	25	71	44	39	73	53	23	36	47	33	51	33	12	32	39	25	9	18	5
19	1	T	10	9	4	62	T	T	3	T	5	.	5	9	1	4	5	.	T	11	6	11	11	T	1	5	T	.	T	T
7	1	1	T	6	27	22	2	6	19	7	2	3	3	9	T	T	1	T	1	15	T	4	13	T	5	4	1	.	T	.
T	.	T	.	T	.	.	.	T	.	T	.	T	.	T	T	T	.	T	T	T	2	1	T	T	T	T	.	1	T	.
1	T	T	.	T	.	.	T	1		1	T	1	1	T	1	T	.	.	T	T	.	1	.	T	1	T	.	T	T	16
.	.	.	3	1	.	.	.	.	.	.	.	.	.	.	.	.	.	T	.	.	.	.	.	.	.	T	.	.	.	.
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9	2	20	.	3	1	8	3	8	1	8	3	1	4	4	3	.	.	3	1	T	.	3	3	9	5	2	1	1	1	10
1	2	2	T	1	T	T	.	1	T	1	1	T	2	1	5	T	1	2	T	T	2	3	1	1	5	2	10	32	21	1

8 of

fitting the central concept are seldom encountered under the specified set of habitat conditions. When vegetation is viewed as a continuum on the landscape (Whittaker 1967, 1973), it becomes apparent that there are transitions between conceptual units of classification. Because the vegetation of the Wapiti map area was sampled within several age classes and across gradients of elevation, soil moisture, climate and soils, there are many stands which may fit nearly as well with more than one vegetation type as recognized here, thus complicating a classification of the vegetation. Many authors avoid this dilemma by putting certain restrictions upon their sampling, for example by sampling only mature self-perpetuating stands. Only very young stands (less than 40 years) and very old stands were not sampled in the present study, as the objectives were to characterize the forest productivity and floristic composition as well as to ascertain successional relationships. The species composition of all the sampled plots is presented in Table 1, with transitional plots included with the group they resembled most. These groupings appear to be fairly homogeneous with respect to soil, other site factors and forest productivity. Most of these types characterize a major portion of one of Rowe's (1972) Forest Sections represented within the Wapiti map area, but others, notably the white spruce types appear to be controlled more by edaphic factors than by elevation (climate) and occur over a wide altitudinal range. A brief description of each of the forest types follows. Plot locations are given in Appendix 3 and plotted on Figure 1.

Vegetation types of the Wapiti map area

1. *Populus tremuloides / Viburnum edulé / Rubus pubescens*

(plots 19,23,26,27,45,46,85,86,87,90,100,106,122,123)

This type represents the aspen forests in the northern sectors of 83L (Plate 3). They occur at low elevations (610 to 960 m) on gentle north slopes (Classes 1 to 5; CSSC 1976). They are young (45 to 125 yr.), have lush shrub and herb understorys and often have plentiful white spruce regeneration. Constant species (over 80% presence in plots within type) which comprise most of the total plant cover, are *Viburnum edule, Lonicera involucrata, Rosa acicularis, Petasites palmatus, Rubus pubescens, Epilobium angustifolium, Pyrola asarifolia, Aster conspicuus, Maianthemum canadense, Cornus canadensis* and *Linnaea borealis*. No species have mean cover greater than seven percent (Table 1). *Aralia nudicaulis* and *Spiraea lucida* are locally abundant. The moss layer has generally low cover (Table 1).

The anticipated climax is the *Picea glauca-Rubus pubescens-Maianthemum canadense* type. The abundant white spruce regeneration and maturing white spruce trees in the understory (Table 2) suggest probable eventual dominance by white spruce. Forest productivity is variable in the aspen forests ranging from CLI class 3 to 5 (Appendix 9) as determined from the plot data.

Soils are well to imperfectly drained and include in order of decreasing abundance, Gleyed Gray Luvisols, Orthic Gray Luvisols, Solonetzic Gray Luvisols and Eluviated Eutric Brunisols on fine-textured lacustro-till, lacustrine and alluvium overlying lacustro-till parent materials. Lodge and Donnelly are the predominant soil groups.

Table 2: Regeneration density and standard deviation, regeneration presence, ranked total volume of major tree species within the 15 vegetation types

Vegetation Type No.		Sw[1]	Sb	Fa	Lp	A	Bp	B
1	Regeneration density[2]	108±102		14±46		295±367	58±165	19±59
(n=14)	Regeneration presence[3]	71		14		64	29	14
	Ranked total volume	3	7	6	2	1	4	5
2	Regeneration density	20						20
(n=1)	Regeneration presence	100						100
	Ranked total volume	2				3	1	4
3	Regeneration density	121±229	189±528	1029±2860		279±364	67±169	13±32
(n=11)	Regeneration presence	45	18	36		55	18	18
	Ranked total volume	1	4	5	6	2	3	
4	Regeneration density	276±474	180±572	762±1456		34±80	11±23	
(n=11)	Regeneration presence	64	27	45		18	27	
	Ranked total volume	1	2	5	6	4	3	7
5	Regeneration density	88±110	56±95	978±866	56±95		18±47	
(n=7)	Regeneration presence	57	14	86	14		14	
	Ranked total volume	1	5	3	2		4	
6	Regeneration density		395±596	56±95				
(n=7)	Regeneration presence		43	14				
	Ranked total volume	2	1		3			
7	Regeneration density		2730±611		25±35			
(n=2)	Regeneration presence		100					
	Ranked total volume		1					
8	Regeneration density	230±463	135±362	399±828	10±21	133±253		
(n=13)	Regeneration presence	38	23	54	23	31		
	Ranked total volume	2	4	5	1	3	7	
9	Regeneration density		49±67	630±1260	31±47			
(n=4)	Regeneration presence		75	25	50	50		50
	Ranked total volume		3		1	2		
10	Regeneration density	696±2325	78±205	192±301	23±33	29±71		15±55
(n=13)	Regeneration presence	54	31	46	46	15		8
	Ranked total volume	3	2	5	1	4	6	
11	Regeneration density	91±203	524±701	30±98	44±78	33±54	3±8	30±91
(n=9)	Regeneration presence	33	67	22	44	33	11	11
	Ranked total volume	3	2	5	1	4		
12	Regeneration density	[illegible]	[illegible]38±654	422±1280	10±26	1±4		
(n=31)	Regeneration presence	[illegible]	42	45	16	3		
	Ranked total volume	[illegible]	2	4	1	5		
13	Regeneration density	[illegible]	258±769	1036±1590	47±105			
(n=11)	Regeneration presence	[illegible]	27	82	18			
	Ranked total volume	4	3	2	1	5		
14	Regeneration density		631±297					
(n=2)	Regeneration presence		100					
	Ranked total volume		2					
15	Regeneration density		25	3707				
(n=1)	Regeneration presence		100	100				
	Ranked total volume	Se 1		2				

1 Sw-white spruce, Sb-black spruce, Fa-subalpine fir, Lp-lodgepole pine, A-aspen, Bp-balsam poplar, B-white birch, Se-Engelmann spruce

2 Stems ha^{-1} of stems less than 1.3 cm DBH

3 Percent of plots of a particular vegetation type in which a particular species of tree regeneration occurs.

2. *Populus balsamifera / Rosa acicularis / Thalictrum venulosum*

(plot 18)

The balsam poplar forests occur sporadically at low elevations (690 m) on alluvial floodplàins which are still subject to periodic flooding. The herb understory is dense but moss cover is sparse. Constant species are *Rosa acicularis, Rubus strigosus, Lonicera involucrata, Thalictrum venulosum, Equisetum arvense, Aster conspicuus, Mertensia paniculata, Calamagrostis canadensis* and *Vicia americana*. Stands of this type are young (ca. 70 yr.) and appear to be succeeding towards the *Picea glauca / Rubus pubescens-Maianthemum canadense* type. This trend is suggested by the many understory species in common to the two types (Table 1) and the presence of white spruce seedlings and maturing white spruce trees in the understory (Table 2). Balsam poplar productivity is fairly high (class 3), but heart rot in this species occurs at an early age.

Soils are well drained Orthic Regosols on alluvial parent material.

3. *Picea glauca / Rubus pubescens-Maianthemum canadense*

(plots 24,25,44,47,48,91,94,95,117,118,124)

These white spruce forests (Plate 4) occur at low to medium elevations (670-1220 m) on generally north-sloping (classes 1 to 6) sites. They are generally young (70 to 140 yr.) and have well developed shrub and herb understorys. Constant species are *Lonicera involucrata, Rosa acicularis, Viburnum edule, Rubus pubescens, Maianthemum canadense, Mitella nuda, Cornus canadensis, Linnaea borealis* and *Petasites palmatus*. *Cornus stolonifera, Alnus crispa, Alnus tenuifolia* and *Aralia nudicaulis* are often evident in this type but are seldom seen in the other white spruce types. *Hylocomium splendens* is the predominant moss. This type can

Plate 3 *Populus tremuloides/Viburnum edule/Rubus pubescens* type (Type 1).

Plate 4 *Picea glauca/Rubus pubescens-Maianthemum canadense* type (Type 3).

commonly be seen on depressional sites within aspen forest, suggesting that succession advances faster on these sites. The abundance of white and black spruce seedlings and fir seedlings in some stands of this type (Table 2) should ensure perpetuation of this type as well as increased abundance of black spruce and subalpine fir in some stands. Forest productivity is good (classes 3 and 4) but appears to be less in the older forests. It is distinguished from the wetter *Picea glauca/Equisetum arvense/Hylocomium splendens* type by the presence of *Maianthemum canadense*, lower *Equisetum arvense* cover, the absence of *Carex capillaris*, less moss cover and by generally better drained soils.

Soils are moderately well to imperfectly drained Orthic Gray Luvisols, Gleyed Gray Luvisols and Luvic Gleysols on alluvium over lacustro-till, lacustro-till, Continental and Cordilleran till. Donnelly, Snipe and Edson are the predominant soil groups.

4. *Picea glauca / Equisetum arvense / Hylocomium splendens*
(plots 5,20,49,50,57,59,61,78,101,121,136)

The white spruce-horsetail forests (Plate 5) occur at low to moderately high elevations (670 to 1450 m) on gentle (classes 1 to 4) generally north-facing slopes. They are young to moderately old (80 to 220+ yr.). White spruce and subalpine fir regeneration is common in many of the stands (Table 2). The understory is herb dominated and a dense *Hylocomium splendens* cover is present with lesser amounts of *Ptilium crista-castrensis* and *Pleurozium schreberi* (Table 1). Constant species include *Rosa acicularis, Lonicera involucrata, Equisetum arvense, Petasites palmatus, Mertensia paniculata, Mitella nuda, Cornus canadensis, Linnaea borealis* and *Rubus pubescens*. *Carex capillaris*, an indicator of the moist conditions of this type, is found in approximately one-half of the plots of this type. Forest productivity is variable (class 2 to 5) and appears to be less in the older forests.

Soils are poorly to imperfectly drained peaty Orthic Gleysols, peaty Luvic Gleysols and Orthic, Luvic, and Rego Gleysols on Continental till, alluvial sand and lacustrotill parent materials. Snipe, Smoky and Gunderson are the predominant soil groups.

5. *Picea glauca / Hylocomium splendens*

(plots 7,10,126,127,128,129,133)

The white spruce-feathermoss forests (Plate 6) occur at low to moderately high elevations (610 to 1280 m), often along valleys of major rivers on old river terraces, on generally north sloping (classes 1 to 6) sites. They are young to moderately old (70 to 170 yr.), have sparse shrub understorys, a herb-dwarf shrub stratum dominated by *Cornus canadensis* and *Linnaea borealis* and a dense cover of *Hylocomium splendens* and *Pleurozium schreberi*. Lodgepole pine forms a large proportion of the basal area in some stands but is being replaced by white spruce. Subalpine fir regeneration is abundant in most of the stands (Table 2), suggesting eventual co-dominance of subalpine fir with white spruce. Constant species are *Cornus canadensis, Linnaea borealis, Pyrola secunda, Hylocomium splendens* and *Pleurozium schreberi*. This type is stable and has moderate forest productivity (class 4 to 5).

Soils are rapidly to well-drained Orthic and Cumulic Regosols, Brunisolic Gray Luvisols and Orthic Gray Luvisols on generally coarse-textured alluvial sands and gravels, outwash gravels, and coarse-textured Cordilleran till. Jarvis and Robb are the predominant soil groups.

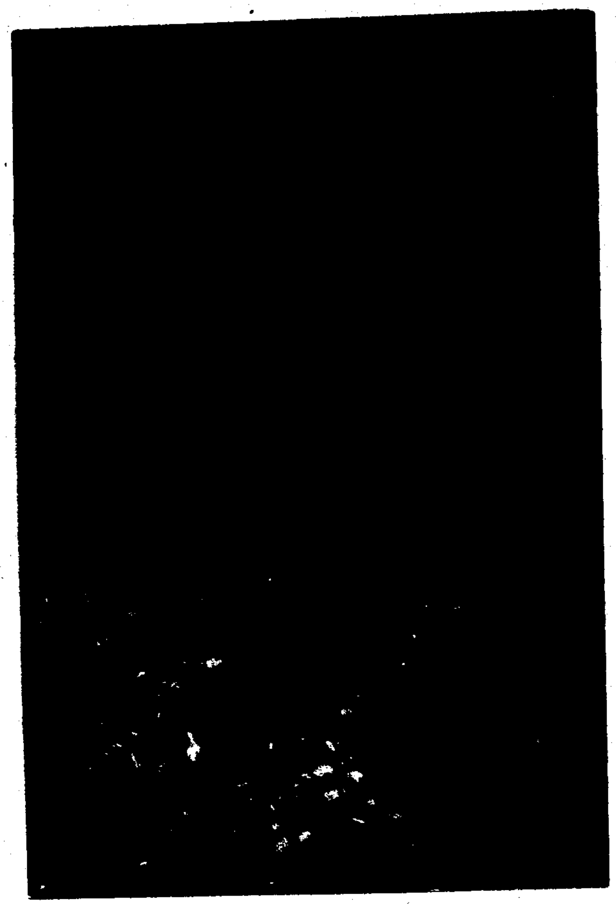


Plate 5 *Picea glauca/Equisetum arvense/Hylocomium splendens* type (Type 4).

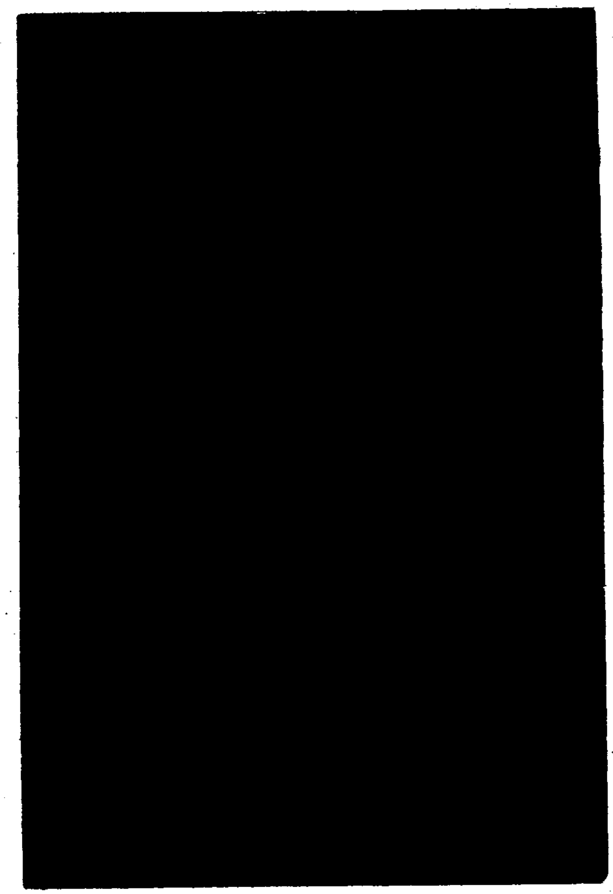


Plate 6 *Picea glauca/Hylocomium splendens* type (Type 5).

6. *Picea mariana / Ledum groenlandicum / Equisetum arvense*

(plots 15,31,63,65,67,73,135)

The black spruce forests occur at low to mid-elevations (840 to 1220 m) on gently sloping (classes 1 to 4) sites with a northerly aspect, and may occur in association with the *Picea mariana / Ledum groenlandicum / Rubus chamaemorus* type. The slight slope of stands of this type probably allows more oxygen to move through the peaty soil than in the black spruce-labrador tea-cloudberry type. The stands are young to fairly old (75 to 180 yr.) and are usually in climax condition, with abundant black spruce regeneration (Table 2). The herb understory is often species rich. Constant species are *Ledum groenlandicum, Vaccinium vitis-idaea, Equisetum arvense, Petasites palmatus, Carex capillaris,* and *Cornus canadensis*. The moss stratum is dominated by *Hylocomium splendens, Pleurozium schreberi* and lesser amounts of *Ptilium crista-castrensis* and *Sphagnum* spp. Though individual trees often attain merchantable size (such as occasional white spruce) in this type, overall productivity is rather low (classes 5 and 6).

Soils are poorly drained Terric Mesisols, peaty Rego Gleysols and Humic Luvic Gleysols on organic and occasionally till parent materials. Kenzie and to a lesser extent, Smoky are the predominant soil groups.

7. *Picea mariana / Ledum groenlandicum / Rubus chamaemorus*

(plots 14,29)

This type represents the black spruce bog vegetation (Plate 7). The bogs occur at low to mid-elevations (915 to 1070 m) in depressions with impeded drainage on level sites with hummocky microtopography. These open forests are often over 200 years old and can be considered climax. The well developed shrub layer is dominated by *Ledum groenlandicum*. The herb-dwarf shrub understory is dominated by *Vaccinium vitis-idaea, Rubus* *chamaemorus* and *Oxycoccus microcarpus*. *Sphagnum* spp. are abundant. Tree cover is sparse and productivity is very low (class 7) and can be considered non-merchantable.

Soils are poorly drained Typic Mesisols and Fibrisols on moss peat parent materials. Kenzie is the predominant soil unit.

8. *Pinus contorta / Viburnum edule / Rubus pubescens*

(plots 58,71,92,93,97,99, 103,104,105,107,108,116,120)

This is a relatively common forest type in 83L on north-sloping (classes 1 to 6) sites at mid-elevations (880 to 1040 m). It is characterized by young (80 to 90 yr.) lodgepole pine stands of fire origin and often plentiful white spruce, black spruce, subalpine fir and paper birch regeneration (Table 2), indicating possible eventual dominance of these species. The occasional occurrence of *Oplopanax horridum* in this type (Appendix 7), and the lush herb understory seem to indicate high precipitation. Constant species include *Viburnum edule, Lonicera involucrata, Rosa acicularis, Rubus pubescens, Cornus canadensis, Linnaea borealis, Pyrola asarifolia* and *Epilobium angustifolium*. *Pleurozium schreberi* dominates the moss layer. Though not restricted to this type, *Sorbus scopulina, Spiraea lucida, Maianthemum canadense* and *Gymnocarpium dryopteris* may be considered to be indicators of these forests. This type is similar to the *Pinus contorta / Spiraea lucida / Cornus canadensis* type but appears to be more moist as indicated by the higher cover of *Viburnum, Sorbus, Rubus* and *Gymnocarpium*. This type also has affinities with the *Picea glauca / Rubus pubescens-Maianthemum canadense* type towards which it might be expected to succeed. Forest productivity is good (classes 3 and 4).

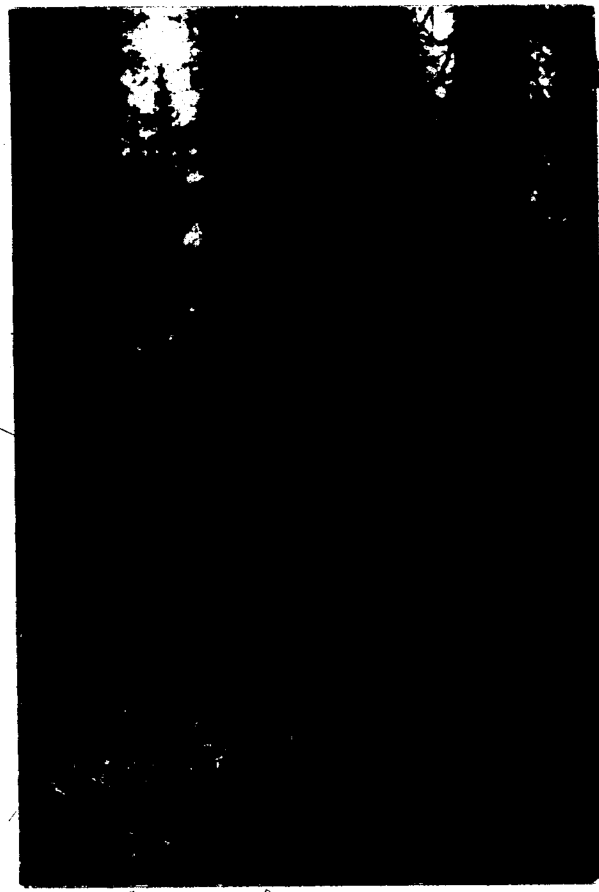


Plate 7 *Picea mariana/Ledum groenlandicum/Rubus chamaemorus* type (Type 7).

Plate 8 *Pinus contorta/Alnus crispa/Cornus canadensis* type (Type 10).

Soils are rapidly to imperfectly drained and include Gleyed Gray Luvisols, Eluviated and Orthic Eutric Brunisols, "bleached" Gray Luvisols (Brunisolic Gray Luvisols with Ae1 horizon of high color value above a darker Ae2 horizon) and Orthic Gray Luvisols on Continental till, sandstone and shale bedrock and aeolian sand parent materials. Edson, Torrens and Copton are the predominant soil groups.

9. *Pinus contorta / Spiraea lucida / Cornus canadensis*

(plots 43,102,119,131)

This type is not common and occurs at low elevations (915 to 1265 m) on sloping topography (Classes 4 to 7) in association with the *Pinus contorta / Viburnum edule / Rubus pubescens* type. It is characterized by young (less than 125 yr.) lodgepole pine stands of fire origin with a lush herb-dominated understory and regenerating aspen, paper birch and some black spruce. Constant species include *Betula papyrifera, Rosa acicularis, Spiraea lucida, Cornus canadensis, Linnaea borealis, Arnica cordifolia, Lycopodium annotinum, Lycopodium complanatum, Pyrola asarifolia* and *Pleurozium schreberi,* the dominant moss (Table 1). Forest productivity is moderate (classes 4 and 5).

Soils are well to moderately well drained Orthic Gray Luvisols and Brunisolic Gray Luvisols on Continental till, Cordilleran till and alluvial sand over bedrock parent materials. Soil groups include Mayberne, Edson, Robb and Lodge over unconsolidated sandstone bedrock.

10. *Pinus contorta / Alnus crispa / Cornus canadensis*

(plots 9,21,22,28,37,62,68,77,83,109,113,114,130)

This type is fairly common and is characterized by young (less than 100 yr.) lodgepole pine stands of fire origin at moderate elevations

(840 to 1280 m). Well developed shrub and herb understorys are present (Plate 8), and many stands have abundant white spruce regeneration (Table 2). Constant species include *Alnus crispa, Vaccinium caespitosum, Cornus canadensis, Linnaea borealis, Arnica cordifolia, Petasites palmatus, Calamagrostis canadensis, Pyrola asarifolia, Equisetum arvense* and *Pleurozium schreberi,* the dominant moss. The shrub *Rubus parviflorus* has sporadic occurrence in this type.

Adequate tree seedling regeneration following clearcutting might be a problem on this type where great increases in competing *Alnus* and *Calamagrostis* cover such as those observed by Corns and LaRoi (1976) for the area north of Edson, Alberta could be anticipated. Forest productivity is moderate (classes 4 and 5).

Soils are moderately well to imperfectly drained Orthic and Gleyed Gray Luvisols, Brunisolic Gray Luvisols and "bleached" Gray Luvisols on Cordilleran or Continental till and shale and sandstone bedrock. Edson, Marlboro and Torrens are the predominant soil groups.

11. *Pinus contorta / Ledum groenlandicum / Pleurozium schreberi*

(plots 12,13,55,60,70,84,88,89,96)

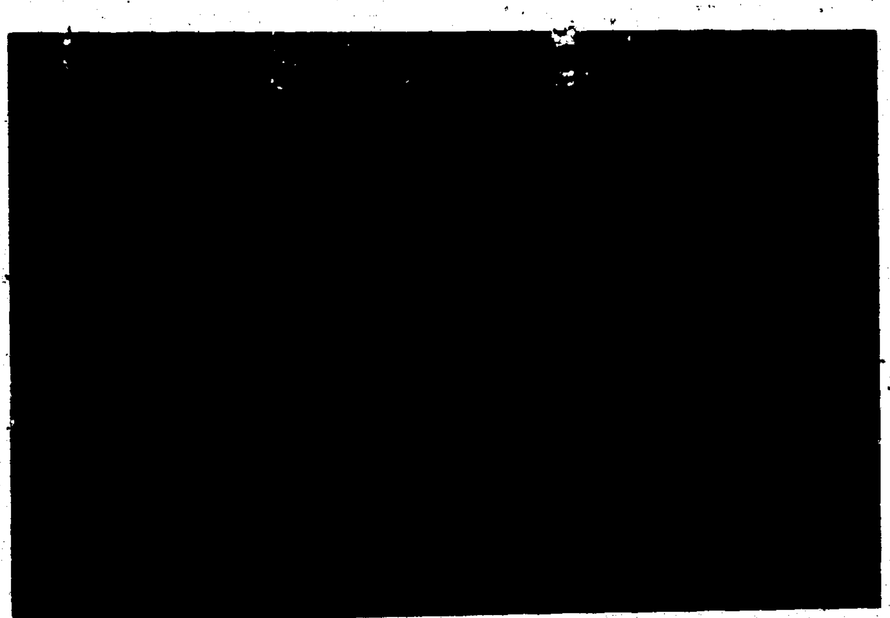
The lodgepole pine - Labrador tea - feathermoss forests (Plate 9) are common at moderate elevations (745 to 1220 m) and are characterized by young to fairly old (80 to 180 yr.) lodgepole pine stands of fire origin on sloping topography (classes 1 to 5). Black spruce is often present (Table 2) and may eventually assume dominance (eg. plot 55). Labrador tea is usually abundant but dwarf shrub and herb cover is usually sparse (Table 1). The moss layer is dominated by a dense cover of *Pleurozium schreberi, Hylocomium splendens* and *Ptilium crista-castrensis* with lesser amounts of the lichen, *Peltigera aphthosa* which reaches its highest cover in this type. Constant species include *Ledum groenlandicum, Vaccinium vitis-idaea, Cornus canadensis, Linnaea borealis, Pleurozium schreberi* and *Peltigera aphthosa*. This type is similar to the lodgepole pine-black spruce-tall bilberry type but seems to occur in areas of lower precipitation at generally lower elevations. It lacks the tall bilberry which is often replaced by the blueberry (*Vaccinium myrtilloides*). Forest productivity is moderate (classes 4 and 5).

Soils are moderately well to imperfectly drained Orthic Gray Luvisols, Brunisolic Gray Luvisols, and "bleached" Gray Luvisols on Continental and Cordilleran till, lacustro-till and bedrock parent materials. Soil groups include Edson, Snipe, Torrens, Copton, Sheep, and Heart.

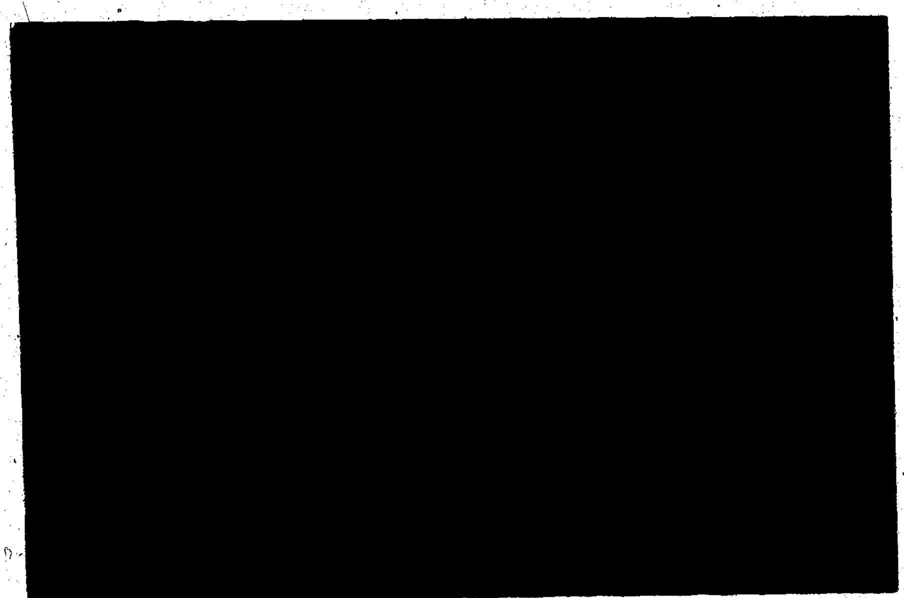
12. *Pinus contorta / Picea mariana / Ledum groenlandicum / Vaccinium membranaceum*

(plots 1,3,4,6,8,11,17,30,34,36,38,39,51,52,64,66,69,72,74-76, 79-82,98,110-112,115,137)

The lodgepole pine-black spruce-Labrador tea-tall bilberry forest type (Plate 10) is more extensive than any of the others in the 83L area and occurs on gently sloping (classes 1 to 5) sites of variable aspect from low to relatively high elevations (840 to 1465 m). It is characterized by young to fairly old (65 to 190 yr.) lodgepole pine and black spruce stands of fire origin. Black spruce forms a tree understory layer of approximately the same age as the pine. Black spruce and subalpine fir regeneration is often abundant (Table 2), indicating probable eventual succession to these species. *Ledum* often forms a dense low shrub understory, and herb cover is moderate. Constant species include *Ledum groenlandicum, Vaccinium membranaceum, Vaccinium vitis-idaea, Cornus canadensis* and *Linnaea borealis*. A dense feathermoss cover of *Pleurozium schreberi* and *Hylocomium splendens* is usual. This type is transitional to the *Pinus contorta /*



late 9 *Pinus contorta/Ledum groenlandicum/Pleurozium schreberi* type (Type 11).



late 10 *Pinus contorta/Picea mariana/Ledum groenlandicum -Vaccinium membranaceum* type (Type 12).

edum groenlandicum / Pleurozium schreberi* type at lower elevations. At he upper limits of type 12, *Rubus pedatus* is common, and *Menziesia glabella, hododendron albiflorum, Tiarella trifoliata,* and *Arnica latifolia* are poradic in occurrence. Forest productivity is moderate (class 5 with a ew exceptions).

Soils are moderately well to imperfectly drained Orthic Gray Luvisols, runisolic Gray Luvisols and "bleached" Gray Luvisols. Edson, Mayberne and arlboro are the predominant soil units.

3. *Pinus contorta / Menziesia glabella / Rubus pedatus*

(plots 32,33,35,40-42,53,54,125,132,134)

The lodgepole pine-false azalea type (Plate 11) is a subalpine forest ype restricted to the south and west portions of 83L at high elevations 1220 to 1555 m) and is characterized by young to fairly old (70 to 180 yr.) odgepole pine stands of fire origin. Black and white spruce and subalpine ir regeneration is commonly abundant in the older stands (Table 2) indicating robable eventual succession to these species. A shrub understory of *enziesia glabella* and often *Rhododendron albiflorum,* another characteristic pecies of subalpine forests is present. Herb cover is moderate. The ubalpine herb *Veratrum escholtzii* occurs sporadically within this type. he predominantly shrub understory could provide competition with tree eedlings following clearcutting on this type. Constant species include *enziesia glabella, Ledum groenlandicum, Vaccinium membranaceum, Vaccinium itis-idaea, Rubus pedatus, Cornus canadensis, Linnaea borealis, Lycopodium nnotinum, Pleurozium schreberi, Ptilium crista-castrensis* and *Hylocomium plendens*. Forest productivity is low (classes 5 and 6).

Soils are well to moderately well drained Brunisolic Gray Luvisols nd "bleached" Gray Luvisols on Continental till and thin Cordilleran till over bedrock parent materials. Mayberne is the predominant soil group with lesser occurrences of Marlboro, Torrens, and Robb.

14. *Pinus contorta / Vaccinium myrtilloides / Cladonia spp.*

(plots 16,56)

The lodgepole pine-blueberry-lichen type was not common and was only sampled twice. It is restricted to well drained, coarse textured soils. The tree canopy is open, and black spruce regeneration is usually present. This type is closely related to the lodgepole pine-Labrador tea-feathermoss type and is characterized by a similar climate and elevational range. Herb and moss cover is sparse but lichen cover may exceed 30%. Constant species include *Ledum groenlandicum, Vaccinium myrtilloides, Vaccinium vitis-idaea, Arctostaphylos uva-ursi, Cornus canadensis, Pleurozium schreberi,* and *Cladonia spp.* Forest productivity is low (class 6), probably due to limited soil water holding capacity.

Soils are well drained Orthic Humo-ferric Podzols and Eluviated Eutric Brunisols on outwash sand and alluvial sand parent materials. Blackmud is the predominant soil group.

15. *Picea engelmannii-Abies lasiocarpa / Menziesia glabella*

(plot 2)

The Engelmann spruce-subalpine fir-false azalea forests (Plate 12) form a climax type which occurs on steep (classes 5 to 7) north-facing slopes at high elevations (above 1670 m) in the south-west corner of the Wapiti map area. *Menziesia* may form a fairly dense shrub understory but herb and low shrub cover is generally sparse. Constant species include *Menziesia glabella, Phyllodoce empetriformis, Vaccinium membranaceum, Rubus pedatus, Pedicularis bracteosa, Cornus canadensis, Lycopodium annotinum*

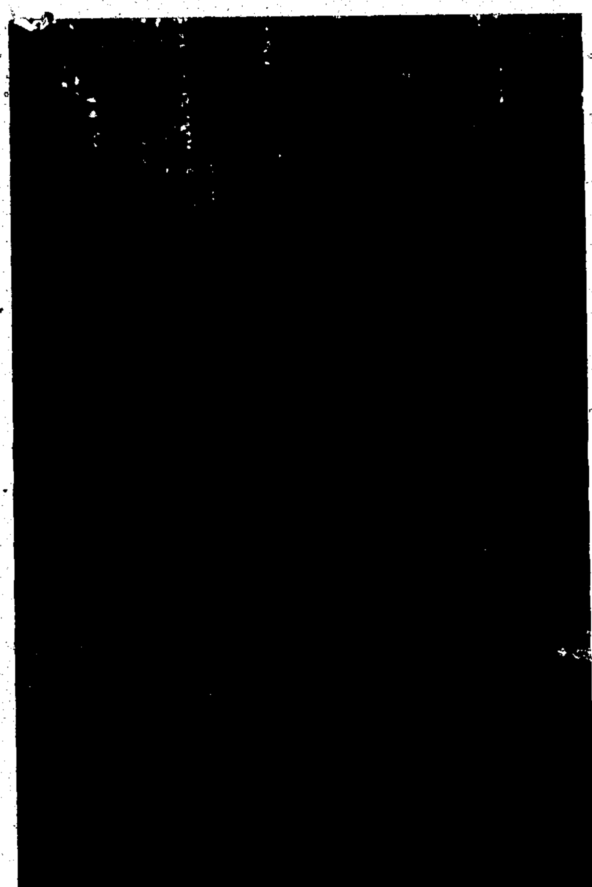


Plate 11 *Pinus contorta/Menziesia glabella/Rubus pedatus* type (Type 13).

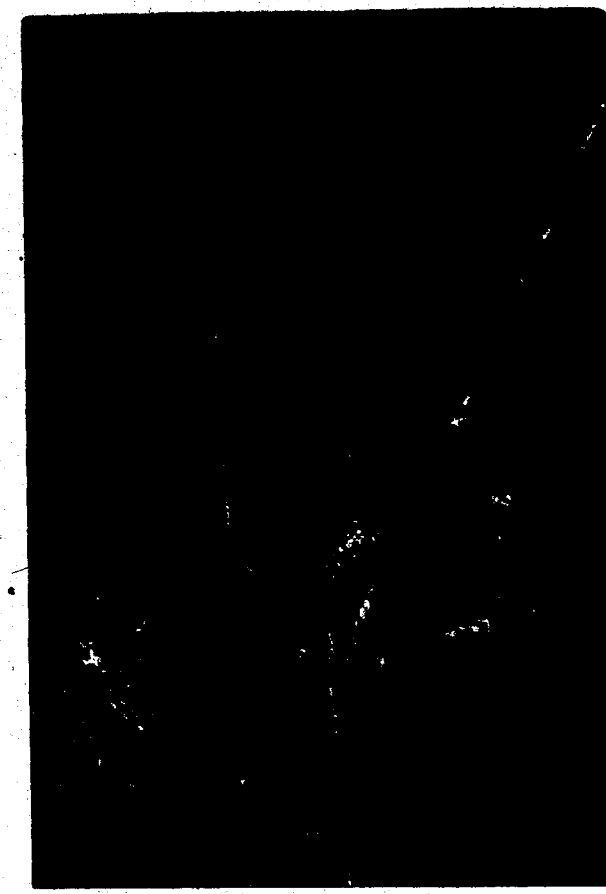


Plate 12 *Picea engelmannii-Abies lasiocarpa/Menziesia glabella* type (Type 15).

and *Arnica latifolia*. Tree growth is slow (classes 5 and 6) and stands are usually not suitable for commercial use. The type is species poor and would show a slow recovery after disturbance.

Soils are moderately well to imperfectly drained Orthic Gray Luvisols on Cordilleran till. Robb and Copton are the predominant soil **groups**.

C. GEOGRAPHIC RELATIONS AND OTHER STUDIES

The flora of the Wapiti map area is predominantly Boreal, though it contains Cordilleran and Pacific elements (Moss and Pegg 1963), notable species with primarily Cordilleran distribution are *Picea engelmannii, Abies lasiocarpa, Pinus contorta* var. *latifolia, Menziesia glabella, Rhododendron albiflorum, Sorbus scopulina, Spiraea lucida, Veratrum eschscholtzii, Rubus pedatus, Vaccinium membranaceum, Phyllodoce empetriformis* and *Arnica cordifolia*. Species with primarily Pacific distributions include *Oplopanax horridum, Rubus parviflorus, Sambucus pubens* and *Tiarella trifoliata*.

Comparisons between the forest types as described here and those described by other workers for the western boreal forest are in large part based upon subjective assessments of floristic composition and dominance due to a lack of published quantitative data. Early forest classifications such as those by Raup (1933, 1934, 1946) and Moss (1953, 1955, Moss and Pegg 1963) are general and in a single grouping may include several of the vegetation types described here. For example, the "upland spruce forests" referred to by Raup (1933, 1934, 1946) would include types 3, 4 and 5 of the present study.

In the following discussion, each of the forest vegetation types of the Wapiti map area are compared briefly with similar vegetation described by other authors for the western boreal forest.

The *Populus / Viburnum / Rubus* type is included within the aspen poplar consociation of the poplar association (Moss 1953) and bears strong resemblance to the *Populus / Aralia / Linnaea* ecosystem of Kabzems et al. (1976) described for central Saskatchewan, and appears to closely resemble the aspen forests at Candle Lake Saskatchewan described by Swan and Dix (1966; Dix and Swan, 1971). The aspen forests of the Wapiti map area bear somewhat less similarity to the *Populus tremuloides* variant of the *Ptilium crista-castrensis / Gymnocarpium dryopteris / Abies lasiocarpa-Picea glauca* association of Wali and Krajina (1973) and to the *Mitella-Cornus* subtype of the *Mitella-Tiarella-Rubus pedatus* type of Kujala (1945) described for north-eastern British Columbia.

The *Populus balsamifera / Rosa acicularis / Thalictrum venulosum* type corresponds to the balsam poplar consociation of the poplar association (Moss 1953) and is similar to the balsam poplar forest vegetation described by Dix and Swan (1971) for the Candle Lake area of Saskatchewan.

Vegetation bearing close resemblance to the *Picea / Rubus-Maianthemum* type has been described by authors in Alberta and Saskatchewan. This vegetation corresponds to the white spruce-shrub-herb faciation of the white spruce association described for Alberta by Moss (1953); is included within the *Lonicera / Rubus-Lathyrus* group described by LaRoi (1967) for western Canada and within the *Picea-Abies / Viburnum-Hylocomium* community type of Achuff and LaRoi (1977) described for the highlands of northern Alberta and appears very similar to the white spruce-sarsaparilla association of Lesko and Lindsay (1973). There is also close similarity to the *Picea glauca / Populus / Cornus / Rubus* ecosystem of Kabzems et al. (1976) described in central Saskatchewan and to the white spruce vegetation described by Swan and Dix (1966) and Dix and Swan (1971) in the Candle Lake area of Saskatchewan. The most similar described vegetation to the west of the Wapiti area is the *Ptilium crista-castrensis / Gymnocarpium dryopteris / Abies lasiocarpa-Picea glauca* association described by Wali and Krajina (1973) for north-eastern British Columbia.

The *Picea glauca / Equisetum arvense / Hylocomium splendens* type corresponds to the feathermoss faciation of the white spruce association described for Alberta by Moss (1953); is included within the *Picea-Abies / Viburnum / Hylocomium* community type of Achuff and LaRoi (1977), described for the highlands of northern Alberta and appears very similar to the white spruce / horsetail association of Lesko and Lindsay (1973) described in west-central Alberta and appears comparable to the *Picea glauca-Equisetum* ecosystem described by Kabzems et al. (1976) for central Saskatchewan. Somewhat similar vegetation described to the west of the study area includes the *Gymnocarpium dryopteris / Oplopanax horridum / Abies lasiocarpa-Picea glauca* association described by Wali and Krajina (1973) for north-eastern British Columbia and the *Mitella-Equisetum* "colony" of Kujala (1945) described in eastern British Columbia.

The *Picea glauca / Hylocomium splendens* type is also included within the feathermoss faciation of the white spruce association described for Alberta by Moss (1953) and appears to be analogous to the white spruce-feathermoss association of Lesko and Lindsay (1973) and to the *Picea glauca / Pleurozium* type of Kabzems et al. (1976) on well drained sites in central Saskatchewan.

The *Picea mariana / Ledum groenlandicum / Equisetum arvense* type is included within the black spruce bog forest described for Alberta by Lewis et al. (1928); within the black spruce-feathermoss association of Moss (1953) and within the *Vaccinium vitis-idaea-Fragaria-Maianthemum* stand group in the *Picea mariana / Rosa-Ribes triste / Mitella-Mertensia* group described for western Canada by LaRoi (1967). The black spruce-Labrador tea-horsetail forests in the Wapiti area also seem to correspond closely to the *Picea mariana / Pleurozium / Hylocomium* ecosystem described by Kabzems et al. (1976) and to the *Sphagnum nemoreum-Pleurozium schreberi-Ptilium crista-castrensis-Hylocomium splendens-Cornus canadensis / Picea mariana* association described by Wali and Krajina (1973).

The *Picea mariana / Ledum groenlandicum / Rubus chamaemorus* type is also included within the black spruce bog forest of Lewis et al. (1928); within the black spruce-peat moss association of Moss (1953) and is included within the black spruce-peat moss bog association of Lesko and Lindsay (1973). This vegetation type corresponds to the *Picea mariana / Ledum / Sphagnum* ecosystem of Kabzems et al. (1976).

The *Pinus contorta / Viburnum edule / Rubus pubescens* type and the *Pinus contorta / Spiraea lucida / Cornus canadensis* type do not appear to have counterparts described for the western Boreal Forest region but the lodgepole pine forests of the Wapiti area have in general, floristic composition similar to those described by Newsome and Dix (1968) for the Cypress Hills of Alberta and Saskatchewan. The *Pinus contorta / Alnus crispa / Cornus canadensis* type appears most similar to the *Pinus / Pleurozium / Lycopodium* ecosystem of Kabzems et al. (1976) with the major difference being that *Pinus banksiana* seems to occupy soils and aspects in Saskatchewan similar to those occupied by *Pinus contorta* in the Alberta foothills.

The *Pinus contorta / Ledum groenlandicum / Pleurozium schreberi* type most closely resembles the *Pinus / Picea mariana-Pleurozium* ecosystem of Kabzems et al. (1976) with the exceptions that in Saskatchewan, jack pine substitute for lodgepole pine and black spruce appears to be more abundant in the comparable community. The *Pinus contorta / Vaccinium vitis-idaea* type of Kujala (1945) also appears to be comparable.

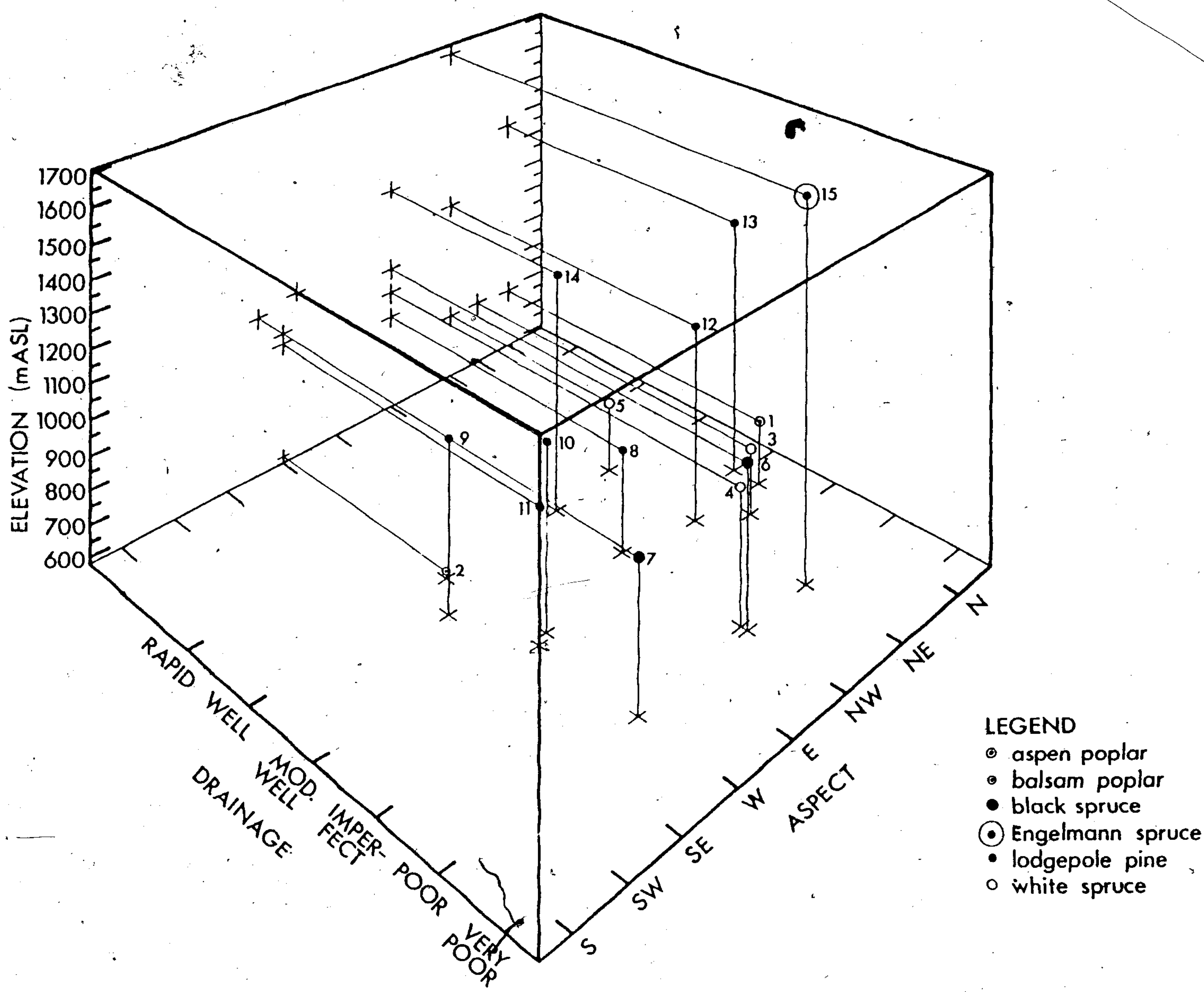
The *Pinus contorta / Picea mariana / Ledum groenlandicum / Vaccinium membranaceum* type bears most resemblance to the *Vaccinium membranaceum* type described by Kujala (1945) for eastern British Columbia which is much more species rich than its Alberta counterpart. The *Pinus contorta / Menziesia glabella / Rubus pedatus* type is primarily subalpine rather than boreal in its distribution and is most comparable to the *Vaccinium membranaceum* type described by Kujala (1945) but is not as species rich as the British Columbia community. Similar vegetation is common in the mountains of Jasper and Banff to the south (Corns and Kojima 1976). In time, the lodgepole pine will be replaced by Engelmann spruce and subalpine fir, as it has been in some of the high elevation forests of the Wapiti area. The Engelmann spruce-subalpine fir-false azalea type is most similar to the subalpine *Menziesia-Vaccinium membranaceum* "colony" and the subalpine *Tiarella trifoliata-Rubus pedatus / Rhododendron albiflorum* "colony" described by Kujala (1945) but is not as species rich as the British Columbia representatives.

The *Pinus contorta / Vaccinium myrtilloides / Cladonia* spp. type has a similar counterpart in the *Cladonia gracilis-Arctostaphylos uva-ursi-Vaccinium myrtilloides / Pinus contorta* association described by Wali and Krajina (1973). It is also comparable to the drier stands of the *Pinus / Vaccinium vitis-idaea / Pleurozium* ecosystem described by Kabzems et al. (1976) except that in Saskatchewan jack pine substitutes for lodgepole pine on rapidly drained sandy sites.

D. INFLUENCE OF ELEVATION, ASPECT AND INTERNAL SOIL DRAINAGE ON VEGETATION TYPE

A three variate representation of vegetation type relationships in

Figure 4: Comparison of the 15 vegetation types of the Wapiti map area with respect to elevation, slope aspect and internal soil drainage.



ELEVATION (mASL)
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
RAPID
WELL
MOD. WELL
IMPER-FECT
POOR
VERY POOR
DRAINAGE
S
SW
SE
W
E
NW
NE
N
ASPECT
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
LEGEND
aspen poplar
balsam poplar
black spruce
Engelmann spruce
lodgepole pine
white spruce

the form of a cube helps to clarify some of the site differences among vegetation types. Figure 4 illustrates such relationships where soil drainage is represented on the X axis, elevation on the Y axis and slope aspect (arranged in order of decreasing insolation received) on the Z axis. Warm, low, dry situations are represented in the bottom left corner and cool, high, moist situations are represented in the upper right corner. The mean elevation and drainage and the modal aspect were plotted for each of the 15 vegetation types sampled.

It is apparent from an examination of Fig. 4 that several of the vegetation types occur on predominantly northerly aspects. Others seem to have no preference for slope aspect and were thus plotted on a neutral (westerly) aspect. Why some vegetation types do not show more pronounced affinities for southerly aspects is not apparent.

As predominant elevation, soil drainage and slope aspect have previously been described for each of the vegetation types, only pronounced similarities in these factors between floristically distinct vegetation types will be discussed in this section. It is expected that the three-dimensional presentation should show for example, successional stages of a particular type in a similar position on the graph, assuming that the successional stages had initially been recognized as separate vegetation types.

On the basis of elevation alone, the aspen (Type 1) and balsam poplar forests (Type 2) are separated at low elevations from the other vegetation types. The Engelmann spruce forests (Type 15) and the lodgepole pine-false azalea type (Type 13) are separated from the other types at high elevations. Most of the other lodgepole pine, white spruce and black spruce types cannot be separated on the basis of elevation alone.

When soil drainage alone is considered, the black spruce bog forests (Type 7), the black spruce-horsetail forests (Type 6) and the white spruce-horsetail forests (Type 4) can be separated from the other forest types. These three spruce types are similar to each other with respect to elevation and slope aspect also. When other factors are considered, it is apparent that the black spruce bogs are usually nearly level and that the water table is very high. Reducing conditions are present at depth due to the anaerobic situation. The white spruce-horsetail type (Type 4) and the black spruce-labrador tea-horsetail types (Type 6) both occur on gentle northerly slopes but the latter occurs on predominantly organic soils as opposed to mineral in the former, and with generally poorer drainage. The floristic composition of these sites further separates them. The white spruce-feather-moss type (Type 5) is separated from the other white spruce types by the higher elevations and better drained soils. The *Picea glauca / Rubus pubescens-Maianthemum canadense* type (Type 3) is moderately well to imperfectly drained and intermediate with respect to internal drainage between the other white spruce types. On Fig. 4, Type 3 is similar to the *Pinus contorta / Viburnum edule / Rubus pubescens* type (Type 8) with respect to elevation, soil drainage and aspect, type 3 having slightly more restricted soil drainage than type 8. The ages of stands of the two types overlap. Species composition of the two types is similar and it appears likely that type 8 would succeed towards vegetation similar to type 3 under the shade of the lodgepole pine canopy.

Type 8 also has affinities with the *Pinus contorta / Spiraea lucida / Cornus canadensis* type (Type 9), from which it differs by having soils with slightly more impeded drainage than type 9. Type 9 might also be expected to succeed toward the *Picea glauca / Rubus pubescens-Maianthemum canadense* type (Type 3) as might the aspen type (Type 1). Successional relationships may be hypothesized with the aid of Figure 4 and will be discussed in more detail in a later section.

Lodgepole types 10, 11 and 12 show differences in soil drainage and mean elevation (Fig. 4). Other differences are described in the type descriptions. They develop independently and are not related successionally to each other. The lodgepole pine-blueberry-lichen type (Type 14) most closely resembles the white spruce-feathermoss type (Type 5) in terms of elevation, soil drainage and aspect but floristically most closely resembles the lodgepole pine-black spruce-Labrador tea-tall bilberry type (Type 12). The lodgepole pine-blueberry-lichen type (Type 14) is likely an edaphic climax due to the difficulty encountered by spruce and fir regeneration in soil with low moisture reserves.

E. SUCCESSIONAL RELATIONSHIPS

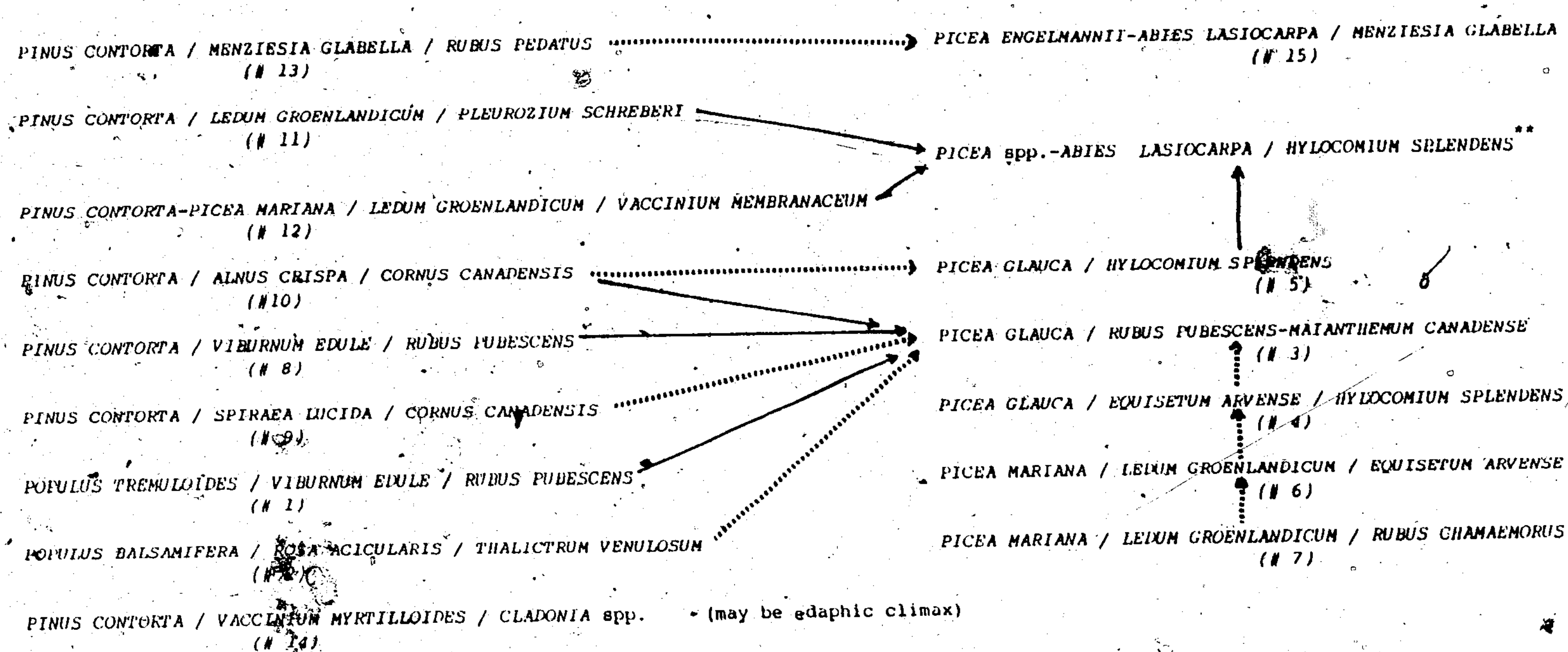
The forests of the Wapiti map area are in general very young, and with a few exceptions are first generation stands which have arisen in the last 200 years. The 15 forest types described have for the most part originated independently and have not succeeded from one of the others. In general most of the area appears to be succeeding toward a white spruce or mixed spruce-subalpine fir climax, on the basis of the presence of these species in the understory layers of many of the present forests (Table 2).

In the mixedwood of the north-eastern portion of the map area, white spruce-dominated stands often occur in depressions within largely aspen-dominated forests. It thus appears that the cool, north-facing slopes and sites with impeded drainage seem to succeed toward their potential "climax" or more stable condition before those in better drained locations.

Figure 5 suggests possible successional relationships between the forest types. The dotted lines indicate extremely slow succession, of the order of hundreds of years. The solid lines indicate more rapid succession,

Figure 5: Suggested successional relationships of vegetation types within the Wapiti map area.*

Vegetation type number is in parentheses.



* - Dotted lines indicate extremely slow succession (several hundred years)
Solid lines indicate more rapid succession (100-300 years)

** - Anticipated climax - no plots sampled of the order of 100 to 300 years from present. In general, the spruce-dominated vegetation is more stable than the lodgepole pine-dominated vegetation, though it is apparent that succession within some of the lodgepole pine types is proceeding very slowly. For example, the nearly 200-year old *Pinus contorta/Menziesia glabella/Rubus pedatus* forests are very similar physiognomically and floristically to much younger (less than 100 yr.) stands on similar sites.

In general it appears that there are at least two successional trends from the present forest vegetation to climax: lodgepole pine, aspen and balsam poplar to white spruce; and lodgepole pine and upland black spruce to mixed spruce-subalpine fir forests (Figure 5). The *Pinus contorta / Ledum groenlandicum / Pleurozium schreberi* type and the *Pinus contorta-Picea mariana / Ledum groenlandicum / Vaccinium membranaceum* type appear to be succeeding towards forest vegetation dominated by *Picea glauca, P. engelmannii* (and hybrids of these two), *P. mariana* and *Abies lasiocarpa*. Lodgepole pine is absent or present only as a relic. The understory is floristically poor in the spruce-fir-feathermoss type with the most prominent feature being a nearly complete cover of *Hylocomium splendens*. The mature or climax *Picea* spp. / *Abies lasiocarpa-Hylocomium splendens* forests are sporadic in occurrence and were not sampled due to their "overmature" appearance, being unsuitable for stem analysis sampling.

The other major successional trend appears to be from types 10, 8 and 1 to *Picea glauca/Rubus pubescens-Maianthemum canadense* (Type 3) forests based upon understory similarities and often abundant white spruce regeneration in the pine and aspen forests. Succession appears to be proceeding at different rates, being most rapid on the moister **sites**. Types 9 and 2 seem to be heading towards type 3 also, but much more slowly. It is unlikely that the balsam poplar forests will succeed to white spruce as long as frequent flooding occurs, covering young spruce seedlings with fresh alluvium.

Other successional trends are less evident. The black spruce-Labrador tea-horsetail forests (Type 6) might be expected to succeed towards the white spruce-horsetail-feathermoss forests (Type 4) if drainage in the former was improved by man or on a much longer time scale, by regional lowering of the water table. White spruce commonly forms a minor component in Type 6 forests (Table 2). Succession from black spruce bog vegetation (Type 7) towards the black spruce-Labrador tea-horsetail forests (Type 6) and from white spruce-horsetail-feathermoss forest (Type 4) to white spruce-dewberry-two leaved Soloman's seal forests (Type 3) might similarly occur with increased soil drainage in type 6 in the former case and type 4 in the latter. A certain amount of drying of the site might be expected to occur naturally since the growing trees of the maturing forest seem likely to demand more water for growth, and transpiration, though quantitative data are scarce (Satterlund 1972 p. 141).

The lodgepole pine-green alder-bunchberry type (Type 10) might go in one of two directions (Fig. 5); towards Type 3 on imperfectly drained sites or towards the better drained white spruce feathermoss forest (Type 5) if the site was currently well drained. The former appears more likely since most of the pine-alder forests tend to be more imperfectly than well drained. Type 5 in time, with maturation of the already abundant *Abies lasiocarpa* seedlings present in many stands (Table 2) will probably succeed towards the *Picea* spp.-*Abies lasiocarpa* / *Hylocomium splendens* type.

In the past, due to the frequency of large devastating fires, climax forest development was achieved only in isolated areas. Today, with greatly improved access and modern fire suppression techniques, fires are much smaller and less intense than those of 75 to 85 years ago when most of the lodgepole pine stands in the Wapiti map area originated (Table 3). However, it is still unlikely that climax forest conditions will be achieved over large areas even in the absence of fire, due to logging and pulp-cutting activities, which are likely to result in successional series somewhat different from those after fire.

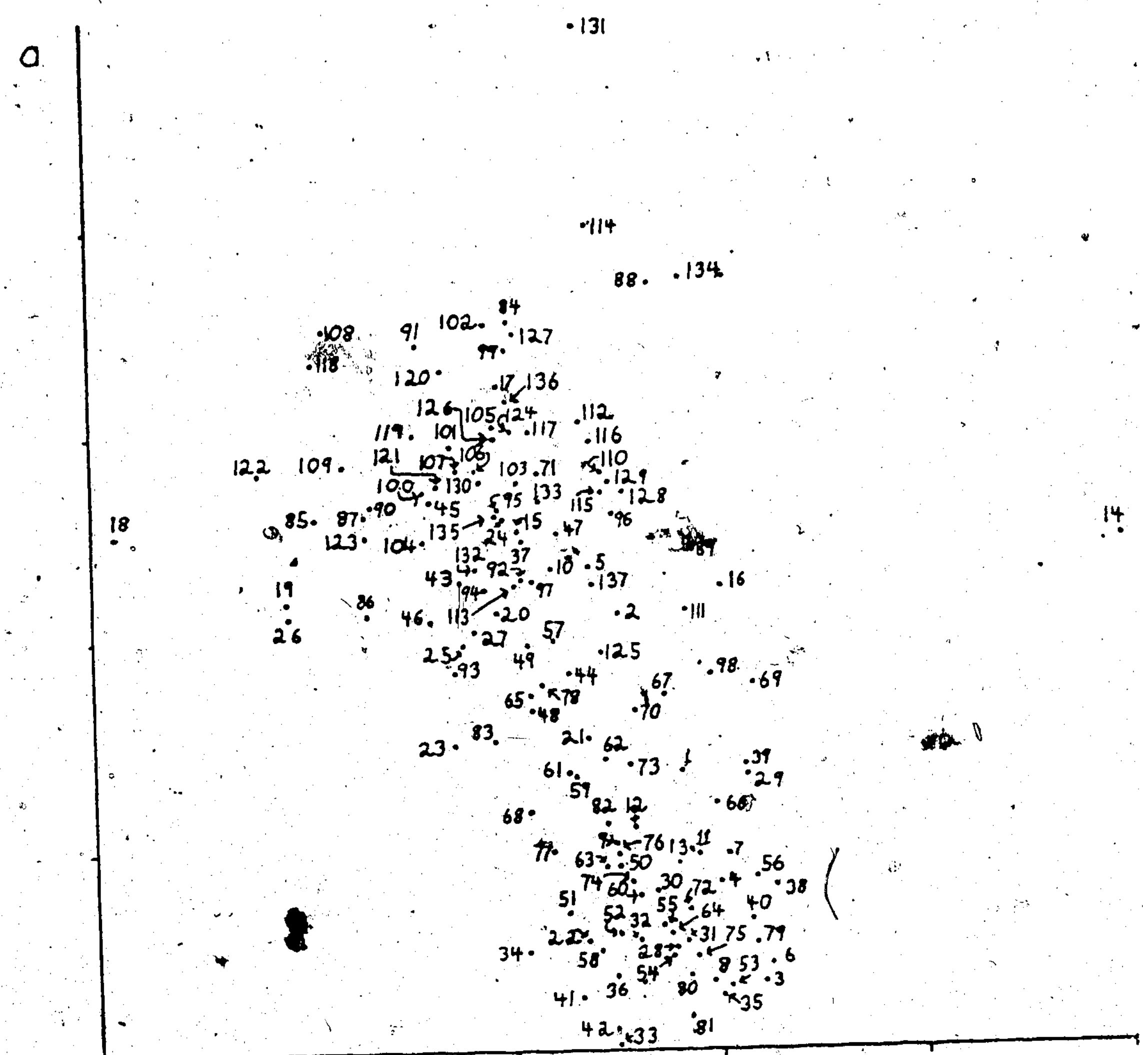
If succession was permitted to continue, vegetation similar to that depicted in Figure 5 might be expected to develop, with a number of diverse early successional stages on different physical sites converging towards a small number of climax or mature forest types in the course of hundreds of years under the influence of regional climate, sensu Clements (1916 et seq.).

F. ORDINATION OF STANDS

The purposes of this section are to describe the vegetational interrelations of the 137 sampled plots and to integrate these relationships with physical habitat data from the plots, using the ordination method of continuous classification developed by Bray and Curtis (1957).

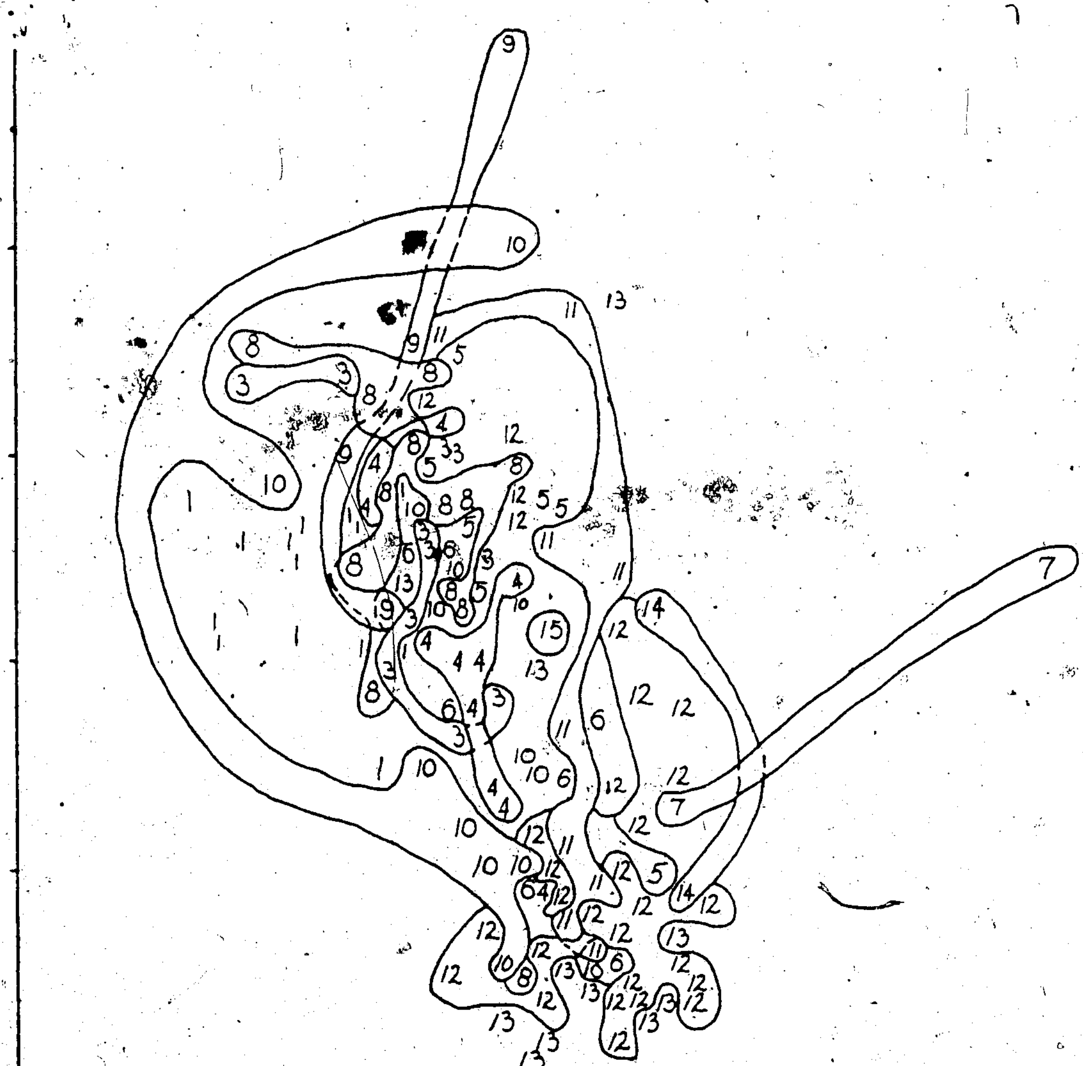
A two-dimensional ordination was constructed using the method of Beals (1960) (Fig. 6a) and an index of vegetational similarity (Bray and Curtis 1957): I=2W/a+b, where a=sum of quantitative values of all species in stand A, b= the same for stand B, and W= sum of quantitative values the two stands have in common. Prominence value (Beals 1960) data for all vascular species (except trees) were used in calculating dissimilarity indices (I-1), where PV = mean cover% X$\sqrt{\text{(frequency \%)}}$. To test the validity of the ordination, 80 random pairs of stands were selected, and a correlation coefficient calculated between interstand ordination distances as measured with a ruler on the ordination field, and the indices of dissimilarity. The r value obtained was significant at the 1% level.

Figure 6: Ordination of the 137 plots showing the distribution of the vegetation types, several individual species populations and soil groups on the ordination field: (a) Plot numbers, (b) Vegetation types, (c) Dominant tree species, (d) *Pyrola asarifolia*, (e) *Rubus pubescens*, (f) *Ledum groenlandicum*, (g) *Hylocomium splendens*, (h) *Pleurozium schreberi*, (i) Soil group.



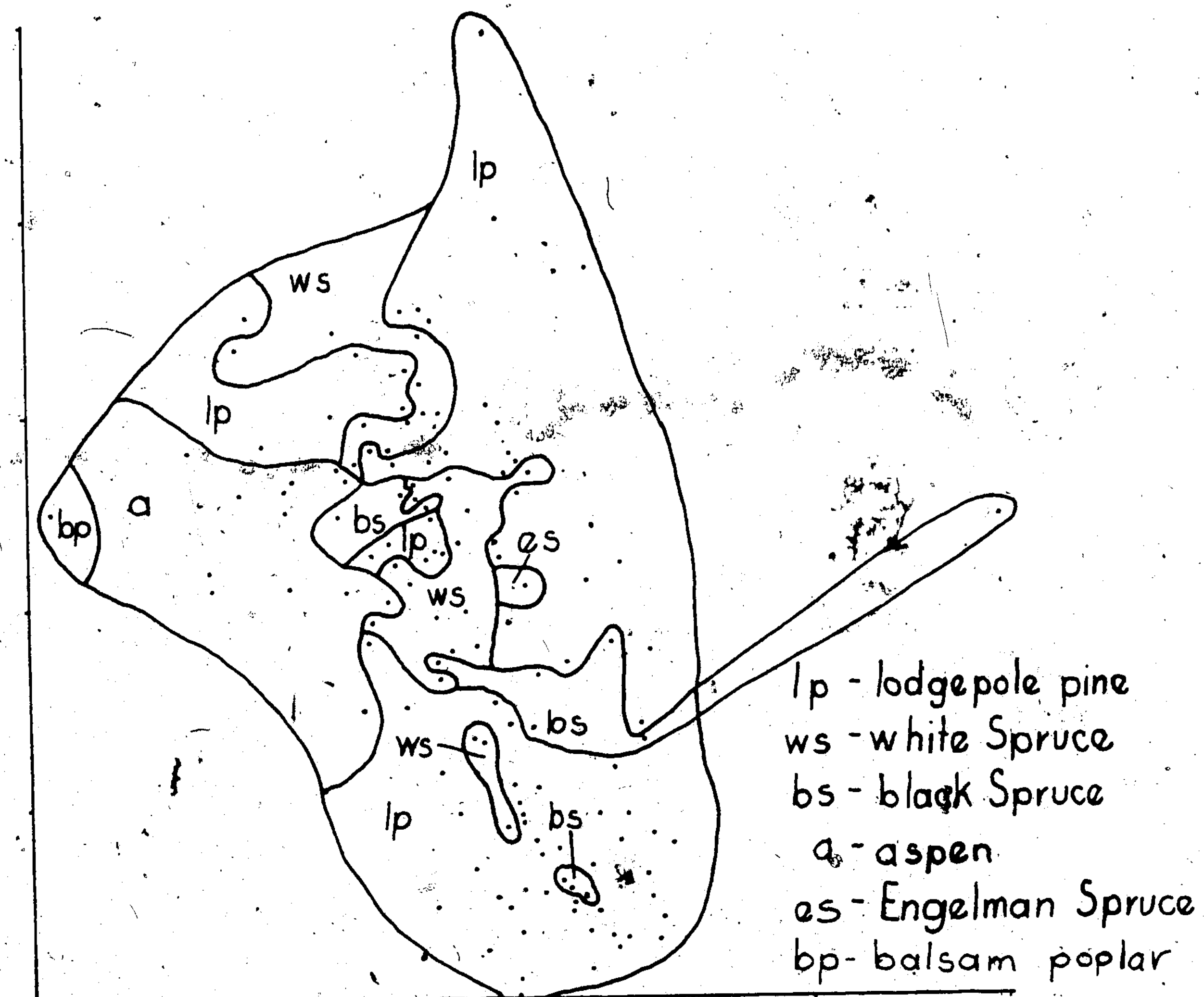
Plot Numbers..

b

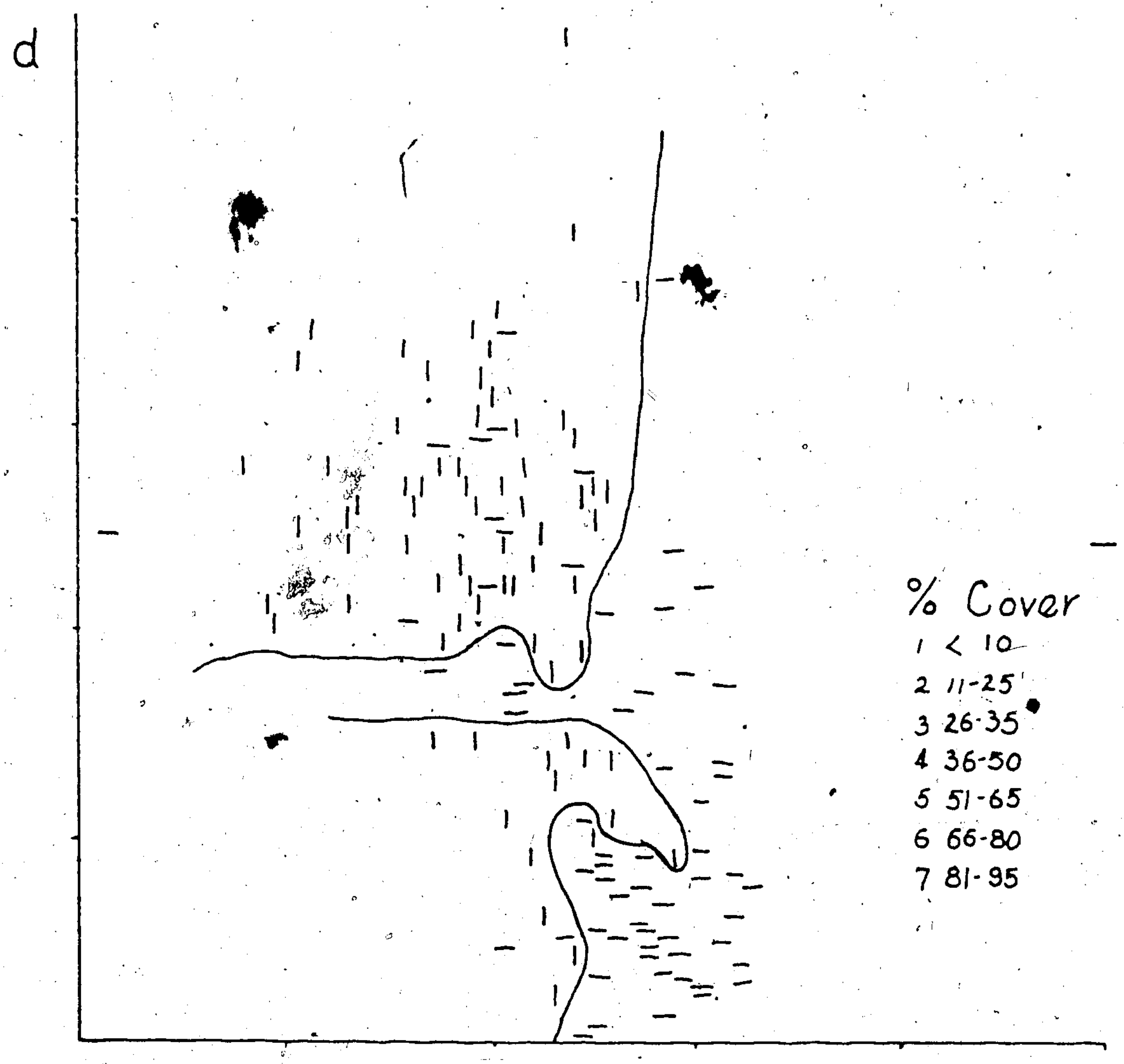


Vegetation Types

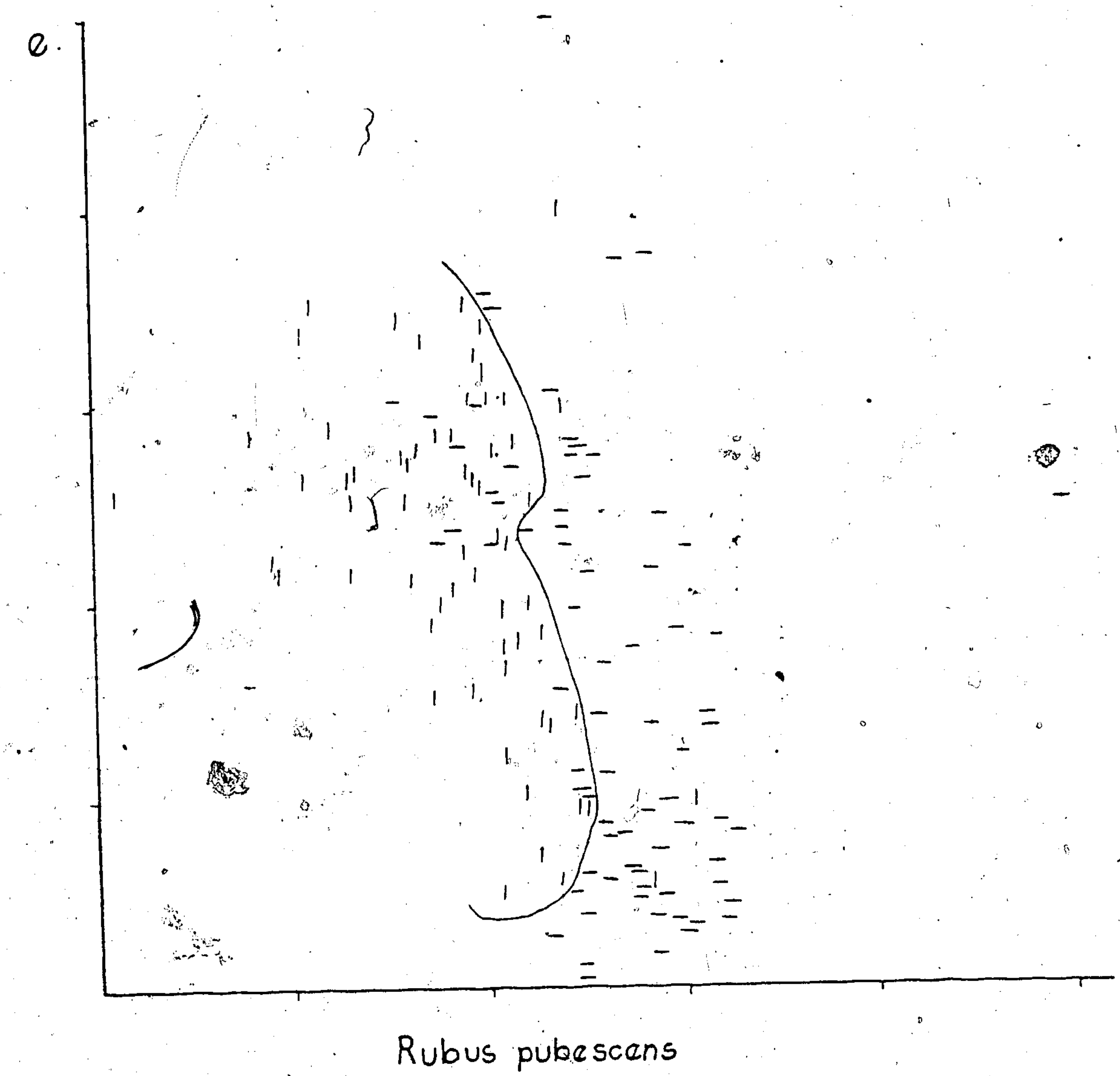
C.

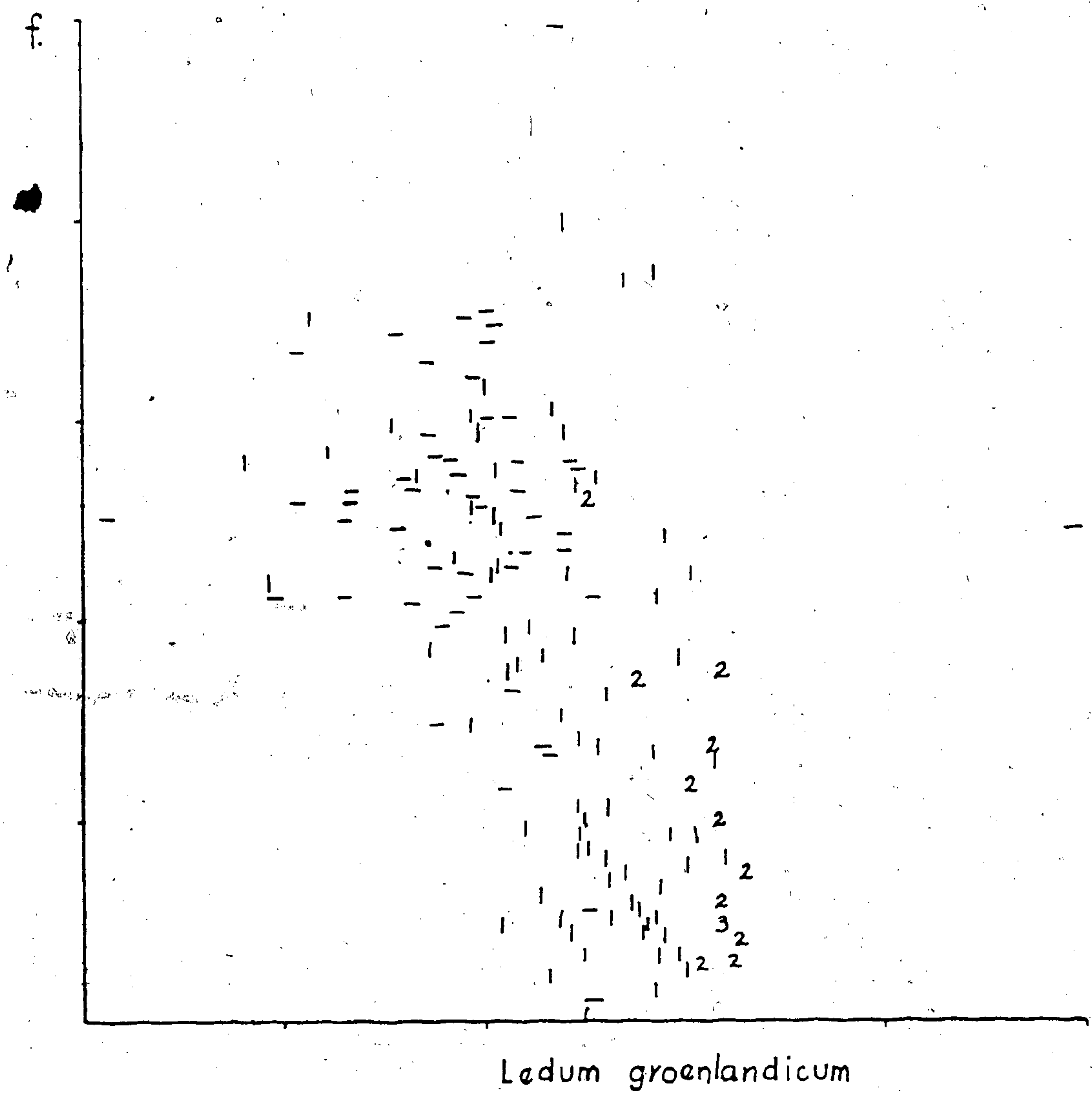


Dominant Tree Species

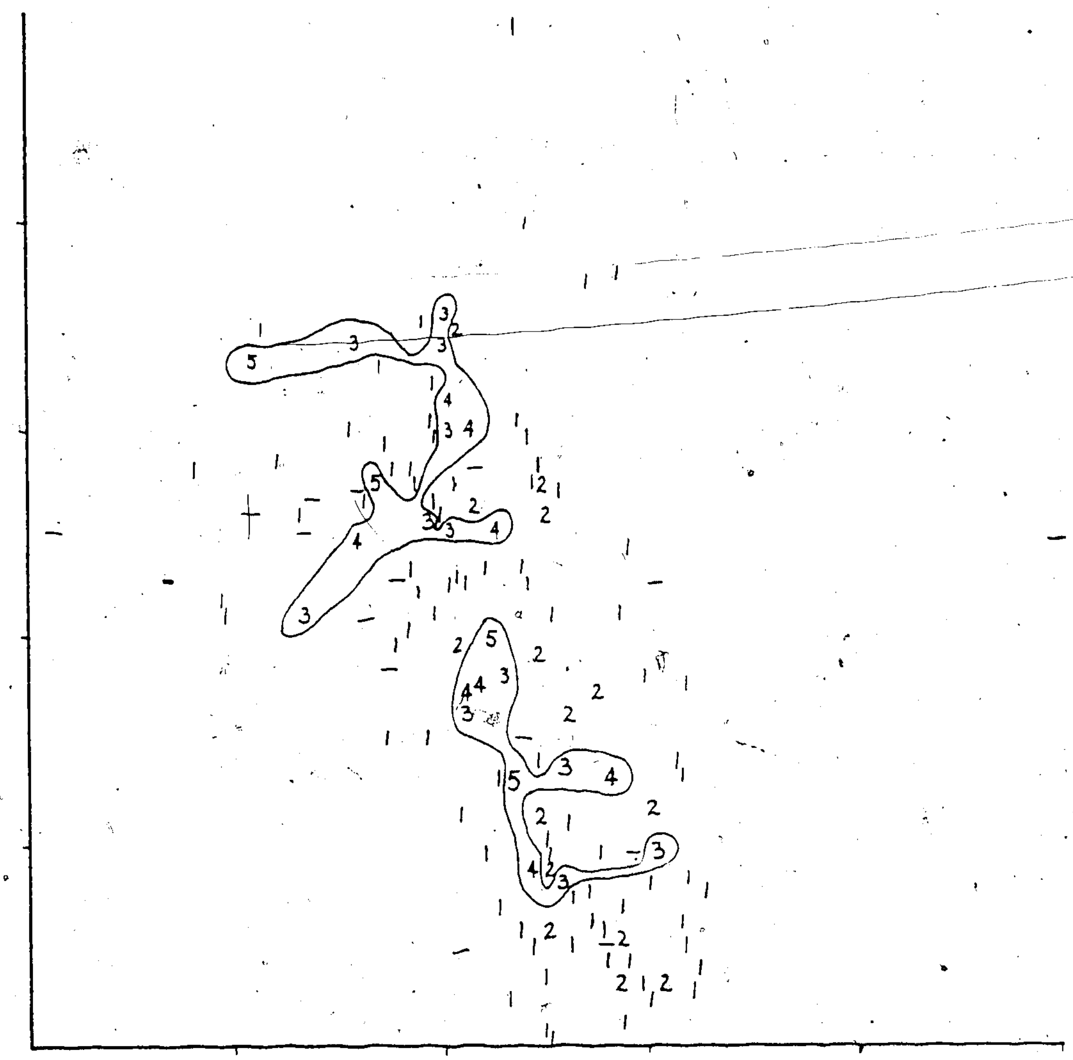


Pyrola asarifolia

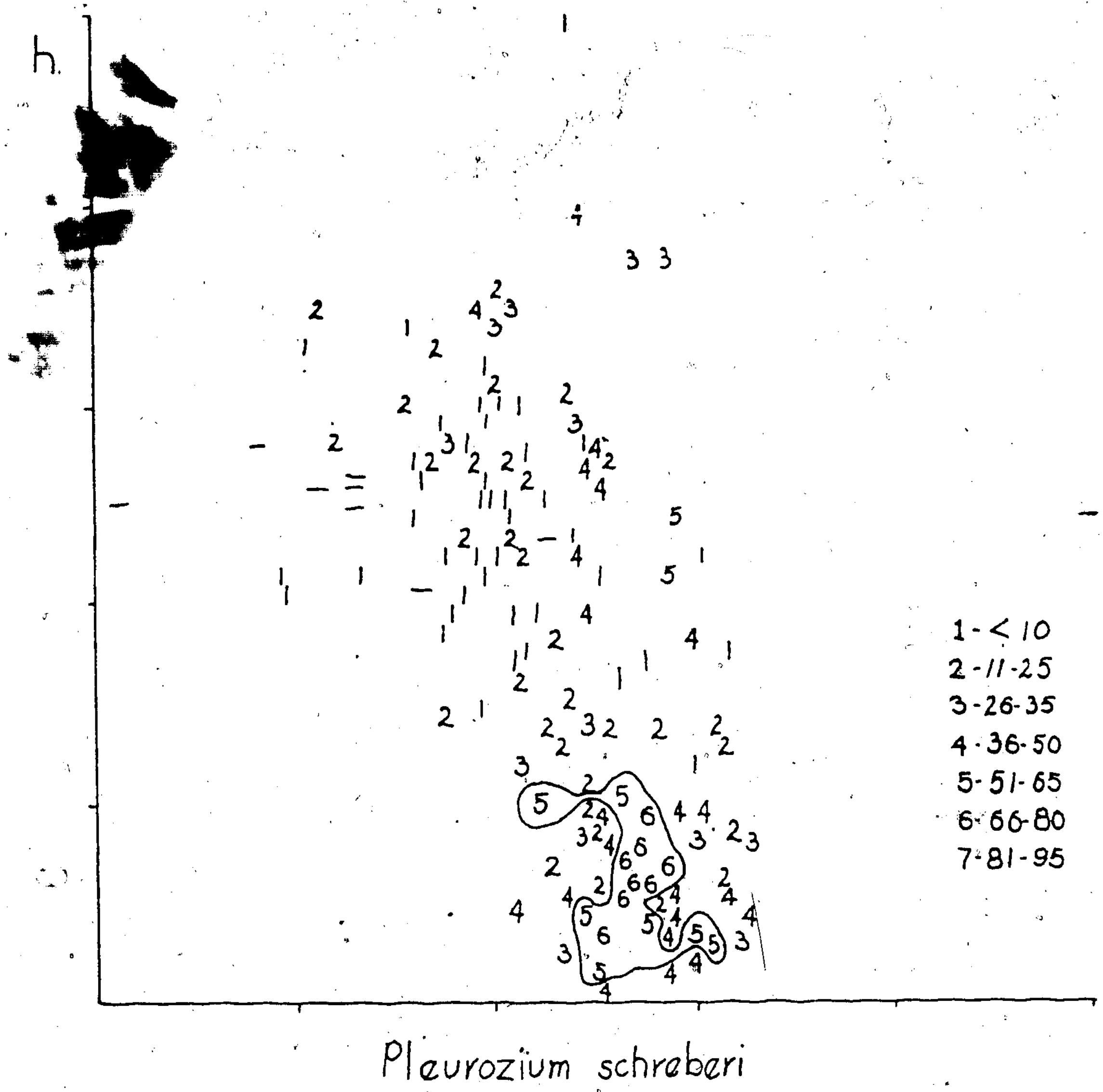

e.
Rubus pubescens

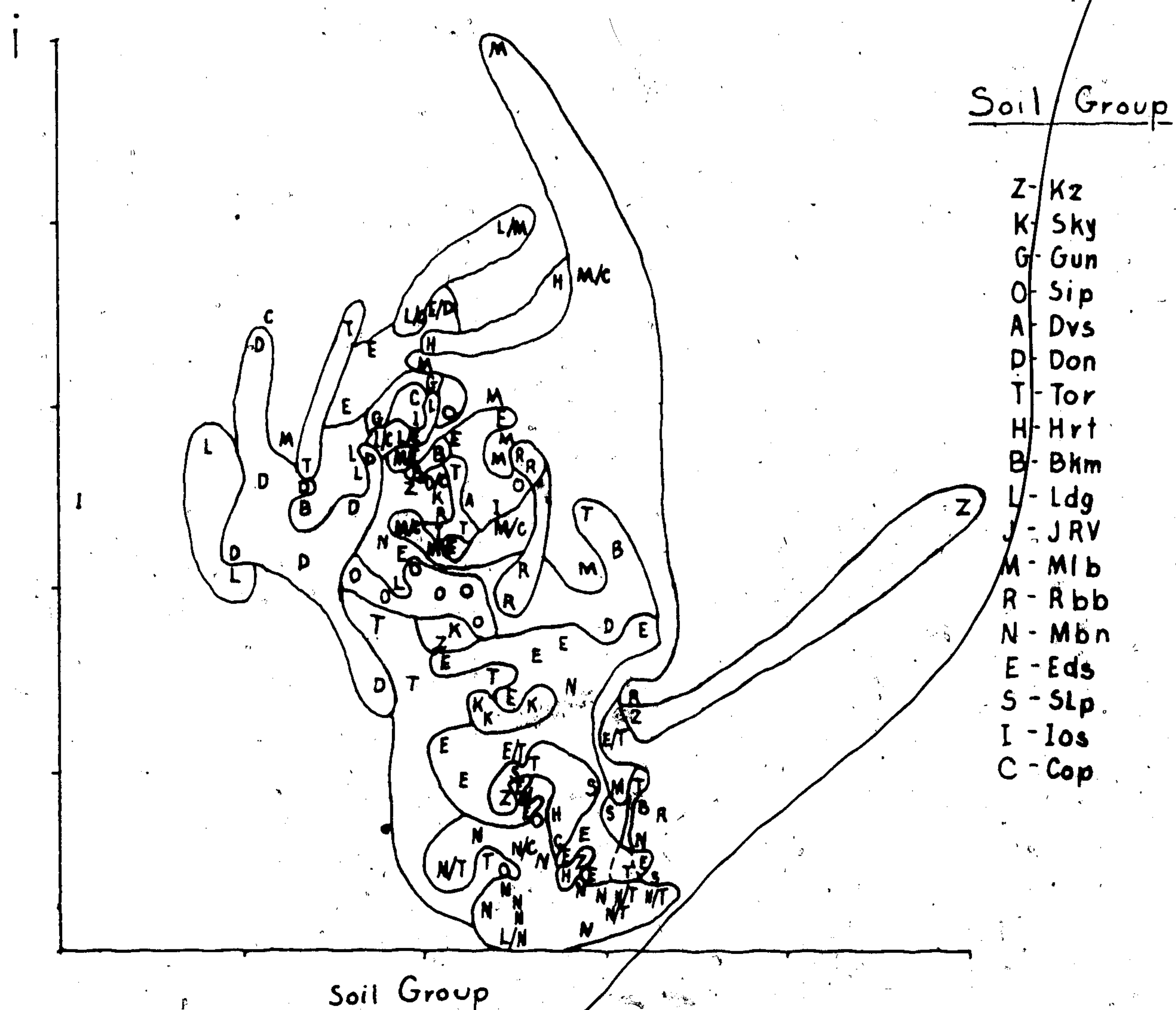

f.
Ledum groenlandicum

g.



Hylocomium splendens


h.
1-< 10
2-11-25
3-26-35
4-36-50
5-51-65
6-66-80
7-81-95
Pleurozium schreberi


Soil Group
Z - Kz
K - Sky
G - Gun
O - Sip
A - Dvs
D - Don
T - Tor
H - Hrt
B - Bkm
L - Ldg
J - JRV
M - Mlb
R - Rbb
N - Mbn
E - Eds
S - SLp
I - Ios
C - Cop
Soil Group

When the 15 vegetation types are delineated on the ordination field (Fig. 6b), it is apparent that several of the types are not distinct from adjacent plots of another type. This situation arises as a result of the inclusion of species with high cover. Some types have similar understory vegetation but different tree dominants. Prominence values for the tree stratum were not calculated and were not included because of their tendency to determine the ordination due to their generally high cover values. The position of the plots on the ordination field is determined largely by the species with the highest cover values; that is, these species contribute the most to the a and b values in the similarity index calculation. The most abundant plant species, for example lodgepole pine, are often not the best indicators of the environment or physical habitat. As discussed previously, the vegetation types were distinguished according to species which are by inference, indicative of certain environmental or habitat conditions.

The distribution of certain species within the 137 plots becomes apparent when their cover values are plotted on the ordination field. Tree cover did not enter into the similarity value calculations, but it became apparent that plots with aspen-or white spruce-dominated canopies occurred together on the ordination field. These groupings indicate an assemblage of understory species that separate the aspen and white spruce plots from lodgepole pine-dominated plots for example (Fig. 6c). The white spruce, black spruce and lodgepole pine groupings are discontinuous, indicating differences in understory vegetation. These differences are discussed in the previous section.

Many other individual species show patterns on the ordination. Five of these are illustrated. *Pyrola asarifolia* (Fig. 6d) is most likely to occur in the white spruce, aspen, and lodgepole pine-green alder (Type 10) stands. *Rubus pubescens* (Fig. 6e) shows a similar distribution. *Ledum groenlandicium* (Fig. 6f) is most abundant in the black spruce-dominated stands and in the lodgepole pine-black spruce-Labrador tea-tall bilberry type. The two most common feathermosses also show patterns on the ordination. *Hylocomium splendens* (Fig. 6g) is most abundant in the white spruce and in the imperfectly drained black spruce stands. *Pleurozium schreberi* (Fig. 6h) on the other hand, is most abundant in the lodgepole pine-dominated stands.

When the various soil units are plotted on the ordination (Fig. 6i) some order is apparent. Certain vegetation types and individual plant species have a higher frequency of occurrence on some soils than on others. Relationships between vegetation types and soils are discussed in more detail in a previous section.

G. DUNCAN'S MULTIPLE RANGE TESTS

One of the original objectives of this study was to compare the site productivity of the various soil map units. Duncan's (1955) multiple range test is an appropriate means of testing for statistically significant differences amoung soil map units. However, when MAI for the 137 plots was stratified according to map unit, it became apparent that productivity varied widely within units and that there were very few plots sampled within some units. It is likely that much of the site variation within soil units is due to soil and topographic features that are important to tree growth, but that are not well described in soil unit definitions. For example, surface soil depth, subsoil texture, aspect, slope position and slope gradient are factors often closely related to site quality but may vary widely within definitions for certain soil mapping units (Carmean 1977).

Thus, much of the variability in MAI within the Wapiti soil units is likely due to the exclusion of, or lack of definition of important site factors in, the map unit definitions. Duncan's tests on MAI among the soil units are therefore not included here. Differences in MAI for all plots, and in site index for pine-dominated plots could be more readily demonstrated.

The results of Duncan's (1955) multiple range test on means of mean annual increment in total volume (MAI) among the 15 vegetation types and on means of lodgepole pine site index in the seven pine-dominated types are illustrated in Figs. 7 and 8. Duncan's tests on means of site index at 70 years were done only for the lodgepole pine types.

The most productive type with respect to MAI was the *Populus balsamifera/Rosa acicularis/Thalictrum venulosum* forest (Type 2). The aspen forests (Type 1) ranked third overall in terms of MAI with a mean of 4.3 $m^3ha^{-1}yr^{-1}$ (Fig. 7).

The most productive white spruce forest type in terms of MAI was the *Picea glauca/Rubus pubescens-Maianthemum canadense* type (Type 3) with a mean MAI of 4.7 $m^3ha^{-1}yr^{-1}$ (Fig. 7). The least productive white spruce type in terms of MAI (3.6 $m^3ha^{-1}yr^{-1}$) was type 5, *Picea glauca / Hylocomium splendens*.

Several of the lodgepole pine forest types were more productive than some of the white spruce types. The most productive pine type was type 8, *Pinus contorta/Viburnum edule/Rubus pubescens*, which occupies similar sites to white spruce type 3 (Fig. 4). The average MAI in type 8 was 4.2 $m^3ha^{-1}yr^{-1}$ (Fig. 7); mean site index for pine was 19.8 m at 70 years (Fig. 8). The least productive lodgepole pine forest type was type 14, *Pinus contorta/Vaccinium myrtilloides/Cladonia* spp., with an average MAI of only 1.3 $m^3ha^{-1}yr^{-1}$ (Fig. 7) and a mean site index for pine of only 11.9 m at 70 years (Fig. 8). Type 15, *Picea engelmannii-Abies lasiocarpa / Menziesia glabella*

Veg. type	7	14	6	15	13	12	11	4	5	10	9	8	1	3	2
$\bar{X}$	0.4	1.3	2.1	2.5	2.7	3.1	3.6	3.7	3.7	4.0	4.2	4.3	4.7	5.0	5.0
$S\bar{X}$	0.1	0.4	0.7	-	0.9	0.9	1.1	1.0	1.2	0.6	1.2	0.7	1.1	1.1	-
N	2	2	7	1	11	31	7	13	11	4	13	14	11	11	1

F = 7.21,
Between treat. d.f.=12
Within treat. d.f. =122

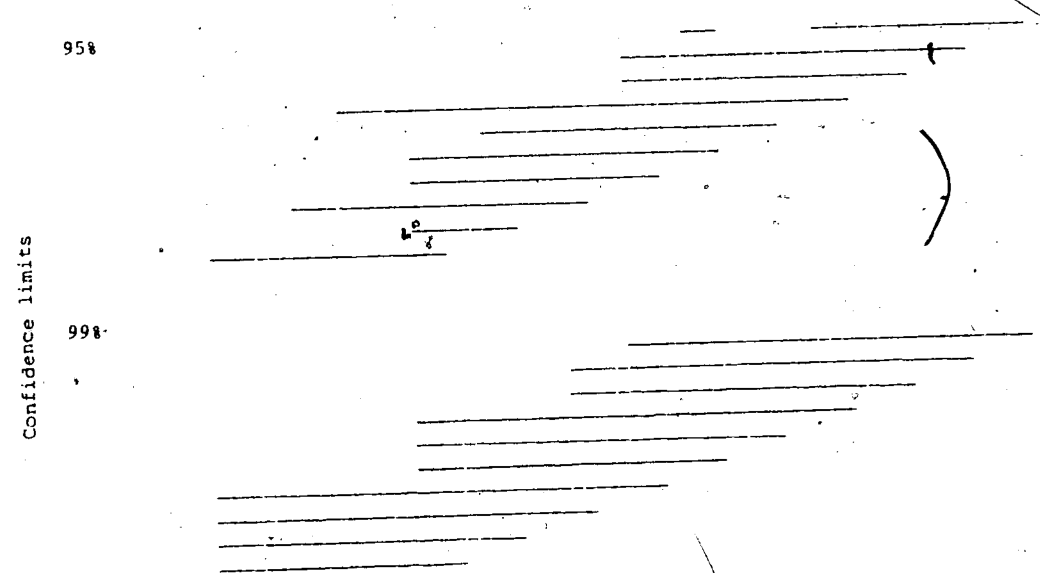


Figure 7: Duncan's multiple range test on means of mean annual total volume increment ($m^3 ha^{-1} yr^{-1}$) for 13 vegetation types. Statistically similar means are underlined; significantly different means at any confidence level are not underlined.

Vegetation type	14	13	12	11	9	10	8
$\bar{X}$	11.9	13.9	14.4	16.3	17.0	18.2	19.8
$S\bar{X}$	2.2	3.2	2.8	5.6	0.5	2.6	2.3
n	2	11	31	9	4	13	13

F = 7.22

Between treatments d.f. = 6

Within treatments d.f. = 76

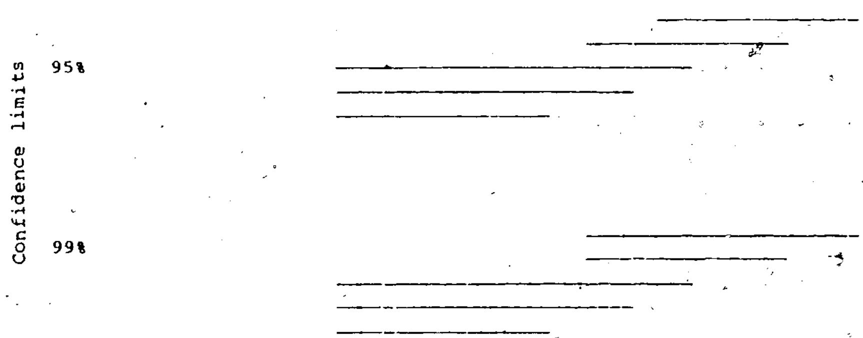


Figure 8: Duncan's multiple range test on means of site index (m) for the seven lodgepole pine-dominated vegetation types. Statistically similar means are underlined; significantly different means at any confidence level are not underlined.

had a higher MAI (2.5 $m^3ha^{-1}yr^{-1}$) than type 14 but had a site index for Engelmann spruce of only 5.5 m at 70 years.

The black spruce types had the lowest productivity. The *Picea mariana-Ledum groenlandicum-Equisetum arvense* type (Type 6) with an average MAI of 2.1 $m^3ha^{-1}yr^{-1}$ (Fig. 7) a mean site index of 8.2 m at 70 years was somewhat more productive than the *Picea mariana/Ledum groenlandicum/Rubus chamaemorus* bog forests (Type 7) which had an average MAI of only 0.4 $m^3ha^{-1}yr^{-1}$ (Fig. 7) and a mean site index of only 4.3 m at 70 years.

The fact that several means, representing several vegetation types are underlined in any particular grouping in the Duncan's tests, indicates that the various vegetation types are not mutually inclusive in terms of productivity and that some of them are quite variable in terms of ranges of MAI or site index for the lodgepole pine-dominated plots. The Duncan's tests do show however, the relationships of the vegetation types to each other in terms of MAI, and site index for the pine types and should be useful in rapid evaluation of productivity classes for forest management purposes.

Only site index data from plots of vegetation types dominated by lodgepole pine were amenable to Duncan's test analysis because the small number of vegetation types dominated by the other tree species (three by white spruce, two by black spruce and only one each by aspen, balsam poplar and Engelmann spruce) precluded meaningful analyses using Duncan's test.

H. STEPWISE MULTIPLE REGRESSION

1. <u>The Forests of the Wapiti Map Area</u>

1.1 The Lodgepole Pine Forests

The sampled lodgepole pine forests have a mean age of 96 years, a mean annual total volume increment (MAI) of 3.0 $m^3ha^{-1}yr^{-1}$, a mean site index of 16.2 m at 70 years and complete their maximum periodic annual total volume increment height at a mean age of 77 years. These forests occur at a mean elevation of 1133m, have a mean total vascular plant cover of 41% and a mean total moss cover of 45%, of which 5% is *Hylocomium splendens* and 32% is *Pleurozium schreberi* (Table 3).

The mean soil profile is moderately well drained with a clay in A horizon/clay in B horizon ratio of 0.5 indicating Luvisols. The mean depth to mottling is 48 cm; mean thickness of moss and litter is 7 cm and mean thickness of A horizon (include Ae1, Ae2 and Bm if present) is 19 cm. The average B horizon (usually Bt) has a thickness of 26 cm, medium subangular blocky structure with friable consistence, a hue of 5.8YR, value of 4.5 and a chroma of 3.6. The average coarse fragment content of the profile is 7% (Table 3).

1.2 The White Spruce Forests

The sampled white spruce forests have a mean age of 123 years, MAI of 3.43 $m^3 ha^{-1} yr^{-1}$ a mean site index of 14.0 m at 70 years and complete their maximum periodic annual total volume increment at a mean age of 104 years. These forests occur at a mean elevation of 956 m, have a mean total vascular plant cover of 34% and a mean total moss cover of 41% (same as lodgepole pine forests), of which 22% is *Hylocomium splendens* and 11% is *Pleurozium schreberi* (Table 4).

The mean soil profile is imperfectly drained with a clay in A horizon/clay in B horizon ratio of 0.7 indicating Luvisols. The mean depth to mottling is 30.5 cm; mean thickness of moss and litter is 15.2 cm and mean thickness of A horizon (includes Ae1, Ae2, and Bm if present) is 8.6 cm. The average B horizon (usually Bt) has a thickness of 18.8 cm, structure grading toward medium angular blocky with friable consistence, a hue of

Table 3 Means and standard deviations for lodgepole pine plot data (n=83). Dependent variables used in multiple regression analyses are indicated by Y; independent variables are indicated by X.

Variable	Mean		Standard deviation
Total volume (m^3ha^{-1})	313.933	±	103.349
Plot age	95.83	±	34.93
Mean Annual Increment ($m^3ha^{-1}yr^{-1}$)	3.408	±	1.082
Y1 MAI (rotation age; $m^3ha^{-1}yr^{-1}$)	3.009	±	1.214
Y2 ,X64 Tree density (stems ha^{-1})	2036	±	1007
Y3 Site index at 70yr	16.18	±	3.48
Total volume per tree (m^3)	0.347	±	0.191
Y4 Periodic annual total volume increment per tree	0.005	±	0.003
Maximum PAI per tree	0.007	±	0.003
Y5 Age of maximum PAI	76.95	±	32.17
Total basal area (m^2ha^{-1})	40.559	±	9.418
Y6 Mean annual basal area increment ($m^2ha^{-1}yr^{-1}$)	0.423	±	0.098
Merchantable volume (m^3ha^{-1})[a]	264.420	±	108.993
X1 Elevation (m)[b]	1132.35	±	191.32
X2 log Elevation	3.05	±	-0.46
X3 Slope %	8.91	±	9.29
X4 Aspect[c]	1.11	±	0.77
X5 Aspect X Slope	10.91	±	14.52
X20 % Si+C in A horizon	55.98	±	23.59
X21 Thickness A horizon (cm)	18.64	±	9.86
X22 Thickness A (Si+C A hor.)	1055.35	±	739.48
X23 % Si+C in B horizon	55.40	±	19.28
X24 % Clay in B horizon	28.20	±	12.03
X25 Thickness B horizon (cm)	25.77	±	14.58
X26 Thickness B (Si+C B hor.)	1445.15	±	945.37

Table 3 cont.

Variable	Mean		Standard deviation
X27 Clay in A hor/Clay in B hor	0.545	±	0.282
X28 % Stone in profile	7.08	±	13.65
X29 Internal profile drainage[d]	3.01	±	0.71
X30 Depth to distinct mottling (cm)	45.37	±	38.99
X31 Hydraulic conductivity (cm day^{-1})	93.92	±	192.89
X32 log Hydraulic conductivity	1.12	±	0.94
X33 Structure B horizon[d]	4.64	±	0.65
X34 Consistence B horizon[d]	2.49	±	0.65
X35 Chroma A horizon[e]	1.88	±	1.09
X36 Hue B horizon	5.78	±	3.66
X37 Value B horizon	4.47	±	0.69
X38 Chroma B horizon	3.55	±	1.57
X60 Canopy cover	47.36	±	11.96
X61 Litter cover	32.60	±	21.92
X62 1/log Litter cover	-1.37	±	0.39
X63 Deadfall cover	8.98	±	7.93
X39 Thickness organic horizon (cm)	6.81	±	2.20
X40 log Thickness organic	0.83	±	0.67
X80 Regeneration density (stems ha^{-1})	941	±	1524
X81 *Rosa acicularis* cover	0.51	±	0.95
X82 *Ledum groenlandicum* cover	4.07	±	6.12
X83 log *Ledum* cover	0.30	±	0.57
X84 *Rubus pedatus* cover	1.12	±	2.32
X85 *Epilobium angustifolium* cover	1.09	±	1.93
X86 *Cornus canadensis* cover	8.26	±	5.92

Table 3 cont.

Variable	Mean		Standard deviation
X87 *Rubus pubescens* cover	0.38	±	0.86
X88 *Calamagrostis canadensis* cover	0.15	±	0.41
X89 Vascular plant cover	41.32	±	18.03
X90 log Vascular plant cover	1.58	±	0.19
X91 *Hylocomium splendens* cover	5.03	±	6.70
X92 *Pleurozium schreberi* cover	31.86	±	20.75
X93 log *Pleurozium* cover	1.32	±	0.54
X94 *Polytrichum commune* cover	0.41	±	0.93
X95 Total moss cover	45.01	±	23.42
X96 log Total moss cover	1.55	±	0.36
X97 Total lichen cover	1.56	±	3.70

Footnotes

a Merchantable volume calculated using minimum top diameter of 7.6cm

b X1 to X5 - site variables; X20 to X40 - soil variables; X60 to X64 - stand variables X80 to X97 - vegetation variables

c Aspect represented by: sine (azimuth + 78.7)+1

d Internal profile drainage, Structure B horizon and Consistence B horizon scales are described in Appendix 2

e Soil colours are Munsell designation

Table 4 Means and standard deviations for white spruce plot data (n=30). Dependent variables used in multiple regression analyses are indicated by Y_i independent variables are indicated by X.

Variable	Mean		Standard deviation
Total volume ($m^3 ha^{-1}$)	462.194		99.317
Plot age	122.83	±	35.54
Mean Annual Increment ($m^3 ha^{-1} yr^{-1}$)	4.016	±	1.280
Y1 MAI (rotation age; $m^3 ha^{-1} yr^{-1}$)	3.445	±	2.074
Y2 Tree density (stems ha^{-1})	1507	±	618
Y3 Site index at 70 yr	13.96	±	4.17
Total volume per tree (m^3)	0.538	±	0.232
Y4 Periodic annual total volume increment per tree	0.009	±	0.005
Maximum PAI per tree	0.011	±	0.005
Y5 Age of maximum PAI	103.88	±	37.65
Total basal area ($m^2 ha^{-1}$)	50.803	±	8.908
Y6 Mean annual basal area increment ($m^2 ha^{-1} yr^{-1}$)	0.413	±	0.073
Merchantable volume ($m^3 ha^{-1}$)[a]	413.801	±	94.467
X1 Elevation (m)[b]	956.06	±	245.74
X2 log Elevation	2.98	±	-0.41
X3 Slope %	6.62	±	7.47
X4 Aspect[c]	1.36	±	0.73
X5 Aspect X Slope	10.35	±	11.70
X20 % Si+C in A horizon	56.42	±	25.95
X21 Thickness A horizon (cm)	8.64	±	9.37
X22 Thickness A (Si+C A hor)	464.49	±	512.01
X23 % Si+C in B horizon	63.20	±	21.70
X24 % Clay in B horizon	30.72	±	16.73
X25 Thickness B horizon (cm)	16.87	±	10.71
X26 Thickness B (Si+C hor)	1105.74	±	812.24

Table 4 cont

Variable	Mean		Standard deviation
X27 Clay in A hor/Clay in B [illegible]	0.71[illegible]	±	0.14[illegible]
X28 % Stone in profile	6.06	±	1[illegible].49
X29 Internal profile drainage[d]	2.15	±	1.08
X30 Depth to distinct mottling (cm)	29.18	±	15.81
X31 Hydraulic conductivity (cm day^{-1})	90.93	±	159.15
X32 log Hydraulic conductivity	[illegible]	±	1.29
X33 Structure B horizon[d]	3.50	±	1.74
X34 Consistence B horizon[d]	2.49	±	0.68
X35 Chroma A horizon[e]	2.5[illegible]	±	1.14
X36 Hue B horizon	[illegible]	±	1.62
X37 Value B horizon	4.22	±	0.81
X38 Chroma B horizon	3.07	±	1.70
X60 Canopy cover	57.91	±	11.44
X61 Litter cover	32.56	±	25.08
X62 1/log Litter cover	-1.25	±	0.41
X63 Deadfall cover	7.40	±	5.41
X39 Thickness organic horizon (cm)	15.16	±	11.20
X40 log Thickness organic	1.18	±	0.7[illegible]
X80 Regeneration density (stems ha^{-1})	1396	±	1429
X81 *Rosa acicularis* cover	1.17	±	1.52
X82 *Ledum groenlandicum* cover	0.93	±	4.04
X83 log *Ledum* cover	0.01	±	0.29
X84 *Rubus pedatus* cover	0.12	±	0.34
X85 *Epilobium angustifolium* cover	0.32	±	0.64
X86 *Cornus canadensis* cover	8.62	±	6.11
X87 *Rubus pubescens* cover	1.68	±	1.62

Table 4 (cont.)

Variable	Mean	Standard deviation
[illegible]	[illegible]	[illegible]
[illegible] vascular plant [illegible]	[illegible]	[illegible]
[illegible] log vascular plant [illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible] total [illegible]	[illegible]	[illegible]
[illegible] log total [illegible]	[illegible]	[illegible]
[illegible] total [illegible]	[illegible]	[illegible]

[illegible]

a [illegible] site variables [illegible] stand variables [illegible] Aspect represented by [illegible]

b Internal [illegible] file [illegible] scales are described in Appendix [illegible]

c [illegible]

5.4YR, value of 4.2 and a chroma of 2.5. The average coarse fragment content of the profile is 6% (Table 4).

1.3 The Black Spruce Forests

The sampled black spruce forests have a mean age of 138 years, MAI of 1.3 $m^3ha^{-1}yr^{-1}$ a mean site index of 11.3 m at 70 years and complete their maximum periodic annual total volume increment at a mean age of 128 years. These forests occur at a mean elevation of 1044 m, have a mean total vascular plant cover of 32% and a mean total moss cover of 63%, of which 21% is *Hylocomium splendens* and 19% is *Pleurozium schreberi* (Table 5).

The mean soil profile is imperfectly drained with a clay in A horizon/ clay in B horizon ratio of 0.8 indicating Luvisols but less clay accumulation in the B than in the white spruce and lodgepole pine forests. The mean depth to mottling is 23.9 cm; mean thickness of moss and litter is 36.1 cm and mean thickness of A horizon (includes Ae1, Ae2 and Bm if present) is 8.9 cm. The average B horizon (usually Bt) also has a thickness of 8.9 cm, is structureless to medium angular blocky with friable consistence, a hue of 4.8YR, value of 4.1 and a chroma of 2.6. The average coarse fragment content of the profile is 3% (Table 5).

1.4 The Aspen Forests

The sampled aspen forests have a mean age of 79 years, a mean productivity of 4.48 $m^3ha^{-1}yr^{-1}$, a mean site index of 19.2 m at 70 years and complete their maximum periodic annual total volume increment at a mean age of 56 years. These forests occur at a mean elevation of 777 m, have a mean total vascular plant cover of 40% and a mean total moss cover of 10%, of which 5% is *Hylocomium splendens* and 3% is *Pleurozium schreberi* (Table 6).

The mean soil profile is moderately well drained with a clay in A horizon/

Table 5 Means and standard deviations for black spruce plot data (n=15). Dependent variables used in multiple regression analyses are indicated by Y; independent variables are indicated by X.

Variable	Mean		Standard deviation
Total volume ($m^3 ha^{-1}$)	253.494	±	116.282
Plot age	138.25	±	45.47
Mean Annual Increment ($m^3 ha^{-1} yr^{-1}$)	2.003	±	1.086
Y1 MAI (rotation age; $m^3 ha^{-1} yr^{-1}$)	1.312	±	1.120
Y2 Tree density (stems ha^{-1})	2858	±	1065
Y3 Site index at 70 yr	8.25	±	3.34
Total volume per tree (m^3)	0.191	±	0.119
Y4 Periodic annual total volume increment per tree	0.002	±	0.002
Maximum PAI per tree	0.003	±	0.002
Y5 Age of maximum PAI	128.16	±	44.54
Total basal area ($m^2 ha^{-1}$)	39.232	±	11.191
Y6 Mean annual basal area increment ($m^2 ha^{-1} yr^{-1}$)	0.284	±	0.081
Merchantable volume ($m^3 ha^{-1}$)[a]	185.825	±	111.480
X1 Elevation (m)[b]	1043.69	±	166.68
X2 log Elevation	3.02	±	-0.45
X3 Slope %	3.50	±	3.39
X4 Aspect[c]	1.13	±	0.81
X5 Aspect X Slope	4.56	±	5.50
X20 % Si+C in A horizon	68.10	±	23.56
X21 Thickness A horizon (cm)	8.97	±	11.31
X22 Thickness A (Si+C A hor)	556.77	±	740.44
X23 % Si+C in B horizon	58.80	±	28.82
X24 % Clay in B horizon	30.43	±	19.40
X25 Thickness B horizon (cm)	8.97	±	10.85
X26 Thickness B (Si+C B hor)	625.85	±	800.33

Table 5 cont.

Variable	Mean		Standard deviation
X27 Clay in A hor/Clay in B hor	0.827	±	0.269
X28 % Stone in profile	3.10	±	8.02
X29 Internal profile drainage[d]	1.60	±	0.89
X30 Depth to distinct mottling (cm)	23.88	±	24.54
X31 Hydraulic conductivity (cm day^{-1})	53.17	±	179.12
X32 log Hydraulic conductivity	0.64	±	0.91
X33 Structure B horizon[d]	2.67	±	1.88
X34 Consistence B horizon[d]	2.57	±	0.82
X35 Chroma A horizon[e]	1.60	±	0.74
X36 Hue B horizon	4.83	±	3.34
X37 Value B horizon	4.07	±	0.88
X38 Chroma B horizon	2.60	±	1.45
X60 Canopy cover	44.35	±	15.89
X61 Litter cover	11.07	±	13.45
X62 1/log Litter cover	-0.84	±	0.41
X63 Deadfall cover	4.55	±	5.42
X39 Thickness organic horizon (cm)	36.07	±	30.87
X40 log Thickness organic	1.56	±	0.89
X80 Regeneration density (stems ha^{-1})	753	±	941
X81 *Rosa acicularis* cover	1.01	±	2.12
X82 *Ledum groenlandicum* cover	5.91	±	4.72
X83 log *Ledum* cover	0.57	±	0.52
X84 *Rubus pedatus* cover	0.13	±	0.49
X85 *Epilobium angustifolium* cover	0.21	±	0.54
X86 *Cornus canadensis* cover	5.81	±	5.94
X87 *Rubus pubescens* cover	0.31	±	0.60

Table 5 cont.

Variable	Mean		Standard deviation
X88 *Calamagrostis canadensis* cover	0.15	±	0.32
X89 Vascular plant cover	31.73	±	12.71
X90 log Vascular plant cover	1.46	±	0.23
X91 *Hylocomium splendens* cover	20.93	±	15.02
X92 *Pleurozium schreberi* cover	18.64	±	20.72
X93 log *Pleurozium* cover	0.92	±	0.67
X94 *Polytrichum commune* cover	0.13	±	0.29
X95 Total moss cover	63.32	±	14.86
X96 log Total moss cover	1.79	±	0.11
X97 Total lichen cover	0.82	±	1.16

Footnotes

a Merchantable volume calculated using minimum top diameter of 7.6 cm

b X1 to X5 - site variables; X20 to X40 - soil variables; X60 to 63- stand variables X80 to X97 - vegetation variables

c Aspect represented by: sine (azimuth + 78.7)+1

d Internal profile drainage, Structure B horizon and Consistence B horizon scales are described in Appendix 2

e Soil colours are Munsell designation

Table 6 Means and standard deviations for aspen plot data (n=17). Dependent variables used in multiple regression analyses are indicated by Y; independent variables are indicated by X.

Variable	Mean		Standard deviation
Total volume ($m^3 ha^{-1}$)	362.552	±	144.496
Plot age	78.85	±	23.16
Mean Annual Increment ($m^3 ha^{-1} yr^{-1}$)	4.605	±	1.205
Y1 MAI (rotation age; $m^3 ha^{-1} yr^{-1}$)	4.511	±	1.483
Y2 Tree density (stems ha^{-1})	1727	±	850
Y3 Site index at 70 yr	19.26	±	2.97
Total volume per tree (m^3)	0.326	±	0.248
Y4 Periodic annual total volume increment per tree	0.007	±	0.005
Maximum PAI per tree	0.008	±	0.005
Y5 Age of maximum PAI	56.53	±	31.45
Total basal area ($m^2 ha^{-1}$)	42.608	±	12.387
Y6 Mean annual basal area increment ($m^2 ha^{-1} yr^{-1}$)	0.540	±	0.157
Merchantable volume ($m^3 ha^{-1}$)[a]	308.075	±	136.829
X1 Elevation (m)[b]	776.34	±	88.45
X2 log Elevation	2.89	±	-0.44
X3 Slope %	3.11	±	3.90
X4 Aspect[c]	1.23	±	0.93
X5 Aspect X Slope	5.83	±	7.76
X20 % Si+C in A horizon	59.85	±	26.48
X21 Thickness A horizon (cm)	11.65	±	7.19
X22 Thickness A (Si+C A hor)	682.44	±	580.30
X23 % Si+C in B horizon	66.94	±	15.32
X24 % Clay in B horizon	42.91	±	16.81
X25 Thickness B horizon (cm)	24.35	±	11.39
X26 Thickness B (Si+C B hor)	1708.22	±	938.22

Table 6 cont.

Variable	Mean		Standard deviation
X27 Clay in A hor/Clay in B hor	0.406	±	0.295
X28 % Stone in profile	0.62	±	1.08
X29 Internal profile drainage[d]	2.71	±	0.75
X30 Depth to distinct mottling (cm)	29.26	±	35.51
X31 Hydraulic conductivity (cm day^{-1})	49.78	±	132.06
X32 log Hydraulic conductivity	-0.06	±	1.23
X33 Structure B horizon[d]	4.29	±	1.36
X34 Consistence B horizon[d]	2.82	±	0.64
X35 Chroma A horizon[e]	2.24	±	0.83
X36 Hue B horizon	5.74	±	3.73
X37 Value B horizon	4.35	±	0.60
X38 Chroma B horizon	3.59	±	1.42
X60 Canopy cover	53.35	±	8.93
X61 Litter cover	71.21	±	17.08
X62 1/log Litter cover	-1.83	±	0.17
X63 Deadfall cover	5.21	±	3.07
X39 Thickness organic horizon (cm)	7.69	±	6.47
X40 log Thickness organic	0.89	±	0.54
X80 Regeneration density (stems ha^{-1})	319	±	361
X81 *Rosa acicularis* cover	2.94	±	3.02
X82 *Ledum groenlandicum* cover	0.09	±	0.27
X83 log *Ledum* cover	-0.01	±	0.03
X84 *Rubus pedatus* cover	0.00	±	0.00
X85 *Epilobium angustifolium* cover	3.08	±	3.10
X86 *Cornus canadensis* cover	5.56	±	3.98
X87 *Rubus pubescens* cover	2.21	±	1.28

Table 6 cont.

Variable	Mean		Standard deviation
X88 *Calamagrostis canadensis* cover	0.42	±	0.71
X89 Vascular plant cover	40.29	±	22.97
X90 log Vascular plant cover	1.55	±	0.21
X91 *Hylocomium splendens* cover	5.11	±	9.67
X92 *Pleurozium schreberi* cover	3.02	±	4.02
X93 log *Pleurozium* cover	0.35	±	0.40
X94 *Polytrichum commune* cover	0.10	±	0.41
X95 Total moss cover	9.55	±	12.74
X96 log Total moss cover	0.57	±	0.68
X97 Total lichen cover	0.12	±	0.17

Footnotes

a Merchantable volume calculated using minimum top diameter of 7.6 cm

b X1 to X5 - site variables; X20 to X40 - soil variables; X60 to X63 - stand variables; X80 to X97 - vegetation variables

c Aspect represented by: sine (azimuth + 78.7)+1

d Internal profile drainage, Structure B horizon and Consistence B horizon scales are described in Appendix 2

e Soil colours are Munsell designation

clay in B horizon ratio of 0.4 indicating Luvisols. The mean depth to mottling is 30.5 cm; mean thickness of moss and litter is 7.6 cm and mean thickness of A horizon (includes Ae1, Ae2 and Bm if present) is 11.7 cm. The average B horizon (usually Bt) has a thickness of 24.4 cm, medium subangular blocky structure with firm consistence, a hue of 6.7YR, value of 4.4 and a chroma of 3.6. The average coarse fragment content of the profile is 1% (Table 6).

The semi-quantitative scales for the soil attributes entered in the regression analyses are presented in Appendix 2.

2. Transformation of Independent Variables

The assumption behind the use of the stepwise multiple regression is that the relationship between the dependent variables and the independent variables is linear. To test whether or not this was in fact the case, each of the dependent variables was plotted against each of the independent variables using a computer scattergram program. A visually estimated best-fit line was drawn through the points on each of the resulting scattergrams. In most cases a straight line seemed to well approximate the relationship between the variable pairs. In other cases a nonlinear relationship was evident. In the latter cases the log of the values (in the case of litter cover, the reciprocal of the log) of the independent variables was plotted against the dependent variables. The log transformation was regarded as best approximating a linear relationship where originally a nonlinear relationship existed. The effectiveness of the log transformation was evaluated by comparing the simple correlation coefficients between the dependent and independent variables before and after transformation. The simple correlation between the dependent variable and the transformed independent variable should be greater than that between the dependent and non-transformed independent variable. The log-transformed variables were subsequently entered into the regression as separate independent variables (Tables 3 to 6). The untransformed independent variables were allowed to remain in the regression because some dependent variables showed a more linear relationship with the untransformed independent variable. The stepwise multiple regression program permitted the selection of either the transformed or untransformed independent variable depending on which exhibited the better linear relationship with the dependent variable.

In two other cases a different transformation was applied. It seemed likely that an interaction between two related independent variables (i.e. product of the two) might contribute more to the R^2 value in the regression than might the two of them alone. The independent variables involved were Si+C content of the A and B horizons and the thicknesses of those horizons. If the interaction variable entered the regression before one or the other components, that is to say, contributed more to the R^2 value, then the two components (thickness and Si+C content) were deleted. Conversely, if Si+C content of the A or B horizon or thickness of the A or B horizon entered the regression before the interaction variable, then the interaction variable was deleted. It became apparent that the interaction of Si+C content and horizon thickness did not contribute more to the R^2 value in the black spruce and aspen equations (Tables 12 and 13), than did Si+C content alone.

3. Selection of the Dependent Variables

For many years, the usual dependent variable used in forest-site studies has been site index, or height at a certain index age, usually the rotation age for that species (Alban 1972, 1974; Carmean 1965, 1967, 1970, 1971; Graney and Ferguson 1971, 1972; Holmes and Tackle 1962). In other studies (Duffy and England 1967, Duffy and Knight 1967, Kabzems et al. 1972), mean annual total volume increment (MAI) has been used as an indication of forest site productivity. This measure is the basis of the Canada Land Inventory land capability rating for forestry. Periodic annual total volume increment (PAI), or the volume increment per unit area at a specified period of years divided by the number of years, has sometimes been used as a measure of forest productivity (e.g. Dumanski et al. 1973). In this thesis several dependent variables including MAI (rotation age), density, site index, PAI/tree, age of maximum PAI and mean annual basal area increment are used.

Periodic annual total volume increment per tree (PAI) will be discussed first. It represents the periodic annual total volume increment for the ten years prior to rotation age (70 years for lodgepole pine and aspen; 100 years for the three spruce species) as determined from the stem analyses. This value could not be multiplied by density to find PAI per unit area because bias in selection of the stem analysis sample trees from which PAI was estimated. This bias was towards trees of superior form and apparent lack of mechanical or disease damage such as might be expected of trees in a well-managed forest stand. More elaborate corrections to estimate PAI on an areal basis were not explored due to the opportunity to determine a good estimate of MAI, generally regarded as a superior expression of site productivity, from the stem analysis data.

Mean annual increment is basically the total tree volume of a given area of land divided by the age of the forest in years. MAI estimates are most useful when the forest stand in question is at or near the commercially-accepted rotation age for that species in the area in question (i.e. when both PAI and MAI has peaked). Tree growth (volume or height) exhibits the sigmoid growth curve characteristic of many organisms and populations, with slow initial growth, rapid intermediate growth and finally much reduced growth as the organism approaches maturity. This trend is illustrated in the stem analysis computer plot of height and volume growth of a lodgepole pine tree in plot 12 (Fig. 3). Thus, mean annual increment estimates tend to underestimate potential productivity in old mature stands because volume increment decreases after a certain age. Conversely, if a MAI estimate is made in a stand much younger than the rotation age, MAI may be overestimated, assuming that the population growth will normally have tapered off by the time it reaches the rotation age. It is especially desirable that prior to harvesting pulpwood species such as lodgepole pine, in order to maximize monetary return, the age of maximum PAI be at least attained, although it is generally regarded as desirable to wait until the MAI growth curve also has peaked, with the rotation age taken as the age when the PAI and MAI curves cross (Davis 1954 p. 228). For species usually used for lumber, such as white spruce, it is often desirable to let the stand grow for a longer time to improve the quality of the saw timber harvested. It is apparent from Davis' (1954) discussion, that rotation age can not be determined on the basis of gross productivity alone. Different utilization standards and sites will cause some deviation of rotation age from average (Kirby 1962).

3.1 Volume Ratio Calculations

A method to standardize MAI estimates to a base age (70 years for lodgepole pine and aspen and 100 years for the three spruce species) is used here. These base ages approximate those currently viewed as optimum rotation ages in the western Alberta forest industry, and not those ages suggested to be optimum from data of this study. The volume ratio corrects MAI's forward in stands less than the base age and backwards in stands greater than the base age and is specific to the different tree species sampled for the area concerned. For each plot, the mean volume at rotation age as determined from the stem analysis, was divided by the mean volume of the sample trees at time of sampling to obtain the "volume ratio." These volume ratios were plotted against the respective age for all field plots, with separate graphs for each of the tree species concerned. A curvilinear relationship was evident. Volume ratio plotted against log age produced a nearly linear relationship. Subsequently a linear regression of volume ratio on log age was calculated for each tree species (Fig. 9). Next the volume ratio at rotation age was calculated for each tree species using the regression equations. This value was then multiplied by the gross MAI to give MAI at rotation age. It is this value that is used as a dependent variable in the stepwise multiple regression equations calculated. It is likely that this method probably gives somewhat conservative estimates of MAI for the stands much older than rotation age because it does not take into account mortality which has occurred between the rotation age and the age at time of sampling. However, it is believed that in most cases, the decrease in the MAI estimate due to decreased productivity after annual increment has peaked, is greater than loss due to mortality during that period of time. The volume ratio regressions are illustrated in Fig. 9.

From the volume ratio graphs it became apparent for the white spruce plots that there were two very distinct white spruce populations in terms of volume growth (Fig. 9b). A closer examination of the sample plot data revealed that the population represented by the lower regression line (Fig. 9b) was composed of sample trees which occupied understory position

Figure 9: Volume ratio equations for the four tree species sampled: (a) lodgepole pine, (b) white spruce, (c) Black spruce, (d) aspen.

Figure 3a Lodgepole pine

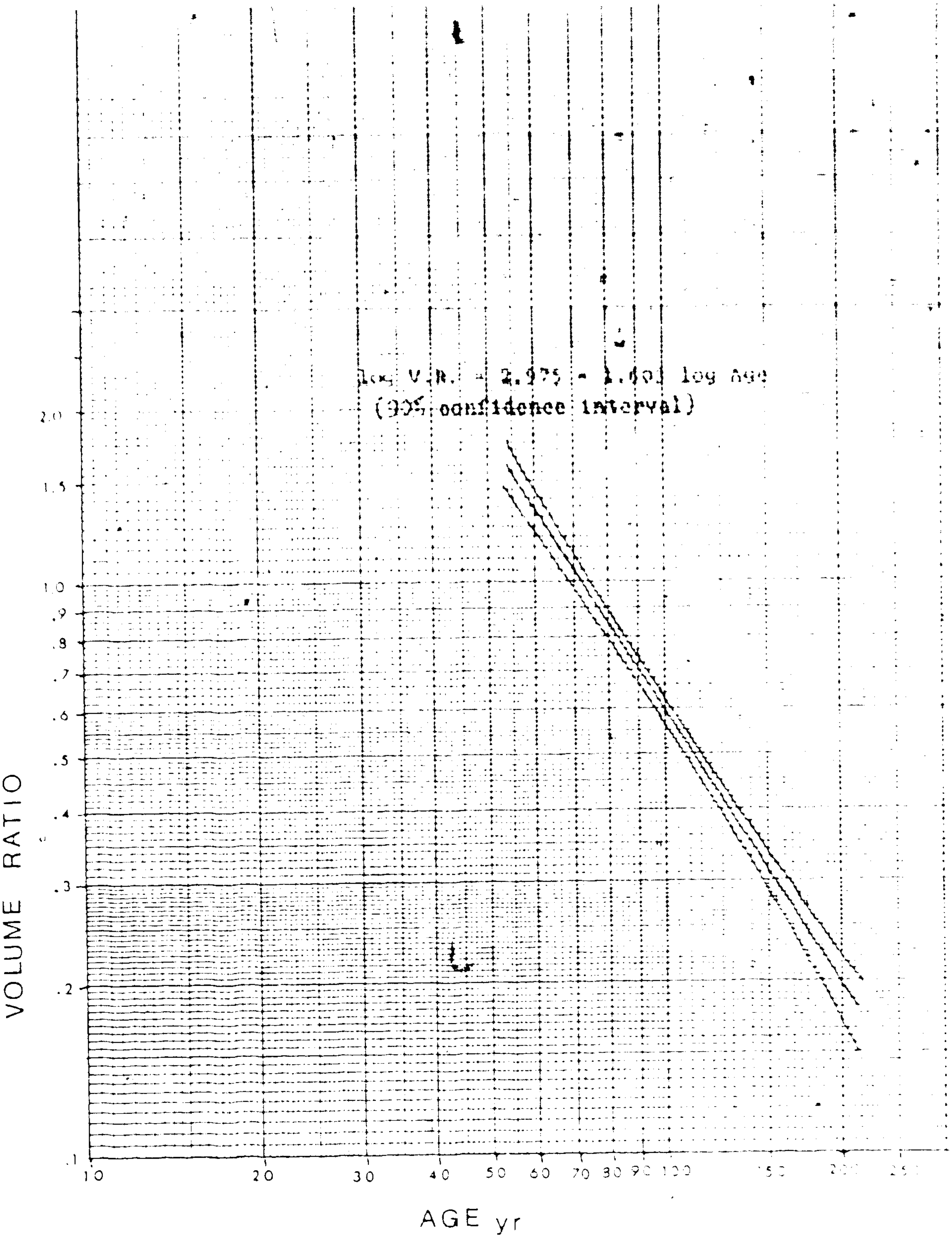


Figure 9b White spruce

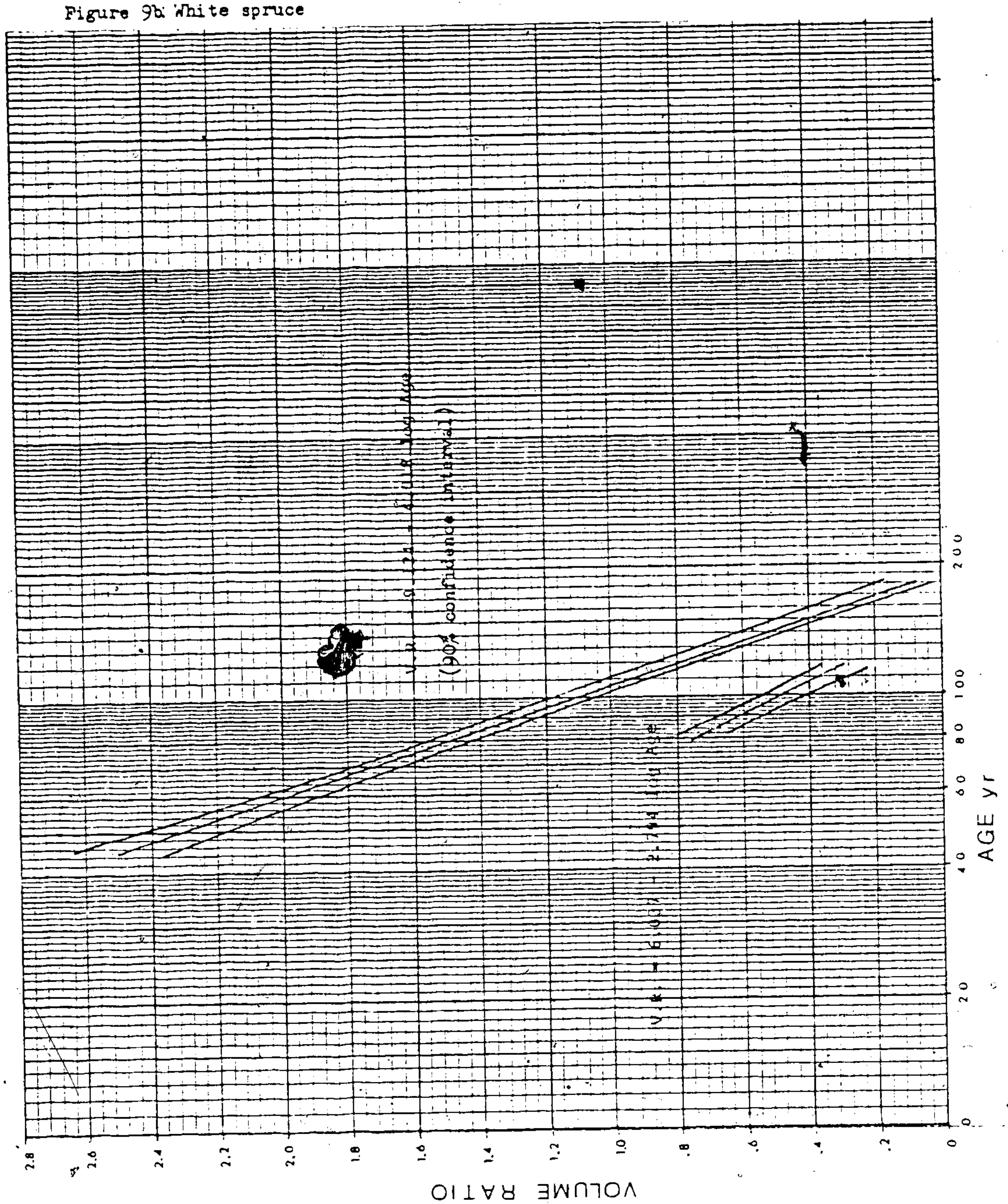


Figure 9c: Black spruce

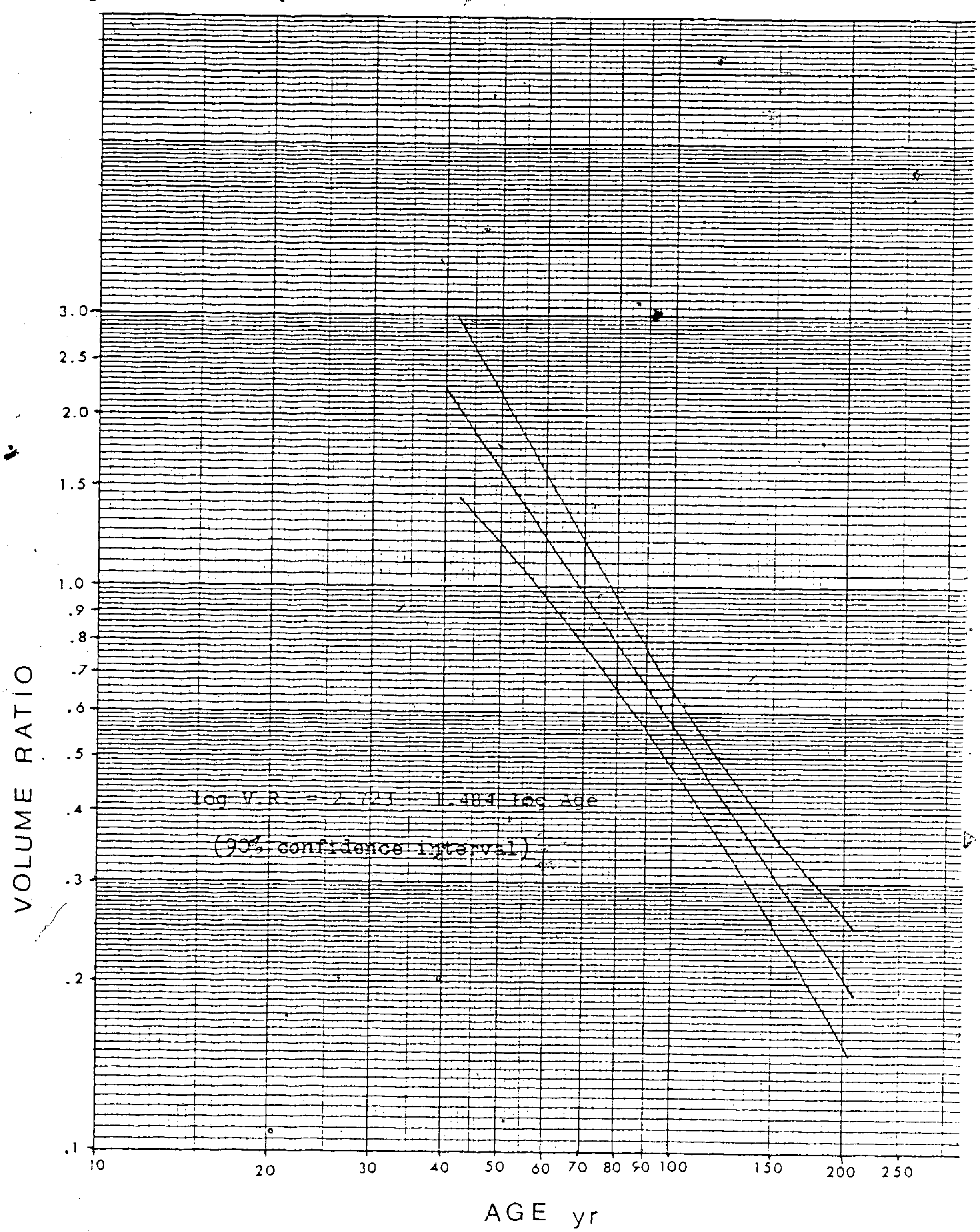
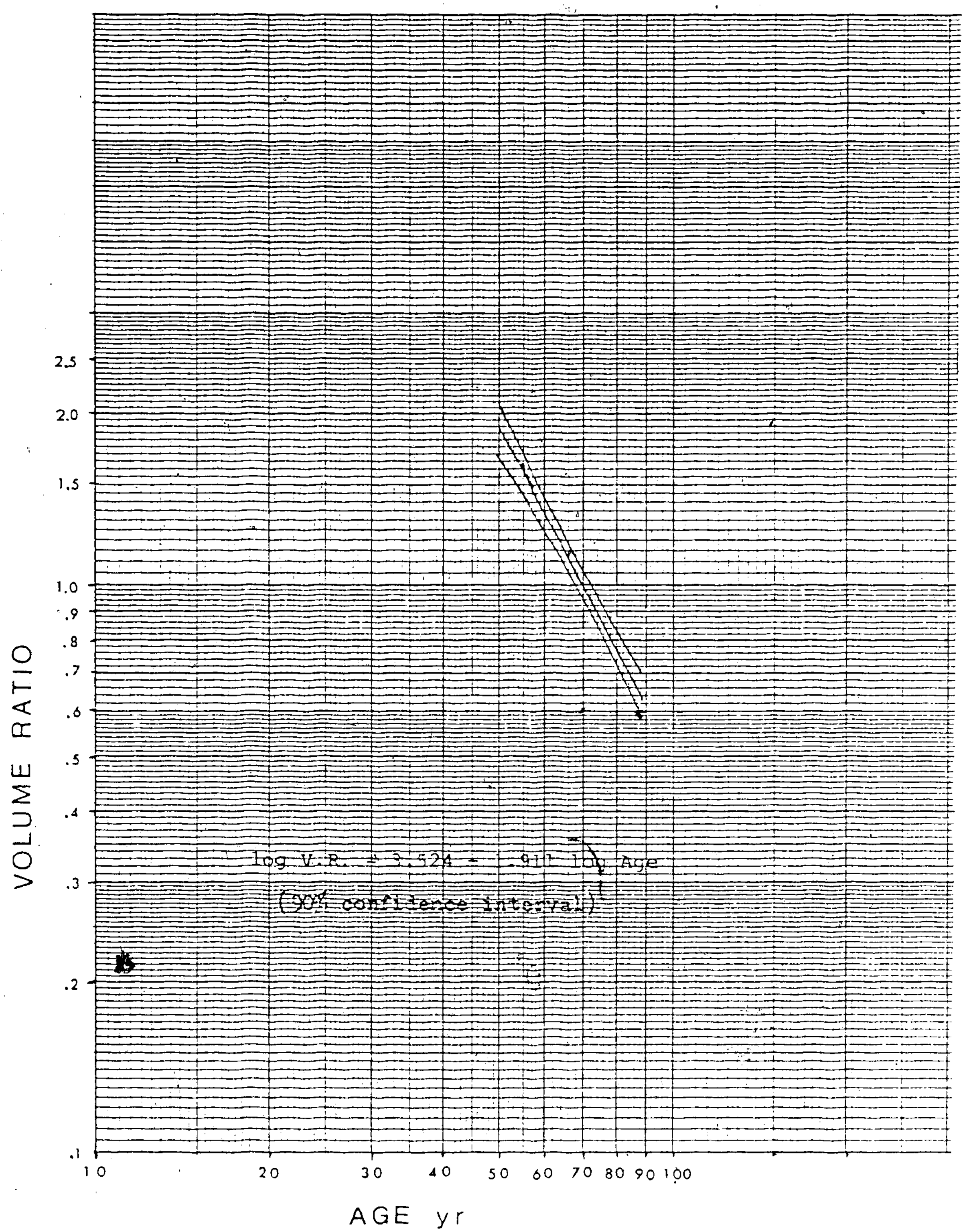


Figure 9d: Aspen



in either aspen or lodgepole pine forests and were thus somewhat suppressed.

Tree density is not usually used as a dependent variable as it is in this thesis. It seemed desirable to determine if factors other than stand history and age were important in determining stand density.

Site index is used in this study as it has been in many others. It is still the most commonly used expression of forest productivity.

The age of maximum periodic annual total volume increment (PAI) is used here as a dependent variable, and is proposed as a means of estimating optimum rotation age for a particular site independently of direct measurements of the trees, enabling this determination to be made on cleared or burned sites.

Mean annual basal area increment is another dependent variable used in this study but is not commonly used elsewhere. It is expected that it should show similar relationships to the independent variables as shown by MAI.

4. The Multiple Regression Equations

The equations which are listed in Tables 7 to 14 represent data from 83 lodgepole pine stands, 30 white spruce stands, 15 black spruce stands and 17 aspen stands. For each of the 36 equations the independent variables are listed in order of importance, relative to the amount they contribute to the R^2 value. A brief description taken from Tables 3 to 6 listing the variables that entered the regression, their means, variances and standard deviations for each of the sampled stand groups, follows. Component vegetation types within each of the stand groups are described in more detail in the previous sections.

Table 7 Multiple regression equations calculated for the lodgepole pine plots (n = 83)

	Equation	R^2	F
	MAI (rotation age)		
1	$Y = -1.00100-29.56604X_{62}^{**}+0.42864X_{60}^{**}-0.56116X_{63}^{**}-1.11525X_{97}^{**}-1.09525X_{30}^{**}-7.29468X_{34}^{**}+0.68724X_{86}^{**}+3.83330X_{4}^{*}+4.28123X_{37}^{**}$	0.66	15.79^{**}
	Stem density/100		
2	$Y = +4.95776-11.95296X_{90}^{**}-0.00383X_{80}^{**}-0.11078X_{3}^{**}-13.53204X_{40}^{**}+1.51143X_{83}^{*}+0.72621X_{81}^{*}+5.91415X_{2}+1.10253X_{33}^{*}-0.57395X_{35}$	0.53	9.04^{**}
	Site index		
3	$Y = +79.96714-46.78500X_{2}^{**}-11.91449X_{62}^{**}-0.72455X_{97}^{**}+2.11283X_{87}^{*}+0.01003X_{80}^{*}+0.38467X_{86}^{**}-4.06938X_{29}^{**}-4.48228X_{34}^{**}-0.33214X_{36}$	0.71	19.61^{**}
	PAI/tree		
4	$Y = +0.05767-0.48004X_{2}^{**}+0.00229X_{89}^{**}+0.00010X_{80}^{**}+0.00132X_{60}^{*}-0.00133X_{95}^{**}+0.07375X_{27}^{**}-0.00457X_{97}^{*}+0.02016X_{4}^{*}-0.00239X_{30}^{*}$	0.76	25.36^{**}
	Age maximum PAI		
5	$Y = +91.02765+48.23885X_{62}^{**}+0.48099X_{60}^{*}-0.03247X_{64}^{*}-0.04445X_{26}^{*}+963764X_{63}-5.68264X_{4}+8.09264X_{33}+8.12937X_{34}-0.873462X_{86}$	0.52	8.75^{**}
	Mean annual basal area increment		
6	$Y = +0.04416-0.92286X_{62}^{**}+0.01352X_{60}^{**}+0.16636X_{81}^{**}-0.01073X_{89}^{**}+0.02595X_{86}^{*}-0.20121X_{29}^{**}-1.81226X_{40}^{*}+0.15764X_{37}^{*}+0.00627X_{95}^{*}$	0.44	6.44^{**}

** t - test on independent variable or F-test of equation significant at p = 0.01

* t - test on independent variable or F-test of equation significant at p = 0.05

Table 8 Multiple regression equations calculated for the white spruce plots (n = 30)

		R^2	F
	MAI (rotation age)		
1	$Y= +2.67259-3.31786X_{32}+1.32719X_{60}^{**}-5.43341X_{82}^{**}-0.00680X_{1}^{**}-9.07564X_{81}^{**}-47.04329X_{88}^{**}+0.03006X_{80}^{**}+12.88160X_{4}^{**}+0.36276X_{28}^{*}$	0.86	13.41^{**}
	Stem density/100		
2	$y= 6.22567+68.75702X_{94}^{**}-8.53992X_{89}^{**}-88.00923X_{38}^{**}+98.69399X_{37}^{*}+24.62280X_{86}^{**}+91.42690X_{34}-84.80815X_{85}-0.15040X_{80}+24.04546X_{33}$	0.70	5.10^{**}
	Site index		
3	$Y= +21.05427-0.00391X_{1}^{**}-1.11010X_{63}^{**}-1.63762X_{82}^{**}+0.91843X_{4}+2.32010X_{29}^{*}+0.76890X_{86}^{**}-1.97201X_{81}^{*}-9.67321X_{62}^{*}+0.58361X_{36}$	0.91	22.75^{**}
	PAI/tree		
4	$Y= +0.00994+0.03931X_{87}^{**}-0.01193X_{63}^{**}0.06439X_{39}^{**}+0.24604X_{90}^{**}-0.01395X_{82}^{**}-0.02974X_{38}^{*}-0.07510X_{85}^{*}-0.23238X_{88}^{*}-0.02612X_{35}$	0.81	9.50^{**}
	Age maximum PAI		
5	$Y= +171.26842+69.51395X_{62}^{**}+3.37351X_{63}^{**}+9.65373X_{39}^{**}+3.91925X_{82}^{**}+8.67594X_{33}^{**}-40.28085X_{27}^{**}-0.01762X_{80}-0.07722X_{26}^{*}-1.05325X_{86}$	0.82	10.22^{**}
	Basal Area annual increment		
6	$Y= +0.04416+0.00323X_{26}^{**}+0.04340X_{60}^{**}-0.13414X_{82}^{**}-0.10341X_{33}^{**}-0.89856X_{88}^{**}-2.14062X_{2}^{**}-0.22102X_{81}^{**}-0.49408X_{96}^{**}-0.14336X_{34}$	0.94	32.71^{**}

** t-test on independent variable or F-test of equation significant at $p = 0.01$

* t-test on independent variable of F-test of equation significant at $p = 0.05$

Table 9 Multiple regression equations calculated for the black spruce plots (n = 15)

		R^2	F
	MAI (rotation age)		
1	$Y= +9.52196+11.97623X_{85}^{**}-0.35788X_{20}^{**}+1.81842X_{81}^{**}-14.91207X_{84}^{**}+2.84896X_{33}^{**}-57.57439X_{96}^{**}$	0.98	73.26^{**}
	Stem density/100		
2	$Y= +9.22182+3.49528X_{38}^{**}+0.08018X_{60}^{**}-0.13146X_{91}^{**}-1.25948X_{97}^{**}-1.06882X_{29}^{**}+0.18491X_{30}^{**}$	0.98	62.95^{**}
	Site index		
3	$Y= +72.12178+8.85409X_{85}^{**}-0.16624X_{20}^{**}+0.95611X_{86}^{**}+0.38318X_{3}-0.30936_{60}^{**}-1.10504X_{82}^{**}-8.68398X_{87}^{**}-45.10241X_{2}^{**}+0.50079X_{63}^{*}$	0.99	67.78^{**}
	PAI/tree		
4	$Y= +0.01935-0.32934X_{96}^{**}+0.00298X_{5}^{**}-0.05285X_{84}^{**}-0.00117X_{20}^{**}-0.01923X_{88}^{**}+0.00078X_{60}^{**}+0.00012X_{31}^{**}+0.02063X_{35}^{**}-0.00542X_{38}^{**}$	0.99	310.97^{**}
	Age maximum PAI		
5	$Y= +138.09671+30.44731X_{62}^{**}+1.46730X_{20}^{**}-16.72929X_{38}^{**}-8.23089X_{81}^{**}-35.49097X_{35}^{**}+20.39029X_{29}^{**}-0.39255X_{91}^{**}$	0.99	102.10^{**}
	Mean annual basal area increment		
6	$Y= +0.38590+0.03132X_{5}^{**}-0.01492X_{20}^{**}+0.01645X_{91}^{**}+0.29300X_{85}^{**}+0.06911X_{36}^{**}+0.01755X_{86}^{**}-0.09373X_{21}^{**}-0.02197X_{39}^{**}$	0.99	78.18^{**}

** t-test on independent variable or F-test of equation significant at p = 0.01

* t-test on independent variable or F-test of equation significant at p = 0.05

Table 10 Multiple regression equations calculated for the aspen plots (n = 17)

	Equation	R^2	F
	MAI (rotations age)		
1	$Y = +3.47556+23.22010X_{39}^{**}-11.74018X_{87}^{**}+12.61456X_{37}^{**}+6.53907X_{33}^{**}+2.00560X_{38}+6.92019X_{35}^{*}+0.73836X_{86}+3.95252X_4-0.43603X_{91}$	0.95	14.77^{**}
	Stem density/100		
2	$Y = +114.88200-15.793.5X_{90}^{**}-12.60983X_{27}^{**}+0.63188X_{85}^{**}-0.10535X_{23}^{**}-0.96054X_{33}^{**}-0.78361X_{35}^{**}+0.16943X_{92}^{**}+0.10596X_{86}^{**}$	0.99	105.31^{**}
	Site index		
3	$Y = +25.84741+3.06704X_{85}^{**}+0.08303X_{22}^{**}-26.71953X_{90}^{**}-2.35816X_{63}^{**}+12.51879X_{27}^{**}+22.03162X_{40}^{*}+0.05187X_{80}^{**}-2.05572X_{38}^{*}+2.02409X_{37}$	0.96	20.34^{**}
	PAI/tree		
4	$Y = +0.02028+0.01118X_{89}^{**}-0.62716X_{82}^{**}+0.12642X_{21}^{**}+1.11317X_{40}^{**}+0.11825X_{88}^{*}+0.07653X_{37}^{*}-0.02227X_{86}^{**}+0.02078X_{30}^{*}-0.08873X_{29}$	0.94	11.44^{**}
	Age maximum PAI		
5	$Y = +365.58667-12.83148X_{36}^{**}+5.34300X_3^{**}-72.38057X_{34}^{**}-0.16480X_{31}^{**}-2.27422X_{85}-11.37129X_{28}^{**}-3.78466X_{63}^{**}-2.79930X_{86}^{**}+27.51016X_{93}^{*}$	0.96	18.55^{**}
	Mean annual basal area increment		
6	$Y = +0.41958-1.69622X_{90}^{**}+0.25339X_4^{**}-0.33095X_{87}^{**}+0.24625X_{33}^{**}+0.41777X_{37}^{**}+0.07120X_{39}+0.04924X_{92}^{*}-0.01754X_{91}^{*}+0.17445X_{34}$	0.94	11.72^{**}

** t- test on independent variable or F-test of equation significant at $p = 0.01$

* t- test on independent variable or F-test of equation significant at $p = 0.05$

Table 11 Multiple regression equations calculated for the lodgepole pine plots - vegetation variables deleted (n = 83)

		R^2	F
	MAI (rotation age)		
1	$Y = +5.31231+3.90325X_{35}^{*}-0.03185X_{22}-0.00129X_{1}-3.64787X_{33}+3.11995X_{4}-5.52983X_{39}$	0.24	3.98^{**}
	Site index		
3	$Y = +104.59529-69.76668X_{2}^{**}+1.54898X_{35}+0.21650X_{3}-0.51947X_{36}-0.01814X_{22}-0.01377X_{31}^{*}+5.44466X_{27}$	0.49	10.27^{**}
	Age maximum PAI		
5	$Y = +40.14442+0.10302X_{22}^{**}+23.49310X_{39}^{*}+6.34278X_{33}-6.66426X_{4}-0.02403X_{26}-6.25313X_{37}+1.11375X_{36}$	0.27	3.90^{**}

Table 12 Multiple regression equations calculated for the white spruce plots - vegetation variables deleted (n = 30)

		R^2	F
	MAI (rotation age)		
1	$Y = +3.80926-12.43255X_{32}^{**}-0.00806X_{1}^{**}+4.97692X_{36}^{**}+1.84740X_{3}^{*}+9.49064X_{37}+17.73521X_{40}$	0.53	4.35^{**}
	Site index		
3	$Y = +15.69618-0.00371X_{1}^{**}+4.66434X_{4}+5.19117X_{37}-3.90037X_{32}^{*}+0.75355X_{3}^{*}+1.41332X_{36}-1.78550X_{38}$	0.58	4.36^{**}
	Age maximum PAI		
5	$Y = +271.33911-0.05817X_{26}+14.93970X_{39}^{**}27.47617X_{37}^{**}-28.17213X_{4}^{**}+10.63427X_{33}^{**}+3.34533X_{30}-0.20056X_{22}-55.39244X_{27}^{*}-14.78355X_{34}$	0.57	2.96^{*}

** t- test on independent variable or F-test of equation significant at p = 0.01

* t- test on independent variable or F-test of equation significant at p = 0.05

Table 13 Multiple regression equations calculated for the black spruce plots - vegetation variables deleted (n = 15)

No.	Equation	R^2	F
	MAI (rotation age)		
1	$Y = -3.59562+4.72312X_4+10.62417X_{37}^{*}+0.05528X_{31}^{**}-1.85783X_{30}^{*}-23.90105X_{29}^{**}+11.90764X_{33}^{*}+11.34751X_{35}^{*}+2.14356X_{39}+0.62092X_{28}$	0.88	4.03
	Site index		
3	$Y = +17.77701+0.19850X_{20}-0.36355X_{35}+8.70567X_4^{**}+7.52490X_{37}^{**}-1.40332X_{30}^{**}-32.87492X_{29}^{*}-60.84918X_{27}^{*}+12.85858X_{33}-0.11130X_{26}$	0.93	7.44*
	Age maximum PAI		
5	$Y = +260.20361+1.13604X_{20}^{**}-45.23471X_{35}^{**}-140.42503X_{27}^{**}-5.15870X_{28}^{**}-8.90018X_3^{**}+11.08644X_{36}^{**}+3.65105X_{30}^{**}-0.08734X_{64}^{*}$	0.97	23.67**

Table 14 Multiple regression equations calculated for the aspen plots - vegetation variables deleted (n = 17)

No.	Equation	R^2	F
	MAI (rotation age)		
1	$Y = +7.33071+24.17542X_{39}^{*}+10.56298X_{32}-24.02571X_{29}^{*}+1.20576X_{30}+8.78822X_4-48.36491X_{27}+10.95263X_{35}+5.93454X_{38}-16.25034X_{34}$	0.79	2.88
	Site index		
3	$Y = -221.73932+193.23841X_2-1.55242X_{34}^{**}+0.04435X_{22}-7.93583X_{28}+7.65253X_{37}-0.28015X_{33}-0.61075X_5-3.98875X_{38}+1.04496X_{36}$	0.74	2.25
	Age maximum PAI		
5	$Y = +882.57813-9.57568X_{36}^{**}+6.88062X_3^{**}-32.61557X_{34}^{**}+0.01216X_{31}-6.69053X_{28}+0.11471X_{64}^{**}+0.47802X_{20}^{*}+11.50050X_{33}^{**}-201.31194X_2^{*}$	0.94	12.42**

** t- test on independent variable or F-test of equation significant at p = 0.01

* t- test on independent variable or F-test of equation significant at p = 0.05

With one exception, the black spruce equations accounted for the largest amount of variability in the six dependent variables: MAI, tree density, site index, PAI per tree, age of maximum PAI, and mean annual basal area increment, with lesser amounts of variability accounted for by the aspen, white spruce and lodgepole pine equations (Tables 7 to 14). The only exception was that the tree density prediction equation for aspen (R^2=0.99) was slightly higher than that for black spruce (R^2=0.98). The prediction equations were on the whole very satisfactory with a large proportion of the variation in the dependent variables being accounted for by the equations. For black spruce and aspen the prediction equations were nearly equally effective with R^2 values ranging from 0.94 to 0.99 (Tables 9 and 10). For the white spruce stands, the strongest prediction equation was for mean annual basal area increment (R^2=0.94) and the weakest was for stem density (R^2=0.70). For the lodgepole pine stands the strongest prediction equation was for PAI per tree (R^2=0.76) and the weakest was for mean annual basal area increment (R^2=0.44). Site index and MAI are probably the most widely used expressions of site productivity. For all four species, site index was predicted with slightly greater precision than was MAI. For all the equations presented, the R^2 values are significant at the 1% probability level.

To determine the effect of the physical site factors alone upon the selected dependent variables, MAI (rotation age), site index and age of maximum PAI, the vegetation cover values and vegetation-related variables were deleted from the regression. Equations derived in this manner should allow estimation of the dependent variables upon sites where trees, understory and litter have been obliterated by major disturbances such as logging or fire, and should provide estimates for soil survey units where plot data can not be obtained. Deletion of the vegetation-related independent variables resulted in a decrease in the R^2 and F values for the regression equations. These decreases were greatest in the lodgepole pine equations, though all F ratios were still significant at the 1% level (Table 11). The white spruce equations showed the next greatest decrease in R^2 and F values but F ratios were still significant at the 1% level except for age of maximum PAI (significant at 5% level; Table 12). The aspen equations showed a smaller reduction in the R^2 value when vegetation variables were deleted than did those for lodgepole pine and white spruce, but showed very substantial decreases in the F ratio values for MAI and site index equations (Table 13), which were not significant at even the 5% level. The black spruce equations showed a tendency similar to those for aspen with relatively small decreases in R^2 but large decreases in F ratio. The F ratio for the black spruce MAI equation was significant only at the 10% level while that for site index was significant at the 5% level. The black spruce age of maximum PAI equation remained significant at the 1% level (Table 14).

Hagglund and Lundmark (1977) discovered that site index equations calculated for Scots pine and Norway spruce in Sweden by vegetation type were more reliable than equations calculated for the whole tree species group as was done in the present study. The small number of sampled stands within several of the vegetation types prohibited this approach for the Wapiti map area. Lowry (1976) reported that when both individual species and species groups were used in multiple regression equations for black spruce in eastern Canada, the species groups showed higher predictive precision than did individual species. Species groups were not used in the present study, and it seems unlikely this approach would contribute substantially in most cases to the already high R^2 values. Hofman (1976) also recently discovered the utility of vegetation variables in estimating beech productivity in East Germany. Twenty site factors including soil physical and chemical properties plus the ground cover percent of nine indicator species were used.

The significance of the individual independent variables in the regression equations was determined by t-tests. The level of significance (5 or 1% level) is indicated for each independent variable in the equations of Tables 7 to 14. Some variables with non-significant t-tests appear in the regressions. These variables however still contribute at least 1% to the R^2 value up to a maximum of nine independent variables per equation (the criterion for order of occurrence in regression eqaation being the contribution to R^2). Discussion on the ecological significance of the independent variables is limited to those established to be statistically significant as determined by the t-tests in addition to being significantly correlated with the dependent variable (r value significant to at least p=.10).

5. Independent Testing of Regression Equations

In order to determine the utility of the regression equations presented in Tables 6 to 9 it seemed desirable to attempt to test their validity. Multiple regression equations, even though they have a high R^2 value may not necessarily be reliable when applied to data independent of that from which the equations were derived, due to inadequate sampling, incomplete data analysis or chance correlation. Errors due to the above factors will not be detected until the equation is tested with independent data (McQuilkin 1976). This test was accomplished by randomly selecting 70% of the plots for the tree species in question and developing growth prediction equations by stepwise multiple regression techniques, from the data from those plots, using MAI and site index as dependent variables. The equations developed in this manner were used to predict MAI and site index in the remaining 30% of the plots. A simple correlation coefficient between actual and predicted values for MAI and site index was subsequently calculated. This procedure was repeated four times, with vegetation variables included and deleted for both lodgepole pine and white spruce plots. The equations developed from the random selection were terminated after nine steps like the originals and after as many steps as were necessary to include all the independent variables present in the original equations.

The best of the four equations, ie. those which corresponded most closely to the equations developed from all plots for the particular tree species and dependent variables concerned are presented in Tables 15 and 16.

In general, there appeared to be good correspondence between the original equations and those derived from the random selection, though the agreement was better for the lodgepole pine equations than for those developed for the white spruce plots. The best equation developed from the random selection for lodgepole pine MAI (vegetation variables included) contained the same nine variables as the original equation in nine steps though the variables were arranged in slightly different order (Tables 7 vs. 15). The MAI (vegetation variables deleted) equation calculated from the random plot selection for pine contained five of the original six variables in the first six steps (Tables 11 vs. 15). Twelve steps were required to include all six of the original variables. The results for the pine site index equations developed from the random sample were similar, with eight of the original nine variables being present in the equation including vegetation variables and all seven of the variables of the original equation with vegetation variables deleted (Tables 7 vs. 15). With the exception of MAI (vegetation variables deleted), the F-ratios calculated for the lodgepole

Table 15: Multiple regression equations calculated from random sample of lodgepole pine plots

	Equation	R^2	F
	MAI (rotation age; vegetation variables included) (n=26)		
1.	$Y=-0.90600-31.62512X_{62}-1.34483X_{97}-0.59451X_{30}-2.26414X_{63}+0.67200X_{86}-7.79799X_{34}+0.32267X_{60}+5.87968X_{37}+4.59288X_{4}$	.75	9.51**
	MAI (rotation age; vegetation variables deleted) (n=23)		
2.	$Y=+6.91375+4.44379X_{35}-0.00583X_{1}-0.98914X_{37}-4.68189X_{33}+3.07988X_{4}-3.37411X_{34}$	.21	2.31
	Site Index (vegetation variables included) (n=26)		
3.	$Y=+103.13524-65.21701X_{2}-12.37116X_{62}-0.65174X_{97}+0.01627X_{80}+0.47018X_{86}-9.54753X_{34}-4.39556X_{29}-0.01347X_{31}+2.75949X_{87}$	.79	12.33**
	Site Index (vegetation variables deleted) (n=23)		
4.	$Y=+115.68838-77.99786X_{2}+3.52405X_{4}-0.01666X_{31}-0.02379X_{22}-0.60819X_{36}+0.24614X_{3}$	.62	14.34**

Table 16: Multiple regression equations calculated from random sample of white spruce plots

	Equation	R^2	F
	MAI (rotation age; vegetation variables included) (n=12)		
1.	$Y=+10.25734-6.95981X_{32}+2.49511X_{97}-3.44197X_{81}-0.00978X_{1}+1.48249X_{3}+3.37938X_{36}-1.91530X_{63}-4.63095X_{82}+38.53136X_{94}$	.86	7.43*
	MAI (rotation age; vegetation variables deleted) (n=11)		
2.	$Y=+5.43795+5.41227X_{25}+4.50891X_{36}-0.00694X_{1}+1.41626X_{3}-9.42158X_{32}+5.88808X_{29}-2.72676X_{33}$	.62	3.01
	Site Index (vegetation variables included) (n=12)		
3.	$Y=+21.56128+3.35146X_{4}-1.50665X_{82}-0.00348X_{1}-1.40500X_{63}+0.63915X_{3}+0.75270X_{36}+0.01771X_{80}-10.2293X_{62}-1.83905X_{33}$	.94	19.66**
	Site Index (vegetation variables deleted) (n=11)		
4.	$Y=+10.27846+10.17295X_{4}-0.00200X_{1}+6.06300X_{33}-6.05117X_{25}-4.26330X_{32}+1.51914X_{36}+2.38739X_{38}$	.69	2.83

** F-test of equation significant at p=0.01

* F-test of equation significant at p=0.05

pine equations derived from the random plot selection and all the simple correlation coefficients between observed and predicted values for MAI and site index were significant to at least p=.05.

The best equations developed from the random selection of white spruce plots showed less resemblance to the original equations than did the pine equations. The equations for white spruce MAI developed from the random plot selection contained four out of nine and four out of seven of the variables present in the original equations with vegetation variables included and deleted, respectively (Tables 8 vs. 16 and 12 vs. 16). The white spruce site index equations contained six out of nine and five out of seven of the variables present in the original equations with vegetation variables included and deleted, respectively (Tables 8 vs. 16 and 12 vs. 16). Only the equations for white spruce MAI and site index (both with vegetation variables included) had F-ratios significant at p=.05. None of the simple correlation coefficients calculated between observed and predicted values for the four white spruce equations in Table 16 were significant at p=.05.

In summary, the lodgepole pine regression equations are in general, reliable and may be used with caution within the Wapiti map area. The white spruce equations are less reliable. A larger and broader data base encompassing a wide range of soil and site characteristics is desirable for white spruce, black spruce and aspen forests within the Wapiti map area, if the equations for these species are to be widely used.

I. DEPENDENT - INDEPENDENT VARIABLE RELATIONSHIPS

The following discussion is an attempt to discern ecological relationships among the various dependent variables and independent variables that had statistically significant t-tests (to at least p = .05) within the growth prediction equations (Tables 17 to 20). Attempts to explain relationships between the dependent and independent variables in question were made only where significant simple correlations to at least the p = .10 level occurred between the dependent and independent variables, as indicated by asterisks on the simple correlation coefficients in Tables 17 to 20. Thus in the following discussion when references are made to "significant" independent variables, these variables had statistically significant t-tests (to at least p = .05), and when references are made to "correlations" between dependent and independent variables, it can be assumed that the simple correlation coefficients in question are statistically significant to at least the p = .10 level.

Variables discussed represent physical habitat attributes and vegetation attributes (species cover). The physical site attributes are those of the external environment of the site such as slope gradient, slope aspect and elevation and also readily field-determinable physical properties of the soil, especially as they may influence soil moisture regime and tree rooting characteristics.

1. External Site Factors

External site factors include elevation, slope gradient, slope aspect and slope gradient X aspect interaction.

Table 17 Simple correlation coefficients between dependent variables and significant independent variables as determined by t-tests in multiple regression equations for the lodgepole pine plots (n=83)

	Mean annual total volume increment	Stem density	Site index	PAI per tree	Age of maximum PAI	Mean annual basal area increment
Elevation (m)						
log Elevation			$-.57^{**}$	$-.58^{***}$		
Slope percent		$-.21^{**}$				
Slope aspect	$+.22^{**}$			$+.32^{***}$		
Aspect X slope						
% Si+C in A horizon					$+.35_{v}^{***}$	
Thickness A horizon (cm)						
Thickness A (Si+C in A hor)						
% Si+C in B horizon						
% Clay in B horizon						
Thickness B horizon (cm)						
Thickness B (Si+C in B hor)					$-.13$	
Clay in A hor/Clay in B hor				$+.21^{**}$		
% Stone in profile						
Internal profile drainage			$-.02$			$-.09$
Depth to distinct mottling (cm)	$+.02$			$+.02$		
Hydraulic conductivity (cm day^{-1})						
log Hydraulic conductivity						
Structure of B horizon		$+.10$				
Consistence B horizon	$-.17$		$-.08$			
Chroma A horizon	$+.34_{v}^{***}$					
Hue B horizon						
Value B horizon	$-.12$					$-.10$
log Total moss cover						
Total lichen cover	$-.21^{**}$		$-.28^{***}$	$-.27^{***}$		

*** Significant at p = .01

** Significant at p = .05

* Significant at p = .10

v Independent variable occurring only in equations with vegetation variables deleted

Table 17 cont.

	Mean annual total volume increment	Stem density	Site index	PAI per tree	Age of maximum PAI	Mean annual basal area increment
Chroma B horizon						
Canopy cover	+ .30***			+ .31***	+ .25***	+ .04
Litter cover						
1/log Litter cover	- .57***		- .51***		+ .61***	+ .32**
Deadfall cover	- .07					
Stem density					+ .02	
Thickness organic horizon (cm)					+ .24**	
log Thickness organic		- .13				+ .13
Regeneration density (stems ha^{-1})		- .23**	+ .15	+ .20		
Rosa acicularis cover		+ .11				- .11
Ledum groenlandicum cover						
log *Ledum* cover		+ .19*				
Rubus pedatus cover						
Epilobium angustifolium cover						
Cornus canadensis cover	+ .28**		+ .33***			- .17
Rubus pubescens cover			+ .51**			
Calamagrostis canadensis cover						
Vascular plant cover				+ .52***		- .07
log Vascular plant cover		- .47***				
Hylocomium splendens cover						
Pleurozium schreberi cover						
log *Pleurozium* cover						
Polytrichum commune cover						
Total moss cover				- .36***		+ .23**

Table 18 Simple correlation coefficients between dependent variables and significant independent variables as determined by t-tests in multiple regression equations for the white spruce plots (n = 30)

	Mean annual total volume increment	Stem density	Site index	PAI per tree	Age of maximum PAI	Mean annual basal area increment
Elevation (m)	- .41**		- .53***			
log Elevation						+ .21
Slope percent	+ .02v		- .02v			
Slope aspect	+ .27				- .26v	
Aspect X slope						
% Si+C in A horizon						
Thickness A horizon (cm)						
Thickness A (Si+C in A hor)						
% Si+C in B horizon						
% Clay in B horizon						
Thickness B horizon (cm)						
Thickness B (Si+C in B hor)					- .42**	- .44**
Clay in A hor/Clay in B hor					+ .22	
% Stone in profile	- .17					
Internal profile drainage			+ .05			
Depth to distinct mottling (cm)						
Hydraulic conductivity ($cm\ day^{-1}$)						
log Hydraulic conductivity	- .42v**		- .41v**			
Structure of B horizon					- .24	- .24
Consistence B horizon						
Chroma A horizon						
Hue B horizon	- .05v					
Value B horizon		+ .23			- .22v	
Chroma B horizon		- .01		- .21		

Table 18 cont.

	Mean annual total volume increment	Stem density	Site index	PAI per tree	Age of maximum PAI	Mean annual basal area increment
Canopy cover	+ .29					- .13
Litter cover						
1/log Litter cover			- .40**		+ .49***	
Deadfall cover			- .43**	- .28	+ .40**	
Stem density						
Thickness organic horizon (cm)				- .16	+ .35*	
log Thickness organic						
Regeneration density (stems ha^{-1})	+ .22					
Rosa acicularis cover	- .13		+ .20			+ .17
Ledum groenlandicum cover	- .26		- .23	- .26	+ .31*	+ .50***
log *Ledum* cover						
Rubus pedatus cover						
Epilobium angustifolium cover				- .16		
Cornus canadensis cover		- .23	+ .25			
Rubus pubescens cover				+ .51***		
Calamagrostis canadensis cover	+ .10			+ .16		- .04
Vascular plant cover		- .44**				
log Vascular plant cover				+ .44**		
Hylocomium splendens cover						
Pleurozium schreberi cover						
log *Pleurozium* cover						
Polytrichum commune cover		+ .46***				
Total moss cover						
log Total moss cover						+ .02
Total lichen cover						

*** Significant at p = .01

** Significant at p = .05

* Significant at p = .10

v Independent variable occurring only in equations with vegetation variables deleted

Table 19 Simple correlation coefficients between dependent variables and significant independent variables as determined by t-tests in multiple regression equations for the black spruce plots (n = 15).

	Mean annual total volume increment	Stem density	Site index	PAI per tree	Age of maximum PAI	Mean annual basal area increment
Elevation (m)						
log Elevation			$- .10$			
Slope percent					$- .15_v$	
Slope aspect			$+ .53_v^{**}$			
Aspect X slope				$+ .50^{*}$		$+ .64^{***}$
% Si+C in A horizon	$- .38$		$+ .60^{*}$	$- .19$	$+ .57^{**}$	$- .50^{*}$
Thickness A horizon (cm)						$+ .23$
Thickness A (Si+C in A hor)						
% Si+C in B horizon						
% Clay in B horizon						
Thickness B horizon (cm)						
Thickness B (Si+C in B hor)						
Clay in A hor/Clay in B hor			$- .34_v$		$- .05_v$	
% Stone in profile					$- .46_v^{*}$	
Internal profile drainage	$- .04_v$	$+ .34$	$+ .16_v$		$+ .13$	
Depth to distinct mottling (cm)	$- .22_v$	$+ .21$	$- .29_v$		$+ .22_v$	
Hydraulic conductivity (cm day^{-1})	$+ .35_v$					
log Hydraulic conductivity				$+ .26$		
Structure of B horizon	$+ .17$					
Consistence B horizon						
Chroma A horizon	$+ .19_v$			$+ .13$	$- .09$	
Hue B horizon					$- .12_v$	$+ .23$
Value B horizon	$+ .40_v$		$+ .58_v^{**}$			

Table 19 cont.

	Mean annual total volume increment	Stem density	Site index	PAI per tree	Age of maximum PAI	Mean annual basal area increment
Chroma B horizon		+ .82***		- .34	- .27	
Canopy cover		+ .20	+ .14	+ .29		
Litter cover						
1/log Litter cover					+ .60**	
Deadfall cover			+ .27			
Stem density					- .04v	
Thickness organic horizon (cm)						- .47*
log Thickness organic						
Regeneration density (stems ha^{-1})						
Rosa acicularis cover	+ .42				- .24	
Ledum groenlandicum cover			- .46*			
log *Ledum* cover						
Rubus pedatus cover	- .14			- .12		
Epilobium angustifolium cover	+ .78***		+ .65***			+ .53**
Cornus canadensis cover			+ .49*			+ .54**
Rubus pubescens cover			+ .13			
Calamagrostis canadensis cover				- .27		
Vascular plant cover						
log Vascular plant cover						
Hylocomium splendens cover		- .27			- .23	+ .45*
Pleurozium schreberi cover						
log *Pleurozium* cover						
Polytrichum commune cover						
Total moss cover						
log Total moss cover	+ .22			- .72***		
Total lichen cover		+ .39				

*** Significant at p = .01

** Significant at p = .05

* Significant at p = .10

v Independent variable occurring only in equations with vegetation variables deleted

Table 20 Simple correlation coefficients between dependent variables and significant independent variables as determined by t-tests in multiple regression equations for the aspen plots (n = 17).

	Mean annual total volume increment	Stem density	Site index	PAI per tree	Age of maximum PAI	Mean annual basal area increment
Elevation (m)						
log Elevation					+ .28$_{v}$	
Slope percent					+ .42*	
Slope aspect						- .20
Aspect X slope						
% Si+C in A horizon					+ .35$_{v}$	
Thickness A horizon (cm)				+ .40		
Thickness A (Si+C in A hor)			+ .43*			
% Si+C in B horizon		- .18				
% Clay in B horizon						
Thickness B horizon (cm)						
Thickness B (Si+C in B hor)						
Clay in A hor/Clay in B hor		- .19	+ .24			
% Stone in profile					+ .17	
Internal profile drainage	- .18$_{v}$					
Depth to distinct mottling (cm)				- .29		
Hydraulic conductivity (cm day^{-1})					+ .27	
log Hydraulic conductivity						
Structure of B horizon	- .34	- .21			+ .29$_{v}$	+ .30
Consistence B horizon			- .47$_{v}^{*}$		+ .12	
Chroma A horizon	- .15	- .01				
Hue B horizon					- .55**	
Value B horizon	+ .11			+ .22		- .27

Table 20 cont.

	Mean annual total volume increment	Stem density	Site index	PAI per tree	Age of maximum PAI	Mean annual basal area increment
Chroma B horizon			+ .30			
Canopy cover						
Litter cover						
1/log Litter cover						
Deadfall cover			- .20		+ .06	
Stem density					- .19v	
Thickness organic horizon (cm)	+ .61***					
log Thickness organic			- .37	- .10		
Regeneration density (stems ha^{-1})			+ .06			
Rosa acicularis cover						
Ledum groenlandicum cover				- .07		
log *Ledum* cover						
Rubus pedatus cover						
Epilobium angustifolium cover		- .22	+ .71***			
Cornus canadensis cover		+ .21		+ .10	+ .15	
Rubus pubescens cover	- .42*					+ .43*
Calamagrostis canadensis cover				- .25		
Vascular plant cover				+ .58**		
log Vascular plant cover		- .60**	+ .23			+ .67***
Hylocomium splendens cover						+ .31
Pleurozium schreberi cover		+ .37				- .14
log *Pleurozium* cover					- .11	
Polytrichum commune cover						
Total moss cover						
log Total moss cover						
Total lichen cover						

*** Significant at p = .01

** Significant at p = .05

* Significant at p = .10

v Independent variable occurring only in equations with vegetation variables deleted

1.1 Elevation (X1, X2)

Elevation or its log was a significant independent variable in seven equations: white spruce MAI (vegetation variables included and deleted), site index (vegetation variables included and deleted) and mean annual basal area increment; black spruce site index; and aspen age of maximum PAI (vegetation variables deleted) (Tables 8, 9, 12, 14). All the correlations between the dependent variables and elevation were negative with the exception of white spruce mean annual basal area increment (Tables 18-20).

The negative correlation between growth and elevation is expected and is an indication of the cooler climate and shorter growing season at high elevations. It is notable that where the elevations of the sampled stand groups are within fairly narrow ranges, such as for black spruce and aspen, factors other than elevation contributed more to the R^2 value in the regression equations (Tables 9, 10, 13, 14). The positive correlation of elevation with white spruce mean annual basal area increment may be a reflection of a tendency at high elevations, for volume growth to be added to the lower part of the tree (greater taper) as MAI is negatively correlated with elevation (Table 18). Other authors have shown similar relationships between productivity and elevation. For example, Mader (1963) demonstrated that five-year volume increment for red pine (*Pinus resinosa* Ait.) was negatively correlated with increasing elevation. Graney and Ferguson (1971) showed that shortleaf pine (*Pinus echinata* Mill.) site index in Arkansas was also negatively correlated with increasing elevation.

1.2 Slope gradient (X3)

Slope gradient was a significant independent variable in five equations: lodgepole pine density; white spruce MAI and site index, both with vegetation variables deleted; black spruce age of maximum PAI (vegetation variables deleted) and aspen age of maximum PAI (vegetation variables deleted) (Tables 7, 8, 12, 14). The simple correlation coefficients between slope gradient and the growth expressions were positive, with the exception of lodgepole pine density (Tables 17-20).

The positive correlation of slope gradient with several of the dependent variables is in agreement with other workers. Dumanski et al. (1973) found that increasing topographic steepness, implying better soil drainage, was associated with increased PAI for lodgepole pine, with optimal slopes being approximately 15-30%, for the Hinton-Edson area of Alberta. Duffy (1964a) found that lodgepole pine height growth was positively correlated with slope gradient on till parent materials in the Rocky Mountain House area, Alberta. Della-Bianca and Olson (1961) also observed that height growth was positively correlated with percent slope in Piedmont hardwood and pine-hardwood upland forests. Myers and Van Deusen (1960) noted similar relationships for ponderosa pine site index in the Black Hills area of South Dakota.

The negative correlation of percent slope with lodgepole pine density is perhaps an indication of the difficulty of seedling establishment on slopes where steepness results in increasing erosion and where young see[illegible] or pine seed may also be washed away.

The positive correlation of slope angle with aspen age of maximum PAI (Table 20) is believed to be due to aspen's high frequency of occurrence on nearly level to gently sloping, imperfectly drained sites, and subsequent better growth on these sites. In the lodgepole pine plots slope is negatively correlated with the thickness of the Ae horizon, (r = -.25) reflecting the lesser amount of leaching possible on steep slopes as well as probable greater erosion on these slopes, particularly following forest fires prior to stand origin. In the white spruce plots, slope was positively correlated with better soil profile drainage. It is interesting to note that the correlation between slope and drainage is not significant for the lodgepole pine plots (R = -0.06) suggesting that the productivity increases on steeper slopes in the lodgepole pine forests may not be due to better drainage as was suggested by Dumanski et al. (1973) for west-central Alberta. In fact, steeply sloping sites, especially in the lower slope position may actually be more moist than their more gently sloping counterparts due to groundwater discharge or seepage within the site. Unfortunately, the effect of slope position on productivity was not evaluated in this study. A more extensive consideration of drainage is included in the separate discussion of drainage.

In the black spruce plots, slope gradient was positively correlated with thickness of the A horizon (usually an Aeg horizon) and profile drainage. Though this correlation is opposite to that of the pine plots (r =+.50), it reflects the negative correlation of slope with the thickness of the organic layer and the tendency for peat accumulation, and restricted Ae development on level black spruce sites.

1.3 Slope aspect (X4)

Slope aspect was a significant independent varia[illegible] grow[illegible] prediction equations [illegible] lodgepole pine MAI and PAI per tree; white spruce MAI and age of maximum PAI (vegetation variables deleted); black spruce site index (vegetation variables deleted); and aspen mean annual basal area increment (Tables 7, 8, 10, 12, 13). In order to be entered as an independent variable in a stepwise multiple regression, aspect must be coded in a form other than as azimuth degrees due to the circular nature of the compass and the obvious difficulty of coding northerly aspects and of averaging aspects. This problem was overcome by using a method adopted by Myers and Van Deusen (1960) and several authors since, who expressed aspect as (sine of azimuth clockwise from southeast)+1, where the southeast exposure was least productive. This method gives a range of transformed aspect from 0 to 2 and gives equal ratings to 0^{o} and 360^{o} azimuth. In this study, the most productive aspect was found to be between north and north-northeast (11.3^{o}), and the least productive were southeast to south-southeast aspects, when MAI values were stratified according to slope aspect. Thus northerly aspect was then assigned a maximum value of 2, (sine 90^{o} +1). The difference between 11.3^{o} and 90.0^{o} is the correction used. The aspect transformation thus became aspect = sine (azimuth+78.0)+1. Thus, positive correlations with slope aspect reflect a tendency towards maximum productivity on north to northeast aspects. In the equations mentioned above for lodgepole pine and black spruce, the significant correlations of aspect with the dependent variable were positive (Tables 17, 19).

Lloyd and Lemmon (1970) found that the optimum rectification for oak site index in the Northern Appalacians was $45\text{-}60^{o}$ depending on soil series. Site index was lowest in the west and highest in the northeast. They decided to use 58^{o} as an average correction as opposed to 45^{o} used by many authors, but emphasized that too much reliance should not be placed on the appropriate rectification for azimuth for any one soil series due to one or more of several factors: (1) perhaps not enough plots were available to adequately sample the population in question, (2) the data may not have properly sampled all sectors of the azimuth circle, and (3) some undefined interactions may have affected the relationships.

Several other authors have discovered preferences of various tree species for particular slope aspects. Duffy and England (1967) observed that sites on steep, north-facing slopes were more productive for a given surface material than those on south-facing slopes in the Kananaskis

Experiment Station, Alberta. Duffy and Knight (1967) noticed the same trends and also that the best forest growth occurred on upper north-facing slope positions, but upper and mid south-facing slopes and imperfectly drained hilltops were less productive in the Whitecourt, Alberta forest area. Dumanski et al. (1973) found that aspect had minimal effect on medium and fine-textured materials but the north aspects tended to outproduce south aspects on sandy and gravelly materials in the Hinton - Edson area, Alberta. Other studies in the eastern United States have also indicated better growth on northerly aspects (Carmean 1965; Graney and Ferguson 1971, 1972; Lee and Sypolt 1974). The more favorable moisture regime on northerly aspects is often given as the explanation. Lee and Sypolt (1974) from observations on adjacent north and south-facing slopes in West Virginia suggested that in areas of high summer precipitation, marked differences in growth are not associated with soil moisture differences. At midday on south-facing slopes it appears that: (1) super-optimum temperatures for net assimilation occur frequently in forest canopies (2) soil temperatures lower than canopy temperatures limit absorption of available water and (3) higher canopy temperatures increase transpiration demand, create leaf water-deficits earlier in the day and magnify the midday depression of net assimilation (Lee and Sypolt 1974). In contrast to the findings of the present study, Lowry (1975) found that black spruce site index in eastern Canada was higher on south aspects and on mineral soil, indicating that the cooler north aspects were limiting to black spruce growth.

West-facing slopes are warmer than east-facing slopes. The maximum solar radiation on east-facing walls was observed two to three hours after dawn, when soils and air are cool. The maximum radiation on west-facing walls was observed two to three hours before sunset. Thus, the same radiation intensity would be expected to heat a west-facing slope to a higher temperature than an east-facing slope (Cunniff 1958 cited in Taylor and Ashcroft 1972 p. 37).

It has been suggested by some authors (Squillace and Bingham 1958 and Hermann and Lavender 1968 cited in Spurr and Barnes 1973 p. 40) that differences in aspect and thus soil moisture may lead to ecotypes found on certain aspects.

1.4 Aspect and slope interaction (X5)

Because slope gradient and aspect act together to influence tree growth, it seemed desirable to include an interaction or product of aspect and slope as an independent variable within the regression. Together slope and aspect determine the amount of insolation at the ground surface which in turn determines air and soil temperatures, influences precipitation distribution and soil moisture conditions.

Surprisingly, the slope X aspect interaction was a significant independent variable in only two equations: black spruce PAI per tree and mean annual basal area increment (Table 9). Both correlations were positive (Table 19) suggesting that black spruce basal area and PAI per tree are favored by steep north aspects. Dukovnikov (1975) used an integrated slope, aspect, relief and altitude index for *Pinus sylvestris*, *Picea abies* and *Abies alba* in Bulgaria, **that effectively integrated these variables.**

2. Internal Site (Soil) Factors

Included in internal site factors are the various soil physical properties which influence or reflect differences in forest growth including soil texture, horizon thickness, drainage, color, structure and consistence.

2.1 Texture and horizon thickness

Several measures of soil texture used in the regression analysis including silt plus clay contents of the A (usually Ae) and B (usually Bt) horizons, a ratio of clay in the A horizon to clay in the B horizon and stone content of the profile are discussed. The thickness of the A horizon and interactions of thickness of the A and B horizons with silt plus clay content of the respective horizons are also discussed here.

Silt plus clay content of the A horizon (Var. X20) was a significant independent variable in seven equations; lodgepole pine age of maximum PAI (vegetation variables deleted); black spruce MAI, site index, age of maximum PAI (vegetation variables included and deleted) and mean annual basal area increment; and aspen age of maximum PAI (vegetation variables deleted) (Tables 7, 9, 10, 11, 13, 14). Lodgepole pine age of maximum PAI, black spruce site index and age of maximum PAI were positively correlated with silt plus clay content (Tables 17, 19) while black spruce mean annual basal area increment was negatively correlated (Table 19).

It appears that increases in silt plus clay content of the A horizon indicate more impeded drainage in the already poorly drained black spruce forests. The positive correlation with age of maximum PAI indicates slower maturation of black spruce on the fine textured soils where profile drainage is likely to be more impeded.

Elsewhere, other authors have found correlations of A horizon silt plus clay content with forest productivity. Mader (1963) found that five-year volume increment for red pine was positively correlated with moisture holding capacity of the A and B horizons. Mogren and Dolph (1972) found for north-central Colorado and south-central Wyoming that lodgepole pine site index was negatively correlated with percent soil particles greater than 0.25 mm diameter in the A horizon, however there was no significant positive correlation with silt plus clay contents in the A and B horizons. They believed that correlations with site index were accounted for by water availability. Mader (1976) discovered that higher silt plus clay contents in the A horizon were associated with better white pine sites in Massachusetts, probably as a result of better water availability and fertility. Lutz and Chandler (1946) emphasized that excessively fine or coarse soils are not productive.

The interaction of A horizon silt plus clay content and A horizon thickness (Var. X22), expressed as a product of the two was significant in only one equation: aspen site index (Table 10). The simple correlation of this interaction with aspen site index is positive (Table 20), indicating aspen's apparent preference for deep, fine textured A horizons.

Thickness of the A horizon (Var. X21) considered alone was a significant independent variable in only two equations: black spruce mean annual basal area increment and aspen PAI/tree, (Tables 9, 10). The only significant positive correlation was with aspen PAI per tree (Table 20) and is probably a reflection of more soil profile leaching and better drainage exerting a favorable influence upon PAI.

Several other authors have determined relationships between A horizon thickness and forest productivity. Duffy (1964a) found for the Rocky Mountain House area, Alberta that lodgepole pine dominant height and average height were positively correlated with the thickness of the Ae horizon, while basal area per acre, total volume per acre and merchantable volume per acre were negatively correlated. Holmes and Tackle (1962) found that lodgepole pine height growth in Montana was positively correlated to the depth of abundant rooting which usually coincides with the depth of the Ae horizon. Hansen and McComb (1958), in southeastern Iowa, observed that height and diameter growth of green ash and black walnut were inversely correlated with the degree of erosion of the Ae horizon. Della-Bianca and Olson (1961) observed for the Piedmont hardwood and pine-hardwood upland forests, that height growth was positively correlated with thickness of the A horizon and with percent organic matter in the A horizon X horizon thickness. Carmean (1965) described black oak site index in Ohio as a function of the depth of the A1+A2 horizons and several other factors for medium-textured, well drained soils and for fine-textured soils with restricted internal drainage. Mogren and Dolph (1972) had similar results and observed that lodgepole pine site index was positively correlated with solum depth and believed that site index was accounted for by water availability.

Silt plus clay content of the B (usually Bt) horizon (Var. X23) was a significant independent variable in only one equation, aspen density, (Table 10) and the correlation was not significant (Table 20).

Elsewhere, other authors have related B horizon silt plus clay content to forest productivity. Fralish and Loucks (1975) reported that aspen site quality in Wisconsin was negatively correlated with sand content of the Bt and positively correlated with available water-holding capacity. Duffy and Knight (1967) found the best forest growth in the Whitecourt Forest area of Alberta on moderately well drained sandy clay loam till sites on upper, north-facing slopes. Some sites had alluvial sandy loam overlays. Page (1976) observed that white spruce and balsam fir site index in Newfoundland were negatively correlated with silt plus clay content in the lower solum. Gessel and Lloyd (1950) observed Douglas-fir site index increases in north-western Washington when soil textures ranged from coarse to medium textures. Douglas-fir site index also increased on soils underlain by an impeding layer when precipitation increased up to a total of 150 cm per year. Hannah and Zahner (1970) discovered that the site index of jack pine and bigtooth aspen in Michigan was significantly greater on soils developed on outwash sands with textural bands of unsorted till-like material. Red pine site index in Minnesota was 2.5 m greater on plots with textural B horizons or textural banding and was more closely related to the surface soil (top 25 cm) than to subsoil when textural bands were absent (Alban 1974). Mader (1976) discovered that increased silt plus clay content in the B horizon was associated with reduced site quality in natural stands of white pine in Massachusetts, perhaps reflecting reduced aeration and poorer rooting. Cation exchange capacity is also greater in fine textured soils. It is thus apparent that no broad generalizations can be made upon the influence of soil texture alone on site quality. A coarse-textured soil may support excellent productivity if the moisture regime is favorable. Influence of soil texture must be discussed in terms of other soil properties if it is to be meaningful, and generalizations cannot be made for large areas. For example, a fine-textured soil which retains optimum soil moisture in one area may retain too much in another area where precipitation is much higher, with resulting decreased yields due to flooding or lack of oxygen for tree roots.

The interaction of silt plus clay content in the B horizon with horizon thickness, expressed as a product of the two (Var. X26), has often proved to be a useful measure for evaluating site quality. In this study, this interaction was a significant dependent variable in three equations: lodgepole pine age of maximum PAI; white spruce age of maximum PAI and mean annual basal area increment (Tables 7, 8). The significant simple correlation of the interaction with white spruce age of maximum PAI was negative (Table 18) indicating more rapid maturity of white spruce on soils with a likely high available water-holding capacity. The negative correlation of the interaction with white spruce mean annual basal area increment (Table 18) is likely indicative of impeded drainage and restricted oxygen availability for white spruce roots on sites with thick, fine-textured Bt horizons. Other authors have shown relationships between site productivity and the interaction of B horizon silt plus clay content and thickness. Duffy (1964a) demonstrated that percent silt plus clay in the Bt X effective horizon thickness /10 was negatively correlated with lodgepole pine dominant height, average height, total volume and merchantable volume on one soil series in the Rocky Mountain House area, Alberta. The correlation with basal area per acre was positive.

The ratio of clay in the A horizon/clay in the B (Var. X27) was used as an independent variable to express the degree of leaching or profile development and to determine whether this process might be related to forest productivity. This ratio was a significant independent variable in six equations: lodgepole pine PAI per tree; white spruce age of maximum PAI (vegetation variables included and deleted); black spruce site index and age of maximum PAI (vegetation variables deleted); and aspen density and site index (Tables 7-10, 12, 13). The only significant simple correlation was with lodgepole pine PAI per tree and was positive (Table 17), suggesting that lodgepole pine PAI per tree is greatest where the Ae horizon is well developed or where a sandy aeolian overlay may be present with a consequent favorable rooting environment in these soils. No examples were found in the literature where clay A/clay B horizon ratios were used as independent variables in growth prediction equations as just described.

Stone content (Var. X28) based upon a visual estimate of coarse fragment in the solum greater than 1 cm diameter was a significant independent variable in three equations: white spruce MAI; black spruce age of maximum PAI (vegetation variables deleted) and aspen age of maximum PAI

(Tables 8, 10, 13). Only the negative correlation of stone content with black spruce age of maximum PAI was significant (Table 19). It is generally regarded that stones in the solum or the subsoil do not have an adverse effect upon forest productivity unless there are so many that rooting volume and/or water-holding capacity is reduced. Lutz and Chandler (1946) suggested that root space becomes constricted when stone content is greater than 20%, but stone content makes fine-textured soils more porous with root penetrability facilitated. Also the presence of stones on and in the soil decreases evapotranspiration losses. In the Wapiti map area, stone content within the profile seldom exceeds 20% and averages from 7% in the pine plots to less than 1% in the aspen plots (Tables 3-6). Black spruce age of maximum PAI is negatively correlated with stone content (Table 19) but is positively correlated with silt plus clay content in the A horizon (Table 19) indicating that stone content is a reflection of coarse texture. Mogren and Dolph (1972) observed that lodgepole pine site index in north-central Colorado and south-central Wyoming was negatively correlated with percent surface stoniness but there was no significant correlation with percent stone in the solum. They attributed the relationship with site index to be a reflection of water availability.

2.2 Soil Profile Drainage

Soil profile drainage and site moisture regime are determined by topographic position, the physical nature of the parent material, depth and position of water table, soil profile features and precipitation (Farrar 1960). Three criteria were used as independent variables to characterize internal soil profile drainage; internal soil drainage class on a five point scale (Appendix 2), depth to distinct mottling (Canada Soil Survey Committee 1970), and hydraulic conductivity as inferred from the texture of the least permeable horizon (Appendix 2). Only one profile drainage-related variable was allowed to enter any one regression equation, namely the variable that accounted for the greatest increase in the R^2 value.

Internal soil drainage (Var. X29) where 1 = poor and 5 = rapid, was a significant independent variable in eight equations: lodgepole pine site index and mean annual basal area increment; white spruce site index; black spruce MAI (vegetation variables deleted), density, age of maximum PAI and site index (vegetation variables deleted) and aspen MAI (vegetation variables deleted) (Tables 7, 8, 9, 13, 14). None of the simple correlations of internal soil drainage with the dependent variables were significant.

Jeglum (1974) reported increased black spruce growth on northern Ontario peatlands as soil aeration improved and that moisture-aeration and nutrient regimes explained large proportions of the variation in minor vegetation. Similar results were observed by Lowry (1974) for black spruce in eastern Canada.

Depth to distinct mottling (Var. X30), a morphological criterion useful in assessment of soil internal drainage, was a significant independent variable in seven equations: lodgepole pine MAI and PAI per tree; black spruce MAI (vegetation variables deleted), density, site index (vegetation variables deleted) and age of maximum PAI (vegetation variables deleted); and aspen PAI per tree (Tables 7, 9, 10, 11). None of the simple correlations of depth to distinct mottling with the dependent variables were significant.

Hydraulic conductivity (Var. X31) or its log (Var. X32), depending upon which gave the better correlation with the dependent variable, was a significant independent variable in seven equations: white spruce MAI (vegetation variables included and deleted) and site index (vegetation variables deleted); black spruce MAI (vegetation variables deleted) and PAI per tree; and aspen age of maximum PAI (Tables 8, 9, 10, 11, 13). Hydraulic conductivity was significantly correlated only with white spruce density and PAI per tree (both negative; Table 18). The inferred hydraulic conductivity is very highly correlated with the silt plus clay content of the B horizon since hydraulic conductivity is inferred from texture (Appendix 2).

Other authors have found relationships between soil drainage and moisture availability with forest productivity. Griffith (1960) found that available soil moisture in the B horizons during the growing season (May to September) was the most important single variable affecting coastal Douglas-fir growth, accounting for 47% of the total variability. Duffy (1964a) discovered that lodgepole pine total volume per acre was negatively correlated with available moisture on a weight basis in the surface 91 cm (36 in) on one soil series in the Rocky Mountain House area of Alberta. Similar results were found by Holmes and Tackle (1962) in Montana. Spurr and Barnes (1973 p. 95) pointed out that the factors that contribute towards making a soil well drained, especially convex surfaces, are apt to ensure good drainage of cold air and indicate a site with lower maximum and higher minimum temperatures than would be indicated by the regional climatic average. They further noted that well drained soils support plants of southerly distribution. These trends were observed in the Wapiti map area, and are especially evident when the vegetation of the poorly drained black spruce - Labrador tea - cloudberry type (Type 7), which is comprised of species of predominantly northern distribution, is compared with the rapidly drained lodgepole pine - blueberry - lichen type (Type 14) which is comprised of species that have ranges extending much farther south than the species of the black spruce bog forests (Type 7). Productivity is limited in the black spruce bog forests (Type 7) due in part to excess water and is limited in the lodgepole pine - blueberry - lichen type by insufficient soil moisture.

2.3 Soil Structure (X33) and Consistence (X34)

Structure and consistence of the B (usually Bt) horizon were entered as independent variables into the regressions in order to determine if these properties had utility in predicting the various dependent variables. The scales used to code these variables are in Appendix 2. Structure of the B horizon (1 = structureless, 7 = platy), implying a gradient from 1 to 7 of increased ease of root penetration, was a significant independent variable in nine equations: lodgepole pine density; white spruce age of maximum PAI (vegetation variables included and deleted) and mean annual basal area increment; black spruce MAI; and aspen MAI, density, mean annual basal area increment and age of maximum PAI (vegetation variables deleted) (Tables 7, 8, 9, 10, 12, 14). None of the simple correlations of structure of the B horizon with the dependent variables were significant.

Soil porosity in part, is a result of structure that allows gaseous exchange with tree roots as well as providing rapid water infiltration. Root penetrability is best into soils with aggregates in the 2-6 mm diameter range (Taylor and Ashcroft 1972). The type of soil aggregation is important to soil permeability. A well-aggregated fine-textured soil may function as a coarse textured soil. Structure is most important in soils high in silt and clay and favorable structure is promoted by the presence of organic matter (Spurr and Barnes 1973). Tree roots enhance soil structure by compressing soil particles into aggregates and decaying plant roots tend to bind the aggregates. Favorable soil structure is best maintained by healthy forest stands of species well adapted to their environment (Lutz and Chandler 1946). Soil structure may be destroyed by the removal of litter and by leaving the soil surface exposed to the pounding of rain that causes compaction and leaching (Spurr and Barnes 1973, Lutz and Chandler 1946).

Soil consistence (Var. X34) was also considered in the regression analysis, and was expressed on a five point scale (Appendix 2) for the B (usually Bt) horizon ranging from loose to extremely firm. Soil consistence is strongly influenced by soil moisture content that in turn is affected by the time of year, with soils usually being more moist in the early part of the growing season, than later in the summer. For this reason, soil consistence as used here might not be as strong an indicator of site productivity as some of the more permanent soil properties such as texture. Nevertheless, consistence of the B horizon was a significant independent variable in five equations: lodgepole pine MAI and site index; and aspen age of maximum periodic annual increment (vegetation variables included and deleted) and site index (vegetation variables deleted) (Tables 7, 10, 14). Only aspen site index (vegetation variables deleted) was significantly correlated with consistence of the B horizon (Table 20). The negative correlation was interpreted as being a result of increased resistance to root penetration as consistance ranges from loose to extremely firm.

This is the only study the author is aware of where soil structure and consistence were introduced as independent variables in a stepwise multiple regression approach to evaluating site quality. The early indications are that these variables might prove useful.

2.4 Soil Color

Color is probably the most easily determined of soil characteristics. Several inferences about other soil characteristics may be drawn from soil color. Dark colors (low value and chroma) may be indicative of undecomposed organic materials or in soils low in organic matter, may indicate compounds of iron and humus, elemental carbon, or compounds of manganese, and magnetite (Soil Survey Staff 1951). Red colors in soil are generally related to unhydrated iron oxide which is relatively unstable under moist conditions and thus indicates good drainage and aeration. The light gray of Ae horizons may indicate a very low content of organic matter and iron (Soil Survey Staff 1951). Yellow colors are largely due to the presence of hydrated iron oxides frequently found in imperfectly drained soils. Dark gray colors may result from poor aeration. The gray color of gleyed horizons of poorly drained soils may be due to the presence of ferrous compounds. Soil color is inherited from the parent material and reflects it's composition and lithology (Soil Survey Staff 1951, Lutz and Chandler 1946).

Four attributes of soil color from Munsell notation were entered as independent variables into the regression analysis: hue of the B horizon, value of the A horizon, chroma of the A horizon and chroma of the B horizon.

Hue is the dominant spectral color of the soil. Within the range for the hue YR (yellow-red), the hue becomes more yellow and less red as the hue numbers increase. Within the range for the hue Y (yellow), the hue becomes more yellow and less green as the hue numbers increase (Soil Survey Staff 1951). For the Wapiti area, within the YR hues, a decrease in hue number (increasing redness) generally corresponds to a change in internal drainage class from imperfectly to rapidly, increased aeration and increased oxidation of iron compounds to the ferric form, rather than with a change in color associated with different parent materials.

Hue of the B horizon (Var. X36) was a significant independent variable in only five equations: white spruce MAI (vegetation variables deleted); black spruce mean annual basal area increment and age of maximum PAI (vegetation variables deleted) and aspen age of maximum PAI (vegetation variables included and deleted) (Tables 9, 10, 12, 13, 14). Only the negative simple correlation with aspen age of maximum PAI was significant (Table 20). In the soils of the sampled plots, the hues of the B (Bt, Bm, Bg, Btg, Btgj, Btj) horizons are almost exclusively within 7.5 YR, 10 YR and 2.5 Y charts, the 2.5 Y colors indicating more restricted drainage and less oxidation of iron compounds than does the 10 YR chart. The negative correlation with aspen age of maximum PAI indicates more rapid maturity on the soil with 10 YR hues (better drainage). Since hue of the B horizon seems to be largely a function of drainage for the soils of the forest stands sampled here, the author believes that soil internal drainage class is probably a better representation of soil moisture regime. Drainage class is assigned partly on the basis of soil hue, and the drainage class scale used here (Appendix 2) permits evaluation of a much wider range of soil drainage conditions than does hue alone.

Color value of the B horizon (Var. X37), an expression of the relative lightness of the color, was a significant independent variable in eight equations: lodgepole pine MAI and mean annual basal area increment; white spruce density and age of maximum PAI (vegetation variables deleted); aspen MAI, PAI per tree and mean annual basal area increment; and black spruce MAI (vegetation variables deleted) and site index (vegetation variables deleted) (Tables 7, 8, 10, 12, 13). The only significant correlation of color value of the B horizon was with black spruce PAI per tree (vegetation variables deleted) and was positive (Table 19). Increasing value or lightness is usually a reflection of more intense weathering or leaching, although the mineralogic composition of the soil is also an important determinant. Soil color value darkens by one-half to three steps between dry and moist (Soil Survey Staff 1951). Because all of the soil colors were determined in the field at close to field capacity moisture conditions, the variation among hue, value and chroma due to differences in soil moisture should be minimal. Soils under lodgepole pine forests often have well developed Ae horizons of high color value, often to the extent where a secondary Ae horizon develops within the first, giving the "bleached" condition (Dumanski et al. 1973). High soil color value of the Bt horizon may be an indication of degrading lodgepole pine site quality. Dumanski et al. (1973) found Bisequa Gray Luvisols (now Brunisolic Gray Luvisols), "Bleached" Orthic Gray Luvisols and Orthic Humo-Ferric Podzols (i.e. soils with high color value in the Ae horizon(s)) to have "high" productivity for lodgepole pine in the Hinton-Edson area of Alberta. However, it does not necessarily follow that high color value in the Ae horizon coincides with high color value in the Bt. It must be conceded that in this study the contribution of organic matter or soil mineralogical composition to soil color value could not be evaluated, and may be important.

Chroma of the B horizon (Var. X38) was a significant independent variable in six equations: white spruce density and PAI per tree; black spruce density, PAI per tree and age of maximum PAI; and aspen site index (Tables 8, 9, 10). Only the positive correlation with black spruce density was significant. This correlation may indicate the greater likelihood of high black spruce density on soils with better aeration and consequent high color values through increased oxidation of iron compounds. Again, the effect of mineralogical composition and organic matter cannot be assessed here.

Chroma of the A horizon (Var. X35) was a significant independent variable in seven equations: lodgepole pine MAI (vegetation variables deleted); black spruce MAI (vegetation variables deleted), PAI per tree and age of maximum PAI (with and without vegetation variables); and aspen MAI and density (Tables 9, 10, 11, 13). Only the positive correlation with lodgepole pine MAI (vegetation variables deleted) was significant (Table 17). Presumably, the differences in productivity are accountable in the same manner as those for chroma of the B horizon.

It seems likely that further investigation into the factors determining soil color would be worthwhile, and that these factors as well as the various expressions of soil color might serve as useful indicators of forest site potential productivity.

3. Stand Factors

Stand factors are characteristics of the forest stand that are functions of the physical site or internal site (soil) factors and of the site productivity. Stand attributes used as independent variables in the regression equations include forest canopy cover, tree stem density, litter cover, deadfall cover and thickness of the organic horizon.

3.1 Canopy Cover (X60) and Stem Density (X64)

Canopy cover or extent of forest crown closure as determined from ocular estimates, was a significant independent variable in nine equations: lodgepole pine MAI, PAI per tree, age of maximum PAI and mean annual basal area increment; white spruce MAI and mean annual basal area increment; and black spruce density, site index and PAI per tree (Tables 7, 8, 9). The only significant correlations occurred between canopy cover and lodgepole pine MAI, PAI per tree and age of maximum PAI (Table 17), and seem to indicate that canopy cover is a good indicator of site productivity in mature lodgepole pine forests.

Stem density (Var. X64) expressed as stems per hectare was a significant independent variable in only three equations: lodgepole pine age of maximum PAI; black spruce age of maximum PAI (vegetation variables deleted), and aspen age of maximum PAI (vegetation variables deleted) (Tables 7,13,14). However, none of the simple correlations between stem density and the dependent variables were significant. Stem density is a function of several factors including fire history, insect or disease outbreaks, site moisture regime and seed availability at the time of stand origin. No attempt was made to determine the causes of stand density; only the effect of density upon productivity was evaluated.

3.2 Organic Matter and Deadfall (X63)

Organic matter here refers to two of the independent variables used in the regression analysis: litter cover and thickness of organic horizons. The organic horizon includes the LFH and/or other organic horizons. It seemed more appropriate to include thickness of organic horizon in this section rather than in the discussion of internal site (soil) variables because it is often an indication of conditions at the ground surface, and is largely determined by the nature of the forest the site supports. It is thus closely related to the other stand factors discussed here, namely litter and deadfall.

Litter refers to the small dead plant material on the ground surface and includes conifer needles, deciduous tree leaves, small twigs and branches and understory plant material. Litter yield is dependent upon several factors including climate and latitude (yield greater in tropics), altitude and exposure (yield generally greater at low to mid-elevations and was found to be higher on NE aspects than on SW aspects in German coniferous forests), fertility (greater on fertile sites) and soil moisture (yield decreases from mesic to dry) (Bray and Gorham 1964). Because the relationship between the dependent variables and litter cover appeared nonlinear on the scatter diagrams, the litter cover values were transformed as 1/log litter cover. Thus a negative correlation of a dependent variable with the 1/log litter cover variable reflects a positive correlation with litter cover.

The 1/log litter cover variable (Var. X62) was a significant independent variable in seven equations: lodgepole pine MAI, site index, age of maximum PAI and basal area annual increment; white spruce site index and age of maximum PAI; and black spruce age of maximum PAI (Tables 7, 8, 9). The 1/log litter cover variable was negatively correlated with lodgepole pine MAI and site index as well as black spruce site index (Tables 17, 19). The other correlations were positive (Table 18). The negative correlations of 1/log litter with the MAI and site index terms are actually positive with actual litter cover, indicating that sites that are productive in terms of volume and height growth also have high foliage production which in turn is reflected by high needle fall and subsequent accumulation. Bray and Gorham (1964) have also indicated that leaf litter may often be an index to net production in coniferous forests. Litter tends to accumulate in cold, acid conditions of boreal forests (Spurr and Barnes 1973 p. 182). Yuasa et al. (1974) observed that Japanese red pine needle fall was greater on better sites. It is interesting to note that the 1/log litter cover variable was not significant in any of the aspen equations, perhaps reflecting the more rapid decomposition and lower accumulation rates of the deciduous leaf litter. Gymnosperms have been shown to yield up to one-sixth more total litter annually than angiosperms (Bray and Gorham 1964). The 1/log litter cover variable was positively correlated with age of maximum PAI in the lodgepole pine, white spruce and black spruce plots, reflecting more rapid maturity (maximum volume increment at an earlier age) on sites with lesser litter cover. The correlation of the 1/log litter cover variable with lodgepole pine mean annual basal area increment is positive (negative with actual litter cover), opposite to that with lodgepole pine MAI, indicating that the increments in pine volume growth are reflected in terms of height growth more so than stem diameter growth. The author is not familiar with other studies where litter cover has been used as an independent variable in growth prediction equations. Its use in this study indicates it might be a reliable indicator of productivity in site studies of coniferous species.

The thickness of the organic horizons (Var. X39) above mineral soil, or the log of its thickness (Var. X40) in the cases of two lodgepole pine equations (Table 7) and two aspen equations (Table 9) was a significant independent variable in nine equations: lodgepole pine density, age of maximum PAI (vegetation variables deleted), mean annual basal area increment; white spruce PAI per tree and age of maximum PAI; black spruce mean annual basal area increment; and aspen MAI, site index and PAI per tree (Tables 7-11). The correlations of organic horizon thickness with lodgepole pine age of maximum PAI (vegetation variables deleted), white spruce age of maximum PAI and aspen MAI were positive (Tables 17, 18, 20), that with black spruce mean annual basal area increment was negative (Table 19). The remainder of the simple correlations were nonsignificant.

In the lodgepole pine forests, the organic horizons are primarily pine needles and feathermosses and the positive correlation between organic horizon thickness and age of maximum PAI (vegetation variables deleted) indicates later maturity in stands with thicker LFH layers. In the white spruce forests, the organic horizon often has a different composition than that in the lodgepole pine forests and is frequently developed under different conditions, especially where restricted drainage or seepage occurs. The organic horizon is thickest in the white spruce forests on Gleysolic soils with humified or very well-decomposed organic matter and on soils with peaty, fibric, organic horizons. Conditions of restricted drainage and limited aeration may account for the negative correlations of organic horizon thickness with black spruce mean annual basal area increment and the positive correlation with white spruce age of maximum PAI, indicating later maturity on poorly drained soils. Page (1976) observed that white spruce and balsam fir site index in Newfoundland were negatively correlated with humus depth. Lowry (1975) reported that black spruce site index was higher on eastern Canada sites where the thickness of the FH layer is less than 20 centimeters. The organic horizon in the aspen forests is composed primarily of deciduous leaf litter and is usually less than 10 cm thick with an average of 7.5 cm (Table 6). Aspen MAI is positively correlated with organic horizon thickness, indicating deep litter accumulation on highly productive sites.

Deadfall (Var. X63), or dead trees lying on the ground as a result of natural mortality through insect damage, disease, windthrow or fire within the current forest generation, expressed as percent cover of the ground surface, was a significant independent variable in seven equations: lodgepole pine MAI; white spruce site index, PAI per tree and age of maximum PAI; black spruce site index; and aspen site index and age of maximum PAI (Tables 7-10). Only the negative correlation of deadfall with white spruce site index and the positive correlation with white spruce age of maximum PAI (Table 18), are significant. The negative correlation with white spruce site index indicates some event in the stand's history which has resulted in mortality and subsequent windthrow. Such natural stand thinning may "release" residual trees. The positive correlation between deadfall cover and white spruce age of maximum PAI, may also be an indication of past events which resulted in a suppression of the growth rate of the white spruce.

4. Vegetation

The discussion of vegetation as independent variables in the regression is separated into four sections: tree regeneration, shrubs, herbs, and mosses and lichens. Vegetation variables accounted for a large percentage of the R^2 value in many of the equations in Tables 7 to 10. The influence of the vegetation variables on the R^2 value is apparent when Tables 7 to 10 are compared to Tables 11 to 14. The R^2 value for the lodgepole pine MAI equation for example drops from 0.66 to 0.24 when the vegetation variables are deleted. This reduction in R^2 value was much more evident on the lodgepole pine and white spruce equations than for the black spruce or aspen equations. The drop in F ratio for the black spruce and aspen equations was more significant, to the point that the F ratios for black spruce MAI, aspen MAI and aspen site index were not significant at the $p = 0.05$ level. A discussion of each of the vegetation variables follows.

4.1 Tree Regeneration Density (X80)

Tree regeneration includes all tree species less than 1.5 m tall and is expressed as stems per hectare. Summation of tree regeneration for all species was entered for each plot in the regression analysis. Regeneration density was a significant independent variable in five equations: lodgepole pine tree density, site index and PAI per tree; white spruce MAI; and aspen tree density (Tables 7, 8, 10). The correlation with lodgepole pine tree density was negative (Table 17), indicating conditions favorable to seedling establishment in open stands. The positive correlation of regeneration density with lodgepole pine PAI/tree (Table 17) probably indicates greater PAI growth in more open stands, also a function of tree density.

4.2 Shrub Cover

The cover values of two shrubs, *Ledum groenlandicum* and *Rosa acicularis* were included as independent variables in the regression analysis. *Ledum groenlandicum* is a common understory species in moist to wet boreal forests, usually where the soil surface is acidic. Heringa and Cormack (1953) found *Ledum* most abundant on till soils in west-central Alberta. *Ledum* has its greatest cover in the black spruce plots (5.9%: Table 5) followed by lodgepole pine (4.1%: Table 3), white spruce (0.4%: Table 4) and aspen stands (0.1%: Table 6). *Ledum groenlandicum* cover (Var. X82) or the log of *Ledum* cover (Var. X83) in the case of lodgepole pine stem density, was a significant independent variable in eight equations: lodgepole pine density; white spruce MAI, site index, PAI per tree, age of maximum PAI and mean annual basal area increment; black spruce site index; and aspen age of maximum PAI (Tables 7-10). The significant correlations with pine density and white spruce age of maximum PAI and mean annual basal area increment were positive, while that with black spruce site index was negative (Tables 17-19). The positive correlation with white spruce age of maximum PAI indicates later maturity on sites with high *Ledum groenlandicum* cover. The positive correlation with mean annual basal area increment indicates that white spruce trees have more taper on sites with higher *Ledum groenlandicum* cover.

Rosa acicularis is another common shrub species and is most abundant in open areas, especially on disturbed sites at low elevations, usually favoring the drier site. *Rosa* cover (Var. X81) is 3% in the aspen plots (Table 6) but is 1% or less for the other tree species (Tables 3 to 5). *Rosa acicularis* cover was a significant independent variable in seven equations: lodgepole pine density and mean annual basal area increment; white spruce MAI, site index and mean annual basal area increment; and black spruce MAI and age of maximum PAI (Tables 7-9). The only significant correlation with *Rosa acicularis* cover was with black spruce MAI (Table 19), and is likely an indication of better growth and earlier maturity with improved soil drainage as reflected by higher *Rosa acicularis* cover.

4.3 Herb Cover

Herbs include all vascular plants with soft, non-woody aerial portions which die back to the rootstock each fall. They include forbs (broad leafed) and graminoids (grasses and sedges). Five common species of herbaceous plants were included in the regression as independent variables: *Cornus canadensis, Rubus pubescens, Calamagrostis canadensis, Epilobium angustifolium* and *Rubus pedatus*.

Cornus canadensis or Canada bunchberry is a common understory species in the boreal forest. It has its highest cover in the white spruce forests (8.6%: Table 4) followed by the lodgepole pine forests (8.3%: Table 3), black spruce forests (5.8%: Table 5) and aspen forests (5.6%: Table 6). *Cornus canadensis* cover (Var. X86) was a significant independent variable in ten equations: lodgepole pine MAI, site index and mean annual basal area increment; white spruce density and site index; black spruce site index and mean annual basal area increment; and aspen density, PAI per tree and age of maximum PAI (Tables 7-10). The significant simple correlations were between *Cornus* and lodgepole pine MAI, lodgepole pine site index;

black spruce site index and mean annual basal area increment and were positive (Tables 17, 19). In general the presence of *Cornus canadensis* seems to indicate favorable site conditions for the four tree species sampled. Illingworth and Arlidge (1960) found that *Cornus canadensis* characterized the best lodgepole pine sites in central British Columbia.

Rubus pubescens is less common than *Cornus canadensis* in the boreal forest, being most abundant at lower elevations on moist sites. It has its highest cover in the aspen forests (2.2%: Table 6) followed by the white spruce forests (1.7%: Table 4), lodgepole pine forests (0.4%: Table 3) and black spruce forests (0.3%: Table 5). *Rubus pubescens* cover (Var. X87) was a significant independent variable in five equations: lodgepole pine site index; white spruce PAI per tree; black spruce site index; and aspen MAI and mean annual basal area increment (Tables 7-10). The simple correlations between *Rubus pubescens* and the dependent variables were positive and significant (Tables 17, 18, 20) with the exceptions of aspen MAI that was negative (Table 20) and black spruce site index (non-significant), indicating that even though *Rubus pubescens* is most abundant in the aspen forests it is not necessarily a good indicator of favorable aspen site conditions.

Calamagrostis canadensis or marsh reed grass is common on moist sites especially in open areas and is capable of rapid increases in cover following drastic disturbances such as clearcutting (Corns and LaRoi 1976). Marsh reed grass has its highest cover in the aspen forests (0.4%: Table 6) followed by the black spruce forests (0.2%: Table 5), lodgepole pine and white spruce forests (0.1%: Tables 3, 4). *Calamagrostis canadensis* cover (Var. X88) was a significant independent variable in five equations: white spruce MAI, PAI per tree and mean annual basal area increment; black spruce PAI per tree; and aspen PAI per tree (Tables 8-10). All correlations between marsh reed grass cover and the dependent variables were not significant. Illingworth and Arlidge (1960) found for central British Columbia that the lodgepole pine - *Calamagrostis* type was second only to the lodgepole pine - *Cornus* - moss type with respect to productivity.

Epilobium angustifolium or fireweed is common in open areas in the boreal forest, particularly on recently disturbed or cleared sites after fire or clearcutting. It has its highest cover in the aspen forests (3.1%: Table 6), followed by the lodgepole pine forests (1.1%: Table 3), white spruce forests (0.3%: Table 4), and black spruce forests (0.2%: Table 5). Fireweed cover (Var. X85) was a significant independent variable in six equations: white spruce PAI per tree; black spruce MAI, site index and mean annual basal area increment; and aspen density and site index (Tables 8-10). Only the simple correlations between fireweed cover and black spruce MAI, site index, and mean annual basal area increment and aspen PAI per tree were significant and all were positive (Tables 19, 20). The positive correlations with the black spruce dependent variables probably reflects the better black spruce growth on more well drained sites where fireweed is likely to be more abundant. The positive correlation with aspen site index is presumably an indication of greater height growth in more open stands.

Rubus pedatus is a species that is often abundant in lodgepole pine-black spruce forests at high elevations in the foothills, usually in association with *Vaccinium membranaceum* and appears to be an indicator of cool, moist conditions. *Rubus pedatus* has its highest cover in the lodgepole pine forests (1.1%: Table 3) followed by the black spruce and white spruce forests (0.1%: Tables 5, 4) and is absent in the aspen forests. *Rubus pedatus* cover (Var. X84) was a significant independent variable in only two equations: black spruce MAI and PAI per tree (Table 9). Neither of the simple correlations was significant.

Total vascular plant cover or the sum of the cover values of all understory shrubs and herbs was entered into the regressions in addition to the cover values of the individual plant species. Vascular plant cover was highest in the lodgepole pine forests (41.3%: Table 3) followed by the aspen forests (40.3%: Table 6), white spruce forests (34.1%: Table 4) and black spruce forests (31.7%: Table 5). The abundance of vascular plant cover seems to be related to the degree of crown closure and to site moisture regime, with generally higher vascular plant cover on the open moist sites. Heringa and Cormack (1953) related plant cover to texture and observed that most species in lodgepole pine stands of central Alberta were most abundant on silt loam textures. This effect may be a reflection of drainage, as drainage and texture are closely related as discussed earlier.

Vascular plant cover (Var. X89) or its log (Var. X90), depending on which gave the closet linear relationship to the dependent variable in question, was a significant independent variable in nine equations: lodgepole pine density, PAI per tree and mean annual basal area increment; white spruce density and PAI per tree; and aspen density, site index, PAI per tree and mean annual basal area increment (Tables 7, 8, 10). The simple correlations between vascular plant cover and pine mean annual basal area increment, white spruce density and aspen density were negative, the remainder positive (Tables 17, 18, 20). Only the correlations with pine mean annual basal area increment and aspen site index were non-significant. These observations can be accounted for by differences in canopy closure and site moisture regime as discussed above.

4.4 Mosses and Lichens

Three common mosses, total moss cover and total lichen cover were entered into the regression as independent variables. The mosses were *Hylocomium splendens*, *Pleurozium schreberi* and *Polytrichum commune*.

Hylocomium splendens is a common feathermoss in boreal and subalpine forests. Its cover was greatest in the white spruce forests (21.9%: Table 4), followed by the black spruce forests (20.9%: Table 5), aspen forests (5.1%: Table 6) and lodgepole pine forests (5.0%: Table 3). *Hylocomium splendens* cover (Var. X91) was a significant independent variable in four equations: black spruce density, age of maximum PAI and mean annual basal area increment; and aspen mean annual basal area increment (Tables 9, 10). The only significant correlation was positive between *Hylocomium splendens* and black spruce mean annual basal area increment (Table 9), indicating greater black spruce basal area growth on well drained sites where *Hylocomium* is likely to be a dominant moss as opposed to poorly drained sites where *Sphagnum* spp. are likely to be dominant.

Pleurozium schreberi is also a common feathermoss of the boreal forest. Its cover was greatest in the lodgepole pine forests (31.9%: Table 3), followed by the black spruce forests (18.6%: Table 5), white spruce forests (10.6%: Table 4) and aspen forests (3.0%: Table 6). *Pleurozium schreberi* cover (Var. X92) or its log (Var. X93) depending on which gave the better linear relationship with the dependent variable in question, was a significant independent variable in three equations: aspen density, age of maximum PAI and mean annual basal area increment (Table 10). All the simple correlations between *Pleurozium schreberi* cover and the dependent variables were non-significant.

Polytrichum commune, another boreal forest moss is locally abundant especially on mineral soil after fire, logging or other surface disturbances. This moss species is not abundant in the sampled forest populations having its greatest cover in the white spruce forests (0.6%: Table 4) and less than 0.5% in the black spruce, pine and aspen forests (Tables 3, 5, 6). *Polytrichum commune* cover (V X94) was a significant independent variable in only one equation: white spruce density (Table 8), with which it is positively correlated, perhaps as a reflection of greater seedling density on mineral seedbeds in the early stages of forest development.

Total moss cover or the cumulative cover of the three species discussed above plus others, was greatest in the black spruce forests (63.3%: Table 5) followed by the lodgepole pine forests (45.0%: Table 3), white spruce forests (40.7%: Table 4) and aspen forests (9.6%: Table 6). Total moss cover (Var. X95) or its log (Var. X96), depending upon which gave the better linear relationship with the dependent variable, was a significant independent variable in five equations: lodgepole pine PAI per tree and mean annual basal area increment; white spruce mean annual basal area increment; and black spruce MAI and PAI per tree (Tables 7-9). Only the simple correlations between total moss cover and pine and black spruce PAI per tree were significant and both were negative (Tables 17, 19), perhaps indicating suppressed growth in old dense stands.

Total lichen cover, comprised primarily of *Cladonia* and *Cladina* spp. plus *Peltigera aphthosa* was greatest in the lodgepole pine forests (1.6%: Table 3), followed by the black spruce forests (0.8%: Table 5), white spruce forests (0.4%: Table 4) and aspen forests (0.1%: Table 6). Lichen abundance was greatest in the lodgepole pine - blueberry - lichen (Type 14) forests on well to rapidly drained loamy sand to sand textures. Lichen cover (Var. X97) was a significant independent variable in four equations: lodgepole pine MAI, site index, and PAI per tree (Table 7) that were negatively correlated with lichen cover (Table 17), and black spruce density (Table 9), that showed no significant correlation. The negative correlation of pine productivity with lichen cover is probably a reflection of poorer pine growth on the dry sites where lichen cover is likely to be greatest, Illingworth and Arlidge (1960) found that abundant *Cladonia* spp. were indicative of poor lodgepole pine site conditions in central British Columbia.

J. SOURCES OF ERROR IN REGRESSION ANALYSIS

Several sources of error are often inherent in forest - site studies (Duffy 1964a, Ralston 1964, and others). These are discussed with reference to the present study.

(1) One of the factors investigated may have been truly unrelated to tree growth but remained correlated due to chance. In the present study, attempts were made to derive plausible explanations for significant correlations between independent and dependent variables. Definite causal relationships were however, difficult to determine. The validity of certain factors may often be checked by an analysis of new data.

(2) One must be careful not to disproportionately emphasize soil or vegetation properties, bearing in mind that vegetation response to change is more rapid than that of soils (Grigal and Arneman 1971). In the present study, consideration was given to soil, site and vegetation properties and the contribution made to the regression by the vegetation variables was determined.

(3) The scale of site factor classification is important. Broadening or narrowing of the scale may yield closer relationships with the dependent variable (Grigal and Arneman 1971). The effect of narrowing and broadening variable scales was not evaluated in the present study.

(4) The method of measuring a given independent variable may not have

been sufficiently refined to have shown a correlation with the dependent variable. For example, quantitative determinations in the laboratory of soil texture, for example, may have yielded closer relationships between soil texture properties and the dependent variables than those attained using textural classes as determined in the field.

(5) Large differences in local climate may not be considered. Due to the very limited availability of climatic data pertinent to the present study, the effect of local climate could not be evaluated except in a very broad sense as related to differences in elevation, for example. Ralston (1964) suggested that meteorological differences can be partly resolved by the subdivision of large geographic areas into relatively homogeneous climatic provinces. The climatic divisions made by McIver et al. (19[illegible]2) for Central Alberta were of limited utility in the present study due to the very small mapping scale.

(6) The correlation between dependent and independent variables may be nonlinear. This source of error was minimized in the present study by making scattergrams of dependent versus independent variables as described in the methods section, and applying the appropriate transformation to the independent variable to approximate a linear relationship.

(7) Stand history effects could not be ascertained. Sites with abnormalities in growth caused by pathogens, insects and competing vegetation could often be avoided but effects associated with genetic origin are unknown and must be regarded as sources of error.

(8) The growth factors or "independent" variables may be e
than causes of tree growth (Broadfoot 1969). Independ
used in the present study that could be interpreted as
growth include litter cover, deadfall cover, thickness
horizon, the percent cover of the various plant specie
soil structure and consistence. However, all the prop
above are undoubtedly influenced by relatively permane

(9) The independent variables should be sampled uniformly
their range, and a uniform distribution should be used
is uncertain (Demaerschalk and Kozak 1974). An attempt
the present study to sample stands over wide range of e
variation. Linearity of independent variable response
variables was handled as in (6).

V SUMMARY AND CONCLUSIONS

1. Fifteen forest vegetation types were identified from data from 137 plots in the Wapiti map area, Alberta (NTS 83L) using association table analysis and a two-dimensional ordination and were described in terms of floristic composition, forest productivity and soils within Mixedwood, Lower Foothills, Upper Foothills and East lope Rockies (Rowe 1972) Forest Sections. The fifteen forest types with mean productivity (expressed as $m^3ha^{-1}yr^{-1}$) are as follows: (1) *Populus tremuloides/Viburnum edule/Rubus pubescens* (4.3), (2) *Populus balsamifera/Rosa acicularis/Thalictrum venulosum* (5.0), (3) *Picea glauca/Rubus pubescens-Maianthemum canadense* (4.7), (4) *Picea glauca/Equisetum arvense/Hylocomium splendens* (3.6), (5) *Picea glauca/Hylocomium splendens* (3.6), (6) *Picea mariana/Ledum groenlandicum/ Equisetum arvense* (2.1), (7) *Picea mariana/Ledum groenlandicum/ Rubus chamaemorus* (0.4), (8) *Pinus contorta/Viburnum edule/ Rubus pubescens* (4.2), (9) *Pinus contorta/Spiraea lucida/ Cornus canadensis* (4.0), (10) *Pinus contorta/Alnus crispa/Cornus canadensis* (3.7), (11) *Pinus contorta/Ledum groenlandicum/ Pleurozium schreberi* (3.1), (12) *Pinus contorta/Picea mariana/ Ledum groenlandicum-Vaccinium membranaceum* (3.1), (13) *Pinus contorta/Menziesia glabella/Rubus pedatus* (2.7), (14) *Pinus contorta/Vaccinium myrtilloides/Cladonia spp.* (1.3), (15) *Picea engelmannii-Abies lasiocarpa/Menziesia glabella* (2.4).

2. Successional relationships among the 15 vegetation types were generalized from the plot data. Most of the 137 forested plots

are of fire origin. Two major successional trends are apparent: lodgepole pine, aspen and balsam poplar to *Picea glauca/Rubus pubescens-Maianthemum canadense;* and lodgepole pine and upland black spruce to *Picea* spp. *-Abies lasiocarpa/Hylocomium splendens* forests. Logging and pulp-cutting activities will prevent climax vegetation from becoming established over large areas and will probably result in successional series somewhat different from those after fire.

3. The two-dimensional ordination graphically demonstrated the similarities among the 137 plots and 15 vegetation types and showed the distribution of several individual plant species and the soil units within the plots and vegetation types.

4. Separate multiple linear regression equations were calculated for 83 lodgepole pine-, 30 white spruce-, 15 black spruce- and 17 aspen-dominated plots, using mean annual total volume increment, stem density, site index, periodic annual total volume increment per tree, age of maximum periodic annual total volume increment and mean annual basal area increment as dependent variables. Independent variables included external site factors including elevation, slope and aspect; internal site (soil) factors including texture, horizon thickness, internal drainage, structure, consistence and soil color; stand factors including canopy cover, stem density, organic matter and deadfall; and vegetation factors including tree regeneration, individual shrub and herb species cover and moss and lichen cover. When both vegetation and physical site factors were allowed to enter the regressions, all equations were

significant at the p=.01 level with large amounts of the variability in the dependent variable being accounted for by the equations: pine (44-66%), white spruce (70-94%), black spruce (98-99%) and aspen (94-99%). Testing the equations with an independent sample reinforced their validity. Important implications are several: (1) Several indices of site productivity including MAI, site index, PAI per tree and basal area annual increment can be reliably estimated for all four species groups within the greater part of the Wapiti map area. (2) Tree stem density in natural stands can be reliably estimated for the four tree species utilizing only site and vegetation factors, indicating factors other than stand history may be responsible for determining stem density. (3) Age of maximum PAI can be reliably estimated in a manner similar to that of stem density for the four tree species indicating that management decisions such as rotation age might be made by an appraisal of the site whether or not a mature forest cover was present. With vegetation variables deleted from the regression equations, the equations lost much of their predictive ability with smaller amounts of variability being accounted for by the equations: pine (24-49%), white spruce (53-58%), black spruce (88-97%) and aspen (74-94%).

5. Each of the 49 independent variables examined appeared in at least one of the prediction equations. Those that appeared with the highest frequency were those related to soil moisture and to climate and microclimate. Several plant species, indicative of particular habitat conditions also entered into many of the growth prediction equations, greatly increasing the predictive ability of several equations especially those for lodgepole pine and white

spruce.

6. Productivity of the soil mapping units could not be reliably compared due to within map unit variability in mean annual total volume increment being greater than that between map units. This may in part be due to a small sample size for some map units.

7. It is concluded that the Wapiti map area includes several well organized systems which can be defined by vegetative, edaphic and other environmental criteria. The forest ecosystems and forest productivity-environment relationships described here for the Wapiti map area may be expected to be similar in adjacent areas of western and north-western Alberta foothills where climate, vegetation and soils are similar, though caution is advised where use of growth prediction equations outside the study area is contemplated.

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APPENDIX 1. Modified Braun-Blanquet cover scale used for plant cover estimates

Symbol		Midpoints for calculation
P	Present only; cover infinitesimally low	0.01%
R	Rare; cover very low	0.1%
+	Occasional; cover less than 1%	0.5%
1	Cover between 1 and 5%	3%
2	Cover between 5 and 15%	10%
3	Cover between 15 and 25%	20%
4	Cover between 25 and 50%	37.5%
5	Cover between 50 and 75%	67.5%
6	Cover between 75 and 95%	85%
7	Cover between 95 and 100%	97.5%

APPENDIX 2. Quantitative and semi-quantitative scales used for coding soils properties for multiple regression analysis.

Soil color - Hue, value, chroma
Munsell designation

Texture

Class	%C	%Si	%S
HC	80	0	20
C	50	25	25
SiC	50	40	10
SC	45	0	55
SiCL	34	56	10
CL	34	33	33
SCL	27.5	9.5	63
Si	6	84	10
SiL	15	65	20
L	17	39	44
SL	10	25	65
LS	7.5	15	77.5
S	5	2.5	92.5

Hydraulic conductivity (cm day^{-1})

HC	0.1
C	0.5
SiC	1.0
SC	4.0
SiCL	7.0
CL	10.0
SCL	32.5
Si	55.0
SiL	77.5
L	100
SL	400
LS	700
S	1000

Drainage

1	Poorly
2	Imperfectly
3	Moderately well
4	Well
5	Rapidly

Consistence

0.5	Loose
1.0	Very friable
2.0	Friable
3.0	Firm
4.0	Very firm
5.0	Extremely firm

Structure

1	Structureless
3	Angular blocky
5	Subangular blocky
6	Granular
7	Platy

APPENDIX 3. Locations of the 137 sampled plots

Plot No.	Latitude	Londitude
1	54° 7.8'N	118° 17.5'W
2	54°11.8'N	119° 25.0'W
3	54°14.3'N	119 12.3'W
4	54°15.4'N	119 34.3'W
5	54°15.0'N	119° 26.5'W
6	54°21.8'N	119° 59.9'W
7	54°25.9'N	118° 21.4'W
8	54° 8.2'N	118° 4.3'W
9	54° 8.3'N	119° 34.7'W
10	54° 7.5'N	119° 18.4'W
11	54°29.4'N	119° 44.2'W
12	5[illegible]8.1'N	119° 50.3'W
13	54°19.2'N	119° 49.4'W
14	54°19.8'N	119° 48.4'W
15	54°27.1'N	119° 43.5'W
16	54°27.2'N	119° 43.8'W
17	54°34.5'N	119° 46.9'W
18	54°56.0'N	118° 53.4'W
19	54°56.0'N	118° 53.4'W
20	54°54.2'N	118° 47.9'W
21	54°38.3'N	119° 15.9'W
22	54°37.4'N	119° 16.6'W
23	54°47.9'N	118° 39.7'W
24	54°44.0'N	118° 33.8'W
25	54°44.7'N	118° 33.5'W

Plot No.	Latitude	Longitude
26	54°47.8'N	118° 38.9'W
27	54°47.2'N	118° 13.5'W
28	54°36.5'N	118° 13.4'W
29	54°34.5'N	118° 10.9'W
30	54°30.7'N	118° 10.3'W
31	54°32.6'N	118° 9.3'W
32	54° 2.5'N	118° 35.2'W
33	54°15.8'N	118° 23.8'W
34	54°14.9'N	118° 24.2'W
35	54°12.2'N	118° 25.4'W
36	54°11.7'N	118° 27.3'W
37	54° 6.9'N	119° 19.0'W
38	54° 6.4'N	119° 18.8'W
39	54° 2.2'N	119° 15.8'W
40	54°10.3'N	118° 28.5'W
41	54° 8.3'N	118° 30.0'W
42	54°16.3'N	118° 24.7'W
43	54°19.6'N	118° 22.2'W
44	54°50.6'N	118° 40.0'W
45	54°50.5'N	118° 37.0'W
46	54°53.3'N	118° 37.1'W
47	54°52.7'N	118° 39.7'W
48	54°43.8'N	118° 46.0'W
49	54°43.8'N	118° 49.2'W
50	54° 3.8'N	118° 32.7'W

APPENDIX 3 cont.

Plot No.	Latitude	Longitude	Plot No.	Latitude	Longitude
51	54°08.8'N	118° 36.0'W	76	54°28.3'N	118° 59.2'W
52	54°02.8'N	118° 43.8'W	77	54°33.2'N	118° 59.3'W
53	54°05.2'N	118° 28.1'W	78	54°19.8'N	118° 55.7'W
54	54°01.3'N	118° 36.9'W	79	54°21.1'N	118° 57.2'W
55	54°00.7'N	118° 03.0'W	80	54°24.8'N	119° 16.6'W
56	54°00.8'N	118° 09.4'W	81	54°24.2'N	119° 12.5'W
57	54°33.0'N	118° 31.5'W	82	54°24.9'N	119° 1.4'W
58	54°31.9'N	118° 33.3'W	83	54°37.9'N	119° 2.8'W
59	54°33.8'N	118° 27.9'W	84	54°59.3'N	119° 58.7'W
60	54°36.0'N	118° 31.5'W	85	54°58.5'N	119° 45.0'W
61	54°35.7'N	118° 33.3'W	86	55°00.0'N	119° 59.4'W
62	54°33.8'N	118° 42.2'W	87	54°59.8'N	119° 59.2'W
63	54°22.2'N	118° 36.0'W	88	54°50.3'N	119° 24.7'W
64	54°26.5'N	118° 44.3'W	89	54°42.5'N	118° 53.8'W
65	54°27.2'N	118° 36.8'W	90	54°42.7'N	118° 54.8'W
66	54°25.3'N	118° 48.8'W	91	54°43.5'N	118° 50.7'W
67	54°27.4'N	118° 47.5'W	92	54°43.3'N	118° 56.5'W
68	54°31.2'N	118° 59.2'W	93	54°39.5'N	118° 59.9'W
69	54°27.4'N	118° 46.1'W	94	54°45.9'N	118° 55.1'W
70	54°29.5'N	118° 45.6'W	95	54°44.7'N	118° 58.5'W
71	54°40.1'N	118° 45.0'W	96	54°44.9'N	118° 59.0'W
72	54°25.6'N	118° 56.2'W	97	54°40.5'N	119° 01.1'W
73	54°23.3'N	118° 58.2'W	98	54°40.4'N	119° 00.8'W
74	54°23.8'N	118° 58.4'W	99	54°50.1'N	119° 25.9'W
75	54°24.4'N	118° 58.6'W	100	54°51.5'N	119° 28.2'W

APPENDIX 3 cont.

Plot NO.	Latitude	Longitude
101	54°51.1'N	119° 28.0'W
102	54°48.2'N	119° 27.0'W
103	54°47.3'N	119° 30.8'W
104	54°45.6'N	119° 35.2'W
105	54°46.9'N	119° 23.8'W
106	54°47.7'N	119° 25.7'W
107	54°49.8'N	119° 28.3'W
108	54°47.8'N	119° 30.1'W
109	54°32.9'N	119° 45.2'W
110	54°35.0'N	119° 46.1'W
111	54°37.0'N	119° 52.4'W
112	54°43.8'N	119° 48.1'W
113	54°42.2'N	119° 47.7'W
114	54°39.6'N	119° 48.6'W
115	54°41.3'N	119° 46.4'W
116	54°43.1'N	119° 41.0'W
117	54°41.4'N	119° 31.4'W
118	54°43.8'N	119° 31.8'W
119	54°43.8'N	119° 39.4'W
120	54°44.3'N	119° 38.2'W
121	54°43.4'N	119° 31.5'W
122	54°41.2'N	119° 31.6'W
123	54°46.0'N	119° 32.0'W
124	54°44.9'N	119° 35.9'W
125	54°14.4'N	119° 50.8'W

Plot No.	Latitude	Longitude
126	54°19.0'N	119° 50.8'W
127	54°15.6'N	119° 51.8'W
128	54°16.5'N	119° 51.1'W
129	54°19.4'N	119° 48.8'W
130	54°31.6'N	119° 44.3'W
131	54°23.0'N	119° 44.2'W
132	54°24.5'N	119° 45.0'W
133	54°23.8'N	119° 45.8'W
134	54°28.4'N	119° 43.2'W
135	54°26.3'N	119° 43.7'W
136	54°27.6'N	119° 43.5'W
137	54°26.1'N	119° 40.9'W

APPENDIX 4 Summarized site data for the 137 sampled plots

Plot No.[a]	Parent material[b]	Soil unit[c]	Classification[d]	Internal drainage[e]	Elevation (ft above sea level)[f]	Slope %	Aspect
1	Cn till	MBN6/St to Sky4	Br.GL	I	4200	5	W
2	Cr till / Br	RBB7 COP1	O.GL	I	5500	18	NNE
3	Cn till / Br.	MBN4/TOR1	O.GL	I	4200	7	S
4	Cr till	SHP1	O.GL	MW	4700	8	W
5	Av	IOS1	O.R	P	3600	0	level
6	Cr till	SHP1	O.GL	MW-I	3900	15	N
7	Av Gv	JRV4	E.DYB	W	2500	2-5	NE
8	Cn till / Br	MBN5/TOR2	GL.GL	MW-I	4150	8	W
9	Cr till	SHP1	O.GL	MW	4200	20	S
10	Gv Ow	JRV4	O.R	W	3900	0	level
11	Cr till	MLB8	O.GL	MW	4000	2	N
12	Av Gv	JRV4	E.EB	MW	3600	2	S
13	Till	SHP1	O.GL	MW	4000	0	level
14	Org	KNZ	F	P	3500	0	level
15	Org/till	SKY1/P	R.G	P	4100	1-3	W
16	OwS	BKM6	O.HFP	W	4100	3	W
17	Cr till	MLB8	O.GL	W	4200	14	W
18	Av	IOS1	O.R	W	2250	2	N
19	Lac till	DON1	O.GL	MW	2250	0	level
20	Lac till	S1P1/P	O.G	I	2250	5	N
21	SsBr	TOR1	O.GL	MW-I	3850	0	level
22	Br	TOR1	O.GL	I	3950	3-4	N
23	Lac till	DON1	GLSZ.GL	I	2400	2	N
24	Lac till	DON1 / COP1	O.GL	MW-I	2650	2	W

APPENDIX 4 cont.

Plot No.[a]	Parent material[b]	Soil unit[c]	Classification[d]	Internal drainage[e]	Elevation (ft above sea level)[f]	Slope %	Aspect
25	Lac till	DON1	[illegible]GL	MW	2500	4	N
26	Lac till	LDG6	SZ.GL	MW	2400	3	N
27	Lac till	LDG8	GLE.EB	I	2750	0-2	N
28	ES	HRT1	O.HFP	W	2750	11	NNW
29	Org	KNZ	TY.M	P	2750	0-1	level
30	ES	HRT1	E.EB	R	2750	9	SSE
31	Org	KNZ	T.M	VP	2750	3	N
32	Cn till	MBN6/s	BR.GL	MW	5050	0	level
33	Av/till	LDG8/MBN6	BR.GL	MW	4400	2	N
34	Cn till	MBN6/TOR1	BR.GL	MW	3750	8	E
35	Cn till	MBN6	BR.GL	MW	4100	3	N
36	Cn till	MBN6	BR.GL	MW	4100	2	E
37	Cr till	RBB7	O.GL	MW	4100	30	E
38	Cr till	RBB7	E.EB	MW	4100	43	SW
39	Cr till	RBB7	BR.GL	MW	4700	11	NE
40	Cn till	MBN6	BR.GL	MW	4250	0	level
41	Cn till	MBN6	BR.GL	MW	4450	8	N
42	Av/Cn till	MBN6	BR.GL	MW	4400	2	N
43	Cn till	MBN6	BR.GL	W	4150	18	E
44	Lac	S1P1	O.LG	P	2250	level	level
45	Av/Lac till	LDG7	GL.GL	I	2250	1	N
46	Lac till	S1P1	GL.GL	I	2150	level	level
47	Av-Lac	DVS2	O.LG	MW-I	2200	1	N
48	Till	EDS4	GL.GL	I	2800	level	level
49	Br	S1P1/P	O.G	P	2500	level	level

APPENDIX 4 cont

Plot No.[a]	Parent material[b]	Soil unit	Classification[d]	Internal drainage[e]	Elevation (ft above sea level)[f]	Slope %	Aspect
50	Cn till	MBN5	GL.GL	I	4750	5	N
51	Cn till	MBN4	O.GL	MW	4250	6	E
52	Cn till / Br	MBN6,t / COP or TOR1	BR.GL	MW	4800	11	SSW
53	Br	TOR1	[illegible].GL	I	4550	level	level
54	Till	MBN6	BR.GL	MW	5150	[illegible]	NNW
55	Br	COP1	O.GL	MW-I	1900	4	NW
56	AvS	BFM8	F.FB	W	4400	5	SW
57	Cn Till or Lac till	SIP1	HU.LG	P	2800	[illegible]	W
58	Lac till	SIP1	HU.LG	I	2950	2	[illegible]
59	Cn till	SKY1	O.LG P	P	[illegible]	1	[illegible]
60	Lac till	SIP1	O.LG	I	3150	1	E
61	Cn till or Lac till	SKY1	O.LG P	I-P	3050	[illegible]	NE
62	Cn till	EDS4	BR.GL	I	3050	level	level
63	Org	KNZ	T.M	P	2750	1.5	N
64	Cn till	EDS4	BR.GL	MW	3500	2	SW
65	Org	KNZ	T.M	P	3300	[illegible]	W
66	Cn till / Br	EDS4,t / TOR1	GL.GL	I	3600	[illegible]	[illegible]
67	Org	KNZ	T.M	P	3050	level	level
68	Cn till	EDS4	O.GL	MW	3000	5	N
69	Cn till	EDS4	BR.GL	MW-I	3200	10	[illegible]
70	Cn till	EDS4	BR.GL	MW	3100	10	N
71	Cn till	EDS4	GL.GL	MW-I	3050	2	N
72	Cn till	EDS4	BR.GL	MW	3500	10	N
73	Cn till	SKY1	HU.LG	P	3900	2	NE
74	Cn till	EDS4	BR.GL	MW	3900	10	[illegible]

APPENDIX 4 cont.

Plot No.[a]	Parent material[b]	Soil unit[c]	Classification[d]	Internal drainage[e]	Elevation (ft above sea level)[f]	Slope %	Aspect
75	Cn till / Br	EDS4	BR.GL	MW	3850	10	S
76	Cn till	EDS4	BR.GL	MW	3500	3	S
77	Cn till	EDS4	O.GL	MW	3250	3	E
78	Cn till	SKY1/P	R.G	P	3850	7	E
79	Cn till	EDS4	GLBR.GL	MW-I[c]	3950	1	E
80	Cn till	MBN6	BR.GL	MW	4600	2	N
81	Cn till	MBN6	BR.GL	MW-I	4550	3	SE
82	Cn till / Br	EDS4 / TOR1	GL.GL	I	4100	level	level
83	Br	TOR1	GL.GL	I	3500	1.5	S
84	Cn till or Lac till	EDS4-DON1	O.GL	I	2850	3	N
85	Cn till	DON1	O.GL	MW-I	2550	0	level
86	Lac till	DON1	GL.GL	I	2800	0	level
87	Lac till	DON1	GL.GL	I	2850	0	level
88	ES	HRT3	BR.GL	MW	2450	3	W
89	Br	TOR1	O.GL	MW	2650	10	W
90	Br	TOR1	O.GL	MW-I	2700	15	N
91	Br	TOR1	O.GL	MW	2550	8	N
92	Br	TOR1	GL.GL	I	3100	3	N
93	Br	TOR1	GL.GL	I	3250	0	level
94	Cn till	EDS4	O.GL	MW-I	2750	9	NE
95	Av Gv	BKM8-JRV4	O.EB	MW	2700	15	NW
96	Lac till	SIP1	O.G	I	2600	8	NW
97	Cn till	EDS4	BR.GL	MW	3150	15	W
98	Lac till	DON1	GL.GL	I	3250	0	level

APPENDIX 4 cont.

Plot No.[a]	Parent material[b]	Soil unit[c]	Classification[d]	Internal drainage[e]	Elevation (ft above sea level)[f]	Slope %	Aspect
99	ES	HRT1	E.EB	R	2550	15	N
100	ES / AvLac	LDG8	BR.GL	W	2500	0	level
101	AvS	GUN1	O.LG	P	2550	5	NW
102	AvS / Br	LDG8 / COP1	BR.GL	MW -W	3100	5	W
103	AvS	BKM6	BR.GL	W	2850	6	NW
104	Lac till	DON1	GLSZ.GL	I	2700	4	N
105	Br	COP1	O.EB	W	3400	22	NNW
106	ES / Cn till	LDG6 / EDS4	O.GL	MW	3150	4	NW
107	ES / Br	LDG8 / COP1	E.EB	MW -W	2850	20	NW
108	Br	COP1	O.EB	W	2950	15	NW
109	Cr till	MLB8	BR.GL	W	4200	18	W
110	Cr till	MLB8	BR.GL	MW	4300	7	NNE
111	Cr till	MLB8	O.GL	MW-I	3300	15	NE
112	Cr till	MLB8	BR.GL	MW	3500	15	SW
113	AvS / Cr till	MLB8	BR.GL	MW	3600	5	N
114	AvS / Cr till	LDG8 / MLB8	GLBR.GL	I	3600	6	NNE
115	Cr till	MLB8	BR.GL	MW	3600	9	NW
116	Cn till	EDS4	BR.GL	MW	3100	22	NW
117	AvS / Lac till	S1P1	O.G	I- P	2900	10	NNE
118	Lac till	DON1	O.GL	MW	2700	15	W
119	Cn till	EDS4	O.GL	MW	3000	7	NE
120	Cn till or Lac till	EDS4	O.GL	MW -I	2900	5	N

APPENDIX 4 cont.

Plot No.[a]	Parent material[b]	Soil unit[c]	Classification[d]	Internal drainage[e]	Elevation (ft above sea level)[f]	Slope %	Aspect
121	Lac till	SlPl/P	O.G	P	2750	4	NW
122	Av / Lac till	LDG6 or DON1	GL.GL	I	3000	6	NE
123	ES	BKM8	E.EB	W	2750	3	NW
124	Av / Lac till	LDG6	GL.GL	I	2700	3	NNE
125	Cr till / Br	RBB7/t	O.GL	W	4200	36	NE
126	AvS +Gv	IOS1	CU.R	W	4200	5	NW
127	Ow	JRV4	O.GL	W	3900	0	level
128	Cr till	RBB7	BR.GL	W	3900	17	WNW
129	Cr till	RBB7	BR.GL	W	4000	35	ENE
130	Cr till / Br	MLB8 / TOR1	O.EB	I	4000	9	SE
131	Cr till	RBB7	E.DYB	W	3800	40	SW
132	Cr till / Br	MLB8/t / COP1	BR.GL	W	4100	23	SW
133	Av / Cr till	JRV4	BR.GL	W	3700	10	E
134	Cr till / Br	MLB8/t / COP1	BR.GL	MW	4000	9	NW
135	Org	KNZ	T.M	P	4000	8	NW
136	Cr till	GUN1	O.G	P	4000	11	W
137	Cr till / Br	MLB8 / COP1	BR.GL	MW	4200	5	SW

Footnotes

a Plots 1 - 43 sampled during 1972
Plots 44 - 83 sampled during 1973
Plots 84 - 137 sampled during 1974

b Cn till - morainal materials derived from the continental glaciation. s-stony. t-thin
Cr till - morainal materials derived from the cordilleran glaciation. s- stony. t-thin

APPENIX 4 cont.

b Lac till - lacustro - till of glacio-lacustrine origin
Lac - stratified fine textured lacustrine deposits of glacio-lacustrine origin
Br - weathered sandstone (Ss) and shale unless 'lithic' is indicated
Av - alluvium of stream deposition
Gv - gravels of stream deposition
Ow - outwash deposits of flowing water from a nearby glacier, usually gravels or sand (S)
ES - eolian sand
Org - organic soils. P-peaty phase

c Soil Units are described in Twardy and Lindsay (1978)

d Soil classification abbreviations follow CSSC (1976)

e Soil internal drainage scale
R - rapid
W - well
MW - moderately well
I - imperfect
P - poor
VP - very poor

f Elevation and tree height in meters = feet ÷ 3.28

APPENDIX 5 Summarized stand measurements for the 137 sampled plots

Plot No.	Species	Mean annual volume increment (ft^3 $acre^{-1}$ yr^{-1}) (all species)[a] Corrected	and Uncorrected	Total volume (ft^3 $acre^{-1}$)[b]	Merchantable volume (ft^3 $acre^{-1}$)	Basal area from stem tally (ft^2 $acre^{-1}$)	Basal area from relascope (ft^2 $acre^{-1}$)[c]	Density per acre of stems (0.5 in. DBH)[d]	Density per acre of tree regeneration (0.5 in. DBH)
	Pl			743.6	617.8	35.4	38.5		
	Sb			1346.3	997.2	106.8	104		470
		30.6	29.0	2089.9	1215.0	142.2	142.5	1630	470
	Se			4026.1	3631.6	182.1	130		
	Fa			1093.2	748.6	73.9	64.3		1500
	Sb								10
		19.1	34.8	51[illegible].3	4380.2	256.0	194.3	1230	1510
	Pl			3401.3	2840.8	158.2	162.8		
	Fa						2.9		30
	Sb			0.9	0.0	0.0			
		48.5	48.6	3402.2	2840.6	158.2	165.7	620	30
	Pl			2563.6	1381.1	148.3	171.0		
	Sb						1.4		
	Fa								20
		28.9	30.9	2563.6	1381.1	148.3	172.4	1190	20
	Sw			7793.0	7038.4	250.4	235.7		50
		17.1	49.0	7793.0	7038.4	250.4	235.7	490	50
	Pl			3471.6	2189.9	175.8	162.8		
	Sb						1.4		10
	Pb						4.2		
	W			118.7	86.9	6.4			
		42.8	47.2	3590.3	2276.8	182.2	168.4	1190	10
	Sw			2063.5	1896.0	62.2	48.6		190
	Pl			1439.4	1365.1	40.1	60.0		
	Sb			38.8	26.8	1.8	5.7		10
	Pb								50
	Fa			1149.9	903.5	55.2	40.0		830
		12.2	28.3	4691.6	4191.4	159.3	153.3	370	1080

APPENDIX 5 cont.

Plot No.	Species	Mean annual volume increment (ft^3 $acre^{-1}$ yr^{-1}) (all species)[a] Corrected	and Uncorrected	Total volume (ft^3 $acre^{-1}$)[b]	Merchantable volume (ft^3 $acre^{-1}$)	Basal area from stem tally (ft^2 $acre^{-1}$)	Basal area from relascope (ft^2 $acre^{-1}$)[c]	Density per acre of stems (0.5 in. DBH)[d]	Density per acre of tree regeneration (0.5 in. DBH)
8	Pl			3524.9	2567.8	169.1	168.7		
	Sb			448.8	166.2	33.1	31.4		1320
	Fa			1.3	0.0	0.1			20
		48.7	51.0	3975.0	2734.0	202.3	200.1	1390	1340
9	Pl			5360.7	4305.6	214.4	235.7		40
	Fa			17.2	6.5	1.6	2.0		190
	Sw								160
		65.6	69.8	5377.9	4312.1	216.0	237.7	960	390
10	Sw			3176.9	2682.8	135.4	157.1		
	Pb			455.6	406.0	18.7	22.9		
	Pl	28.3	36.9	423.0	389.3	15.4	18.6		
				4055.5	3478.1	169.5	198.6	500	
11	Pl			3250.3	1766.4	166.1	120.0		
	Sb			23.8	0.3	2.4	10		
		35.9	39.9	3274.1	1766.7	168.5	130.0	1390	
12	Pl			2836.8	1854.4	141.2	144.7		10
	A			43.6	4.3	3.2	2.9		20
	Fa								30
	Sw								30
		28.3	32.7	2880.4	1858.7	144.4	147.6	990	90
13	Pl			2429.5	1791.1	124.0	118.6		
	Sw			0.4	0.0	0.0			50
	Fa								10
	Sb			21.1	13.5	1.6	5.7		220
		28.0	27.5	2451.0	1804.6	125.6	124.3	740	280
14	Sb			681.3	256.6	55.4	52.9		1280
		3.3	4.1	681.3	256.6	55.4	52.9	630	1280

APPENDIX 5 cont.

Plot No.	Species	Mean annual volume increment (ft^3 $acre^{-1}$ yr^{-1}) (all species)[a] Corrected	Uncorrected	Total volume (ft^3 $acre^{-1}$)[b]	Merchantable volume (ft^3 $acre^{-1}$)	Basal area from stem tally (ft^2 $acre^{-1}$)	Basal area from relascope (ft^2 $acre^{-1}$)[c]	Density per acre of stems (0.5 in. DBH)[d]	Density per acre of tree regeneration (0.5 in. DBH)
15	Sb			2584.7	2067.2	139.6	127.1		370
	Sw			100.1	81.3	5.7			
		28.5	26.8	2684.8	2148.5	145.3	127.1	680	370
16	Pl			1056.0	780.1	69.6	74.3		1100
	Sb			23.8	0.0	2.5	1.4		170
		14.4	13.8	1079.8	780.1	72.1	75.7	700	1270
17	Pl			4200.2	3279.6	182.1	184.3		20
	Sw			40.0	10.9	3.7	4.3		10
	Fa								
	A			12.5	4.6	1.1	1.4		
		51.7	54.5	4252.7	3295.1	186.9	189.0	910	30
18	A			9.7	2.0	1.0	1.4		
	Sw			10.0	0.0	1.2	1.4		
	B			5.8	0.0	0.6			20
	Pb			4820.9	4212.6	185.0	152.9		20
		66.4	72.3	4846.4	4214.6	187.8	155.7	660	40
19	A			2682.4	1923.1	124.1	131.4		
	Sw			71.6	48.0	3.6			
	Pb			305.7	217.8	14.8	8.6		30
		43.6	47.1	3059.7	2188.9	142.5	140.0	740	30
20	Sw			4393.6	3694.7	153.8	137.1		40
	A			4618.1	4015.9	147.7	68.6		
	Pb			243.5	216.1	7.9			
		106.6	97.4	9255.2	7926.7	309.4	205.7	800	40
21	Pl			2282.6	1664.2	114.5	114.3		10
	Fa								10
		27.3	30.0	2282.6	1664.2	114.5	114.3	610	20

APPENDIX 5 cont.

ot. o.	Species	Mean annual volume increment (ft^3 $acre^{-1}$ yr^{-1}) (all species)[a] Corrected	and Uncorrected	Total volume (ft^3 $acre^{-1}$)[b]	Merchantable volume (ft^3 $acre^{-1}$)	Basal area from stem tally (ft^2 $acre^{-1}$)	Basal area from relascope (ft^2 $acre^{-1}$)[c]	Density per acre of stems (≥ 0.5 in. DBH)[d]	Density per acre of tree regeneration (< 0.5 in. DBH)
	Pl			3340.0	2701.5	144.6	105.7		
	Sb			1418.8	625.3	90.4	82.9		230
	Fa						2.9		20
	Sw								
		60.5	66.1	4758.8	3326.8	235.0	191.5	1530	250
	Sw			809.8	247.3	64.1	67.1		40
	A			3243.4	2810.7	112.5	85.7		
	B			0.7	0.0	0.1			10
		88.7	90.1	4053.9	3058.0	176.7	152.8	1290	50
	Sw			3719.1	3303.0	125.8	107.1		20
	Fa			295.5	235.7	12.8	10.0		3870
	B			699.2	598.0	25.8	38.6		
	W			17.5	9.0	1.4			
		89.1	68.6	4731.3	4145.7	165.8	155.7	420	3890
	Sw			2478.7	2145.6	98.2	104.3		20
	A			2941.0	2326.2	108.1	100.0		40
	Fa			28.2	16.2	1.5	1.4		
	B			331.0	268.4	12.0	7.1		
		73.4	75.1	5778.9	4756.4	219.8	212.8	730	60
	A			2906.7	2321.3	108.3	134.3		160
	Pb			45.8	13.7	2.5	2.9		50
	B								10
	Fa								10
		46.4	46.9	2955.5	2335.0	110.8	137.2	480	230

APPENDIX 5 cont.

Plot No.	Species	Mean annual volume increment (ft^3 $acre^{-1}$ yr^{-1}) (all species)[a] Corrected	and Uncorrected	Total volume (ft^3 $acre^{-1}$)[b]	Merchantable volume (ft^3 $acre^{-1}$)	Basal area from stem tally (ft^2 $acre^{-1}$)	Basal area from relascope (ft^2 $acre^{-1}$)[c]	Density per acre of stems (0.5 in. DBH)[d]	Density per acre of tree regeneration (0.5 in. DBH)
27	Sw			3216.3	2915.0	108.6	72.9		50
	B			413.7	332.4	18.0	14.3		90
	Pl			830.7	790.8	26.0	7.1		
	Fa			20.8	11.9	1.5	1.4		70
	A			1814.7	1627.5	57.5	52.9		240
	Pb						2.9		250
		30.5	50.1	6296.2	5677.6	211.6	151.5	690	700
28	Pl			3476.3	2817.4	131.6	140.0		20
	Sb			264.6	141.6	17.3	17.1		10
		42.1	45.1	3740.9	2959.0	148.9	157.1	670	30
29	Sb			1515.8	784.2	111.7	102.9		930
	L			4.6	0.0	0.5			20
		5.1	7.3	1520.4	784.2	112.2	102.9	1100	950
30	Pl			1536.8	363.2	106.1	62.9		
	Sw			0.8	0.0	0.0			
	Sb								80
		12.4	17.9	1537.6	363.2	106.1	62.9	1610	80
31	Sb			1811.2	1132.4	109.7	94.3		510
	Pl			788.0	536.6	44.3	17.1		
		31.4	34.2	2599.2	1669.0	154.0	111.4	1150	510
32	Pl			3930.5	3426.5	180.1	162.9		
	Fa			361.1	271.1	18.2	21.4		260
	Sb			124.5	105.4	4.9	1.4		
		18.8	20.4	4416.1	3803.0	203.2	185.7	670	260
33	Pl			3999.1	3442.7	159.2	170.0		
	Fa			1458.5	1124.9	64.6	57.1		810
	Sb			284.5	239.9	12.4	4.3		
		25.3	31.9	5742.1	4807.5	236.2	231.4	880	810

APPENDIX 5 cont.

Plot No.	Species	Mean annual volume increment (ft^3 $acre^{-1}$ yr^{-1}) (all species)[a] Corrected	Uncorrected	Total volume (ft^3 $acre^{-1}$)[b]	Merchantable volume (ft^3 $acre^{-1}$)	Basal area from stem tally (ft^2 $acre^{-1}$)	Basal area from relascope (ft^2 $acre^{-1}$)[c]	Density per acre of stems (≥ 0.5 in. DBH)[d]	Density per acre of tree regeneration (< 0.5 in. DBH)
34	Pl			3944.8	3084.4	171.6	168.3		20
	Fa								10
	Sw								30
		52.2	51.2	3944.8	3084.4	171.6	168.3	770	60
35	Pl			3834.0	3439.7	147.3	112.9		1040
	Sb			357.4	184.8	24.2	25.7		
	A			352.6	285.3	15.0	11.4		
	Fa								30
		60.3	61.4	4544.0	3909.8	186.5	150.0	680	1070
36	Pl			3814.3	2551.7	173.8	158.6		
	Sb			15.2	5.1	1.1			
		50.3	51.7	3829.5	2556.8	174.9	158.6	1040	
37	Pl			2990.6	2099.1	146.1	154.3		20
	Fa								10
	Sw								
		41.7	38.8	2990.6	2099.1	146.1	154.3	850	30
38	Pl			2140.0	1760.1	99.3	105.7		50
	Sb			4.5	0.0	0.4			340
	Fa								20
		31.6	29.0	2144.5	1760.1	99.7	105.7	480	410
39	Pl			4766.1	4183.3	181.7	158.6		50
	Sb			21.2	11.7	1.4	8.6		2720
	Fa								
		52.2	52.0	4787.3	4195.0	183.1	167.2	530	2770
40	Pl			1971.2	829.2	120.6	54.3		10
	Fa								
		27.2	27.4	1971.2	829.2	120.6	54.3	1360	10

APPENDIX 5 cont.

Plot No.	Species	Mean annual volume increment (ft^3 $acre^{-1}$ yr^{-1}) (all species)[a] Corrected	and Uncorrected	Total volume (ft^3 $acre^{-1}$)[b]	Merchantable volume (ft^3 $acre^{-1}$)	Basal area from stem tally (ft^2 $acre^{-1}$)	Basal area from relascope (ft^2 $acre^{-1}$)[c]	Density per acre of stems (0.5 in. DBH)[d]	Density per acre of tree regeneration (0.5 in. DBH)
41	Pl			3955.4	3024.6	165.1	155.7		
	Sw								30
		44.6	52.0	3955.4	3024.6	165.1	155.7	830	30
42	Pl			5746.4	5148.0	186.8	172.9		
	Fa			945.0	751.1	40.3	44.3		840
	Sb			41.7	12.7	2.6	4.3		
		37.2	38.0	6733.1	5911.8	229.7	221.5	680	840
43	Pl			3908.5	2235.6	208.0	175.7		
		89.3	66.3	3908.5	2235.6	208.0	175.7	1550	
44	As			1504.3	1231.1	59	48.6		
	Pb			242.9	183.7	11	10.0		
	W						1.0		
	Sw			2700.5	1988.8	121	84.3		
	Sb			151.0	77.5	11	32.9		710
	L								
		66.1	53.5	4598.7	3481.1	202	176.8	1070	710
45	As			4582.7	4018.9	146	100.0		440
	Pb			330.1	288.4	11	21.4		2[illegible]
	Sw			2033.1	1687.9	85	63.8		50
		89.0	78.9	6945.9	5995.2	242	185.2	540	510
46	As			3894.6	3272.7	122	114.3		
	Pb			1057.1	939.2	33	25.7		
	Sw			961.4	847.0	34	42.9		10
		71.9	68.0	5913.1	5058.9	189	182.9	440	10
47	As			2093.7	1836.6	63	45.7		240
	Pb						12.9		220
	Sw			6173.0	5498.0	181	147.1		
		70.2	81.1	8266.7	7334.6	244	205.7	490	460

APPENDIX 5 cont.

Plot No.	Species	Mean annual volume increment (ft^3 acre^{-1} yr^{-1}) (all species)[a] Corrected	and Uncorrected	Total volume (ft^3 acre^{-1})[b]	Merchantable volume (ft^3 acre^{-1})	Basal area from stem tally (ft^2 acre^{-1})	Basal area from relascope (ft^2 acre^{-1})[c]	Density per acre of stems (0.5 in. DBH)[d]	Density per acre of tree regeneration (0.5 in. DBH)
48	As			350.8	313.1	10	.7		420
	Sw			5258.1	4779.7	154	134.3		220
	B								20
		30.8	41.9	5608.9	5092.8	164	135.0	290	660
49	Sw			5994.2	5461.4	170	130.0		10
	Pb						2.9		10
	Sb			1342.7	1112.6	56	25.7		20
		15.1	42.2	7336.9	6574.0	226	158.6	520	40
50	Sw			6975.1	6316.5	238	161.4		10
	Pl						.6		1710
	Fa			465.6	383.2	20	21.4		
		15.4	34.0	7440.7	6699.7	258	183.[illegible]	520	1720
51	Pl			4254.6	2866.8	205	167.1		
		56.5	59.1	4254.6	2866.8	205	167.1	1230	
52	Pl			6187.8	5756.7	213	141.4		390
	Fa			271.1	233.0	10	10.0		70
	Sw			430.7	370.0	18	14.3		
	Sb						1.4		
		26.2	38.1	6889.6	6[illegible]59.7	241	167.1	410	460
53	Pl			4886.5	4184.1	170.8	135.7		
	Sw			4.2		.5	5.7		240
	Fa			306.0	266.4	12.2	10.0		
	Sb			16.8	8.3	1.3	1.4		
		16.4	27.6	5213.5	4458.8	184.8	152.8	610	240
54	Pl			1663.2	1006.6	110.0	100.0		110
	Fa						1.4		300
	Sw			.6		.1			90
		23.5	23.8	1663.8	1006.6	110.1	101.4	910	500

APPENDIX 5 cont.

Plot No.	Species	Mean annual volume increment (ft^3 $acre^{-1}$ yr^{-1}) (all species)[a] Corrected	and Uncorrected	Total volume (ft^3 $acre^{-1}$)[b]	Merchantable volume (ft^3 $acre^{-1}$)	Basal area from stem tally (ft^2 $acre^{-1}$)	Basal area from relascope (ft^2 $acre^{-1}$)[c]	Density per acre of stems (0.5 in. DBH)[d]	Density per acre of tree regeneration (0.5 in. DBH)
55	Sb			2333.9	799.1	150	120.0		880
	Pl			412.9	299.6	22	21.4		
		6.6	21.1	2746.8	1098.7	172	141.4	2020	880
56	Pl			1684.8	981.4	102	107.1		
	Sb			234.7	38.9	23	18.6		340
		23.2	23.4	1919.5	1020.3	125	125.7	1800	340
57	Sw			5596.3	5077.7	169	122.9		230
	Sb			1255.8	1079.7	47	28.6		770
	Fa			171.8	146.0	6	5.7		
		31.1	51.7	7023.9	6303.4	222	157.2	520	1000
58	Pl			3484.9	2596.5	129	135.7		
	Sb			1389.2	633.1	86	84.3		
	W						1.4		
	B			18.2	9.9	1.4	1.4		
	Fa								20
		43.6	59.7	4892.3	3239.5	216.4	222.8	1590	20
59	Sw			7769.4	6727.3	253	190.0		
	Sb						1.4		10
	Fa								90
		52.1	66.4	7769.4	6727.3	253	191.4	660	100
60	Pl			3266.6	2736.1	114.9	101.4		90
	Sw			15.1		1.4	4.3		250
	Sb			105.0	92.5	4.2	8.6		360
	Fa			3.0	0.0	0.3			80
	W					0.0			40
	B					0.0			20
	A			0.6		3.4			30
		41.1	42.9	3390.3	2828.6	124.2	114.3	630	870

APPENDIX 5 cont.

Plot No.	Species	Mean annual volume increment (ft^3 $acre^{-1}$ yr^{-1}) (all species)[a] Corrected	Uncorrected	Total volume (ft^3 $acre^{-1}$)[b]	Merchantable volume (ft^3 $acre^{-1}$)	Basal area from stem tally (ft^2 $acre^{-1}$)	Basal area from relascope (ft^2 $acre^{-1}$)[c]	Density per acre of stems [illegible] in. DBH[d]	Density per acre of tree regeneration [illegible] in. DBH
61	Sw			6167.5	5434.5	203	157.1		[illegible]
	Fa			15.3		1	4.3		[illegible]
	B			151.3	130.9	5	2.9		
		96.2	78.2	6334.1	5565.4	209	164.3	[illegible]	[illegible]
62	Pl			3956.6	3321.8	144	118.6		[illegible]
	Sb			175.4	151.0	7	5.[illegible]		[illegible]
	Sw								[illegible]
	B								[illegible]
		42.6	49.9	4132.0	3472.8	151	124.3	54[illegible]	4[illegible]
63	Sb			3098.2	2157.1	156	144.3		
	Sw			675.8	591.6	24	5.[illegible]		
		3.7	21.9	3774.0	2748.7	180	150.[illegible]	[illegible]	
64	Pl			2910.2	2463.0	[illegible]	95.6		
	Sb			2600.4	2036.5	[illegible]	[illegible]		
		11.3	31.1	5510.6	4499.5	[illegible]	[illegible]	[illegible]	
65	Sb			6696.6	5658.8	[illegible]	[illegible]		
	Pl						[illegible]		
		17.3	38.9	6696.6	5658.8	[illegible]	[illegible]	64[illegible]	
66	Pl			5051.6	4676.9	[illegible]	[illegible]		
	Sb			1730.8	1470.5	[illegible]	4[illegible]		[illegible]
	[illegible]						[illegible]		[illegible]
		18.2	39.0	6782.4	6147.4	[illegible]	[illegible]	49[illegible]	[illegible]
67	Sb			3256.9	1667.[illegible]	[illegible]	[illegible]		
		5.9	18.5	3256.9	1667.[illegible]	[illegible]	[illegible]	[illegible]	
68	Pl			3585.[illegible]	3249.9	[illegible]	[illegible]		
	A			[illegible]	[illegible]4.9	4[illegible]	[illegible].9		[illegible]
	Sw			60.3	45.9	[illegible]	[illegible]		[illegible]
	Fa								[illegible]
		54.4	59.5	[illegible]	[illegible]	[illegible]	[illegible]	4[illegible]	[illegible]

APPENDIX 5 cont.

Plot No.	Species	Mean annual volume increment (ft^3 $acre^{-1}$ yr^{-1}) (all species)[a] Corrected	and Uncorrected	Total volume (ft^3 $acre^{-1}$)[b]	Merchantable volume (ft^3 $acre^{-1}$)	Basal area from stem tally (ft^2 $acre^{-1}$)	Basal area from relascope (ft^2 $acre^{-1}$)[c]	Density per acre of stems (0.5 in. DBH)[d]	Density per acre of tree regeneration (0.5 in. DBH)
69	Pl			5179.9	4732.7	172	130.0		
	Sb			947.2	670.5	45	52.9		
	A						2.9		
	Fa								10
		17.4	35.0	6127.1	5403.2	217	185.8	590	10
70	Pl			2774.6	2207.8	103	101.4		
	Sb			3075.8	2165.3	129	111.4		
		16.0	50.9	5850.4	4373.1	232	212.8	1210	
71	Pl			5002.7	4536.5	165	135.7		10
	Sw			122.6	108.3	4	4.3		40
	Fa			2.4		2			70
	B								10
		53.5	61.0	5127.7	4644.8	171	140.0	420	130
72	Pl			2837.2	1922.0	130	137.0		
	Sb						1.4		
		27.9	34.2	2837.2	1922.0	130	138.4	800	
73	Pl			108.1	88.0	5	5.7		
	Sb			3679.9	2715.2	171	121.4		240
		11.9	23.2	3788.0	2803.2	176	127.1	900	240
74	Pl			7126.5	6566.1	219	154.2		
	Sb			1359.1	1155.5	52	34.2		10
		17.9	47.9	8485.6	7721.6	271	188.4	560	10
75	Sb			1926.2	1426.2	88.5	84.2		540
	Pl			1820.1	1298.4	82.0	72.8		
		11.4	21.8	3746.3	2724.6	170.5	157.0	990	540
76	Pl			3623.1	1912.4	165.1	140.0		
	Sb			336.5	82.6	18.6	12.8		
		35.2	47.1	3959.6	1995.0	183.7	152.8	1540	

APPENDIX 5 cont.

Plot No.	Species	Mean annual volume increment (ft^3 $acre^{-1}$ yr^{-1}) (all species)[a] Corrected	Mean annual volume increment (ft^3 $acre^{-1}$ yr^{-1}) (all species)[a] Uncorrected	Total volume (ft^3 $acre^{-1}$)[b]	Merchantable volume (ft^3 $acre^{-1}$)	Basal area from stem tally (ft^2 $acre^{-1}$)	Basal area from relascope (ft^2 $acre^{-1}$)[c]	Density per acre of stems (≥ 0.5 in. DBH)[d]	Density per acre of tree regeneration (< 0.5 in. DBH)
77	Pl			4691.2	3849.9	173.2	151.4		10
	Sw								20
		50.3	61.7	4691.2	3849.9	173.2	151.4	710	30
78	Sw			3785.1	3481.4	118.6	65.7		
	Sb			1693.6	1298.3	72.4	85.7		
	Pl						7.1		
		28.4	40.9	5478.7	4779.7	191.0	158.5	550	
79	Pl			2297.4	1449.3	105.7	152.8		
		26.6	30.3	2297.4	1449.3	105.7	152.8	790	
80	Pl			873.8	788.8	35.4	38.6		20
	Sb			647.6	491.2	32.4	45.7		60
	Se			1662.3	1416.7	69.0	24.3		
	Fa			590.5	433.7	27.5	20.0		770
		20.8	26.2	3774.2	3130.4	164.3	128.6	580	850
81	Pl			4202.5	3590.3	167.8	162.9		10
	Fa			313.9	266.4	13.2	8.6		700
	Sb								40
		22.3	38.9	4516.4	3856.7	181.0	171.5	600	750
82	Pl			5228.9	4105.5	186.3	158.6		
	Sb			2457.1	1725.7	101.0	71.4		
		34.6	60.5	7686.0	5831.2	287.3	230.0	1420	
83	Pl			4712.3	4286.5	152.8	137.1		10
	Sb			159.7	134.6	6.3	8.6		30
	A			703.7	603.3	23.3	20.0		90
		64.5	72.4	5575.7	5024.4	182.4	165.7	400	130

APPENDIX 5 cont.

Plot No.	Species	Mean annual volume increment (ft^3 $acre^{-1}$ yr^{-1}) (all species)[a] Corrected	and Uncorrected	Total volume (ft^3 $acre^{-1}$)[b]	Merchantable volume (ft^3 $acre^{-1}$)	Basal area from stem tally (ft^2 $acre^{-1}$)	Basal area from relascope (ft^2 $acre^{-1}$)[c]	Density per acre of stems (0.5 in. DBH)[d]	Density per acre of tree regeneration (0.5 in. DBH)
84	Pl			3770.6	3438.6	139.4	179		
	A			368.8	319.5	12.6	14		
	Sw			63.6	57.0	2.8			
	Sb			845.9	665.3	45.0	56		
		45.4	51.5	5048.9	4480.4	199.8	249	970	
85	A			4628.3	3926.5	159.1	176		
	Sw								70
		74.7	70.1	4628.3	3926.5	159.1	176	710	70
86	Pl			1106.2	1043.3	36.4	26		
	Sw			871.3	689.1	44.7	60		
	Sb			48.6	42.6	2.3			
	A			2393.6	2085.1	86.9	116		10
	Pb			343.6	304.2	12.2	7		
		40.3	50.1	4763.3	4164.3	182.5	209	750	10
87	A			4269.5	3657.0	162.4	123		400
	Sw								50
	Pb								
		44.5	50.8	4269.5	3657.0	162.4	123	660	450
88	Pl			4469.5	4158.4	161.1	123		
	A			11.0	0.0	1.0	1		60
	Sb			59.0	52.6	3.2	3		280
	Pb								
	L								10
		56.3	58.2	4539.5	4211.0	165.3	127	570	350
89	Pl			3365.4	3045.7	129.0	127		50
	Sb			41.5	31.9	2.6	3		40
	Sw			0.9	0.0	0.1			
		39.0	42.1	3407.8	3077.6	131.7	130	580	90

APPENDIX 5 cont.

Plot No.	Species	Mean annual volume increment (ft^3 $acre^{-1}$ yr^{-1}) (all species)[a] Corrected	and Uncorrected	Total volume (ft^3 $acre^{-1}$)[b]	Merchantable volume (ft^3 $acre^{-1}$)	Basal area from stem tally (ft^2 $acre^{-1}$)	Basal area from relascope (ft^2 $acre^{-1}$)[c]	Density per acre of stems (0.5 in. DBH)[d]	Density per acre of tree regeneration (0.5 in. DBH)
90	A[c]			4109.1	3629.7	154.6	79		140
	Pl			166.6	155.5	7.2	4		
	B			19.6	13.4	1.2	1		
	Sw						4		10
	Pb						7		
		36.6	49.4	4295.3	3798.6	163.0	95	390	150
91	Sw			3630.2	3370.9	109.0	90		
	Pl			2661.5	2333.3	67.0	54		
	A			2978.0	2678.0	72.9	60		20
	Fa								10
		37.5	61.3	9269.7	8382.2	248.9	204	440	30
92	Pl			5062.2	4804.8	159.4	124		10
	A			674.7	603.8	20.3	19		80
	B			65.4	56.8	2.8			260
	Sw								
	Fa								20
		62.1	69.9	5802.3	5465.4	182.5	143	310	370
93	Pl			3297.4	3039.4	118.5	109		
	Sb			444.6	386.5	20.7	37		
	Sw			392.4	364.5	14.4	16		10
	Fa			107.4	74.8	6.2	16		600
		47.3	52.4	4241.8	3865.2	159.8	178	570	610
94	Sw			4938.2	4681.6	146.9	126		250
	A			1004.3	906.0	27.2	29		140
	Pb			705.3	635.2	21.1	16		80
	B						6		40
		22.1	48.5	6647.8	6222.8	195.2	177	190	510

APPENDIX 5 cont.

Plot No.	Species	Mean annual volume increment (ft^3 $acre^{-1}$ yr^{-1}) (all species)[a] Corrected	and Uncorrected	Total volume (ft^3 $acre^{-1}$)[b]	Merchantable volume (ft^3 $acre^{-1}$)	Basal area from stem tally (ft^2 $acre^{-1}$)	Basal area from relascope (ft^2 $acre^{-1}$)[c]	Density per acre of stems (0.5 in. DBH)[d]	Density per acre of tree regeneration (0.5 in. DBH)
95	Sw			4126.1	3860.3	127.9	137		20
	Pb			966.8	869.5	27.9	13		
	B			736.2	650.2	23.3	11		
	Fa			173.0	148.5	8.1	9		150
		69.8	63.8	6002.1	5528.5	187.2	170	360	170
96	Pl			4551.9	4245.4	145.0	121		
	Sb			283.4	251.2	12.4	20		130
	A			546.6	487.5	16.3	11		30
	Sw			56.2	46.8	3.5	1		
	Pb						1		10
	B								110
		67.9	71.6	5438.1	5030.9	177.2	154	500	280
97	Pl			4331.8	4072.2	123.7	147		30
	A			624.8	558.3	17.4	14		250
	Sb								10
	Fa								
		50.3	57.6	4956.6	4630.5	141.1	161	310	290
98	Pl			4378.8	4076.0	152.5	80		
	Sb			263.5	229.2	13.0	63		
	Fa			341.6	298.5	13.2	13		20
	B								20
		56.4	62.3	4983.9	4603.7	178.7	156	550	40
99	Pl			1826.8	1733.3	59.2	49		
	Fa			1597.8	1400.6	70.9	66		1130
	Sw			1358.7	1278.1	42.7	39		
		52.3	59.8	4783.3	4412.0	172.8	154	460	1130
100	A			2215.7	1457.6	112.3	130		
	Sw			24.1	0.0	2.8	4		140
	Pb			335.6	253.5	16.0	3		
		69.1	51.5	2575.4	1711.1	131.1	137	1630	140

APPENDIX 5 cont.

Plot No.	Species	Mean annual volume increment (ft^3 $acre^{-1}$ yr^{-1}) (all species)[a] Corrected	and Uncorrected	Total volume (ft^3 $acre^{-1}$)[b]	Merchantable volume (ft^3 $acre^{-1}$)	Basal area from stem tally (ft^2 $acre^{-1}$)	Basal area from relascope (ft^2 $acre^{-1}$)[c]	Density per acre of stems (0.5 in. DBH)[d]	Density per acre of tree regeneration (0.5 in. DBH)
101	Sw			4391.6	4029.4	132.3	141		280
	Pb			612.6	545.7	18.2	11		
	A			427.9	385.1	12.2	9		50
	Fa			237.0	222.0	6.0	1		380
		13.2	36.6	5669.1	5182.2	168.7	162	440	710
102	Pl			2953.2	2687.0	112.0	140		10
	A			824.3	710.3	32.3	43		30
	B								220
	Sb								10
	Fa								
		36.9	45.5	3777.5	3397.3	144.3	183	570	270
103	Pl			5348.5	5032.4	161.5	144		
	Sw			138.1	128.5	5.0	4		
	A			0.7	0.0	0.1	3		70
	B								120
		60.0	66.9	5487.3	5160.9	166.6	151	370	190
104	Sb			1650.0	1407.5	75.3	57		190
	Pl			1214.3	1130.6	42.5	31		
	Sw			574.3	524.4	19.5	24		
	A			942.2	835.3	30.6	23		
	Pb			182.2	134.3	9.9	20		
		59.5	62.5	4563.0	4032.1	177.8	155	750	190
105	Pl			7136.5	6702.6	223.3	213		
	B								
		79.5	86.0	7136.5	6702.6	223.3	213	520	
106	A			2520.3	2231.8	92.6	97		90
	Pb			22.4	2.9	2.1	1		10
	Fa			1.7	0.0	0.2			
	Sw								70
		49.0	43.1	2544.4	2234.7	94.9	98	270	170

APPENDIX 5 cont.

Plot No.	Species	Mean annual volume increment (ft^3 $acre^{-1}$ yr^{-1}) (all species)[a] Corrected	and Uncorrected	Total volume (ft^3 $acre^{-1}$)[b]	Merchantable volume (ft^3 $acre^{-1}$)	Basal area from stem tally (ft^2 $acre^{-1}$)	Basal area from relascope (ft^2 $acre^{-1}$)[c]	Density per acre of stems (0.5 in. DBH)[d]	Density per acre of tree regeneration (0.5 in. DBH)
107	Pl			2483.3	2317.4	80.5	93		
	A			1980.2	1727.1	67.6	73		30
	Pb			840.4	747.4	29.3	21		
	Sw			164.9	146.6	7.6	11		210
	B								120
	Fa								60
		54.2	64.3	5468.9	4938.5	185.0	198	530	420
108	Pl			4432.1	4160.0	137.0	119		
	Sw			645.0	610.9	19.7	13		340
	Pb			154.7	134.7	5.9	14		
	Sb			16.6	11.9	1.1			510
		62.3	66.4	5248.4	4917.5	163.7	146	380	850
109	Pl			3655.7	3373.0	143.6	143		
	Sw			147.8	134.9	6.9	17		
	Sb			22.3	17.2	1.3	2		70
	Pb								
		33.7	39.4	3825.8	3525.1	151.8	162	500	70
110	Pl			5099.5	4750.5	194.8	164		
	Sw			211.5	177.4	11.2	10		
	Fa			323.2	285.6	15.0	13		570
	Sb			27.5	18.2	1.7			
		67.3	71.7	5661.7	5231.7	222.7	187	730	570
111	Pl			3713.0	3445.6	132.8	129		
	Sb			479.6	410.6	24.1	27		
	Sw			264.4	209.1	14.2	21		
	Fa						1		10
		42.5	45.5	4457.0	4065.3	171.1	178	640	10
112	Pl			4250.6	3835.5	160.8	153		
	Sb			209.7	170.1	11.0	11		10
		54.0	55.1	4460.3	4005.6	171.8	164	740	10

APPENDIX 5 cont.

Plot No.	Species	Mean annual volume increment (ft³ acre⁻¹ yr⁻¹) (all species)[a] Corrected	Uncorrected	Total volume (ft³ acre⁻¹)[b]	Merchantable volume (ft³ acre⁻¹)	Basal area from stem tally (ft² acre⁻¹)	Basal area from relascope (ft² acre⁻¹)[c]	Density per acre of stems (0.5 in. DBH)[d]	Density per acre of tree regeneration (0.5 in. DBH)
113	Pl			2839.6	2642.8	105.4	104		
		33.3	36.9	2839.6	2642.8	105.4	104	300	
114	Pl			2352.2	2238.5	80.3	39		
	Sw			2523.9	2293.0	95.3	74		20
	Sb			80.4	66.2	4.8	14		
	Fa			9.3	4.3	0.7			210
		68.5	57.1	4965.8	4602.0	181.1	127	470	230
115	Pl			3666.0	3267.9	143.5	107		
	Sb			118.5	84.5	7.8	7		10
		42.7	46.2	3784.5	3352.4	151.3	114	730	10
116	Pl			4432.8	3897.1	172.7	139		
		43.1	53.4	4432.8	3897.1	172.7	139	870	
117	Sw			4865.4	4580.3	145.6	131		
	Pb			1025.8	918.5	34.4	14		
	A			813.4	733.5	25.9	10		
	Pl						6		
	Sb			265.7	251.1	8.7	3		
		80.2	76.6	6970.3	6483.4	214.6	164	280	
118	Sw			6939.0	6454.7	208.9	114		310
	A			578.4	515.6	16.0	19		
	Pl			1059.7	1006.5	31.6	16		
	Pb			643.3	576.1	20.0	9		
		83.9	81.6	9220.4	8552.9	276.5	158	540	310
119	Pl			4017.1	3718.0	143.4	133		
	A			390.4	350.0	14.1	19		170
	Sb								60
	B								30
		48.1	55.1	4407.5	4068.0	157.5	152	460	260

APPENDIX 5 cont.

Plot No.	Species	Mean annual volume increment (ft^3 $acre^{-1}$ yr^{-1}) (all species)[a] Corrected	and Uncorrected	Total volume (ft^3 $acre^{-1}$)[b]	Merchantable volume (ft^3 $acre^{-1}$)	Basal area from stem tally (ft^2 $acre^{-1}$)	Basal area from relascope (ft^2 $acre^{-1}$)[c]	Density per acre of stems (≥ 0.5 in. DBH)[d]	Density per acre of tree regeneration (< 0.5 in. DBH)
120	Pl			4151.8	3920.3	138.1	107		610
	Sw			1411.5	1313.7	51.6	46		200
	Fa								
		65.5	70.4	5563.3	5234.0	189.7	153	370	810
121	Sw			5906.9	5470.4	187.3	104		100
	A			925.4	828.7	26.2	19		30
	Pb			1084.0	973.7	33.2	14		
	Pl						14		
	Sb			338.2	310.1	11.0	10		
		59.9	74.4	8254.5	7582.9	257.7	161	540	130
122	A			5593.8	4695.7	202.9	173		50
	Sw								
	Fa								
		83.1	81.1	5593.8	4695.7	202.9	173	960	50
123	A			7236.7	6480.3	218.9	187		140
	Pb			335.3	295.4	12.7	4		
		75.7	86.1	7572.0	6775.7	231.6	191	350	140
124	Sw			2481.1	2181.3	87.7	77		10
	Sb			1411.6	1214.6	61.8	40		130
	Pb			1004.2	892.3	34.5	20		
	Pl			302.9	286.2	10.0	6		70
	A			2001.6	1798.9	60.9	13		550
	Fa								
		105.0	90.0	7201.4	6373.3	254.9	156	880	760
125	Sw			1365.8	1161.4	58.0	53		30
	Pl			2493.7	2375.5	84.0	50		2120
	Fa			711.9	601.6	30.5	27		
	Sb			46.5	41.1	2.4	1		
		34.3	41.2	4617.9	4179.6	174.9	131	640	2150

APPENDIX 5 cont.

Plot No.	Species	Mean annual volume increment (ft^3 $acre^{-1}$ yr^{-1}) (all species)[a] Corrected	Uncorrected	Total volume (ft^3 $acre^{-1}$)[b]	Merchantable volume (ft^3 $acre^{-1}$)	Basal area from stem tally (ft^2 $acre^{-1}$)	Basal area from relascope (ft^2 $acre^{-1}$)[c]	Density per acre of stems (0.5 in. DBH)[d]	Density per acre of tree regeneration (0.5 in. DBH)
126	Sw			5484.6	5065.2	190.4	94		20
	Pl			1258.0	1185.3	40.8	46		790
	Fa			75.1	63.7	3.7	4		
	Sb			62.8	56.7	3.0	1		
		41.6	52.5	6880.5	6370.9	237.9	145	570	810
127	Pl			4806.8	4544.7	150.0	79		
	Sw			2553.5	2273.3	94.1	50		
	Pb			100.0	87.8	3.4	4		
	Fa								90
		50.1	66.6	7460.3	6905.8	247.5	133	690	90
128	Sw			4700.3	4219.5	165.2	81		10
	Pl			2557.2	2357.9	85.7	66		630
	Fa						4		
	Sb						3		
		54.5	62.0	7257.5	6577.4	250.9	154	870	640
129	Sw			2802.6	2590.8	97.7	64		20
	Pl			2778.8	2640.6	88.1	56		320
	Fa			105.0	96.4	3.9	9		
		43.7	49.4	5686.4	5327.8	189.7	129	380	340
130	Pl			3304.5	3100.6	118.4	61		
	Sw			2010.9	1816.1	81.3	50		
	Sb			726.9	619.3	33.4	23		
	Pb			187.8	168.1	6.2	1		
		67.4	69.2	6230.1	5704.1	239.3	135	750	
131	Pl	—		7608.2	7171.5	239.6	184		40
	Sb			34.9	28.9	1.7	1		10
	Fa								1020
		48.0	62.7	7643.1	7200.4	241.3	185	520	1070

APPENDIX 5 cont.

Plot No.	Species	Mean annual volume increment (ft^3 $acre^{-1}$ yr^{-1}) (all species)[a] Corrected	and Uncorrected	Total volume (ft^3 $acre^{-1}$)[b]	Merchantable volume (ft^3 $acre^{-1}$)	Basal area from stem tally (ft^2 $acre^{-1}$)	Basal area from relascope (ft^2 $acre^{-1}$)[c]	Density per acre of stems (0.5 in. DBH)[d]	Density per acre of tree regeneration (0.5 in. DBH)
132	Pl			3984.4	3693.3	147.8	120		100
	Sb								40
	Fa								
		50.6	52.4	3984.4	3693.3	147.8	120	460	140
133	Sw			2420.0	2164.7	94.4	74		100
	Pl			2738.0	2594.6	95.3	53		10
	Fa								110
		77.8	67.9	5158.0	4759.3	189.7	127	520	220
134	Pl			3204.0	2710.8	157.7	79		
	Sb			547.2	227.6	47.6	29		70
		46.1	47.5	3751.2	2938.4	205.3	108	2140	70
135	Sb			2909.9	2437.8	129.6	73		
	Sw			1946.6	1735.5	71.1	39		
	Pl						3		
	Fa								10
		38.9	44.6	4856.5	4173.3	200.7	115	1110	10
136	Sw			4280.2	4017.7	144.6	86		
	Sb			2354.9	1975.4	112.2	53		
	Pl			169.2	157.2	6.6	9		
	Pb						1		10
	Fa								10
		15.8	37.8	6804.3	6150.2	263.4	149	880	20
137	Pl			4836.5	4366.7	179.6	181		
	Fa								10
		63.6	65.4	4836.5	4366.7	179.6	181	750	10

Footnotes

a $m^3ha^{-1}yr^{-1} = ft^3ac^{-1}yr^{-1} \times 0.070$

b Volume in $m^3 = ft^3 \times 0.028$

c $m^2ha^{-1} = ft^2ac^{-1} \times 0.230$

d trees ha^{-1} = trees $ac^{-1} \times 2.471$

e Tree species abbreviations:

Pl - lodgepole pine

Sw - white spruce

Sb - black spruce

Se - Engelmann spruce

Fa - subalpine fir

A - Aspen

Pb balsam poplar

B - white birch

L - tamarack

W - tree willow (*Salix scouleriana*)

APPENDIX 6 Summarized stem analyses for the 137 sampled plots.

Plot No.	Species[a]	Age	Site index at 70yr (ft)[b]	Total volume per tree (ft^3)[c]	PAI per tree (ft^3)	Maximum PAI per tree (ft^3)	Age of maximum PAI
1	Pl	65.0±10.0[d]	34.9±6.9	3.3±2.6	0.3±0.2	0.4±0.3	37.5±2.5
	Sb	71.5± 1.7	27.9±2.3	1.2±0.2	0.4±0.1	0.2±0.0	56.2±8.7
2	Se	147.2±12.5	17.9±2.3	7.5±1.8	1.0±0.3	0.7±0.1	28.9±15.5
3	Pl	70.0±0.7	54.3±0.8	6.2±0.1	0.3±0.1	1.7±0.2	49.2±1.2
4	Pl	82.7±0.5	41.6±1.6	3.3±0.5	0.6±0.1	0.8±0.1	57.7±3.5
5	Sw	159.3±17.1	18.9±1.7	9.8±3.5	0.4±0.1	2.4±0.9	154.3±16.7
6	Pl	76.3±1.6	43.9±1.0	4.0±1.0	0.8±0.2	1.1±0.2	59.7±3.8
7	Sw	166.3±1.8	30.8±4.7	11.6±1.8	0.9±0.2	2.0±0.4	159.7±5.5
8	Pl	82.0±0.0	43.2±3.0	4.3±1.7	0.5±0.1	0.9±0.4	52.0±0.0
	Sb	74.0±0.1	28.5±0.7	1.4±0.2	0.5±0.1	0.5±0.1	74.0±0.1
9	Pl	77.3±3.3	56.4±1.4	6.1±0.8	1.0±0.1	1.4±0.2	60.7±5.3
10	Sw	110.0±4.1	27.6±4.3	8.2±2.3	1.6±0.3	2.0±0.4	98.0±5.2
	Pl	97					
11	Pl	82.2±1.0	44.3±1.2	4.7±1.1	0.9±0.2	1.6±0.4	62.2±1.0
	Sb	73.5±3.5	21.6±1.1	0.8±0.0	0.3±0.1	0.3±0.1	73.5±3.5
12	Pl	87.5±1.4	47.0±1.9	6.0±1.2	1.0±0.2	1.2±0.2	75.8±7.1
13	Pl	88.5±1.5	48.0±2.9	6.5±1.4	0.7±0.2	1.3±0.3	58.5±4.1
	Sb	67					

APPENDIX 6 cont.

Plot No.	Species[a]	Age	Site index at 70yr (ft)[b]	Total volume per tree (ft^3)[c]	PAI per tree (ft^3)	Maximum PAI per tree (ft^3)	Age of maximum PAI
14	Sb	165.8±23.6	16.1±1.1	2.3±0.6	0.2±0.0	0.3±0.0	140.8±23.[illegible]
15	Sb	100.2±4.8	32.6±1.6	6.9±2.9	1.1±0.5	1.4±0.6	54.[illegible]±4.5
	Sw	87	33.0	4.0	1.6	1.6	[illegible]
16	Pl	77.8±0.6	33.7±3.8	4.0±0.9	0.6±0.1	1.1±0.3	51.[illegible]±[illegible]
	Sb	42		0.2	0.1	0.1	42
17	Pl	78.0±0.6	51.5±0.6	6.3±0.5	1.1±0:1	1.3±0.1	64.[illegible]±6.6
18	A			NO STEM ANALYSIS			
	Pb	72	60				
19	A	70	50				
	Pb			NO STEM ANALYSIS			
20	Sw	94.8±6.4	56.1±4.4	6.1±1.5	1.8±0.8	3.0±1.6	74.8±[illegible]
21	Pl	76.0±2.3	48.1±2.8	5.5±1.6	1.4±0.3	1.6±0.5	[illegible]±5.6
22	Pl	79	52.8	10.5	1.8	2.8	59
	Sb	71.6±1.6	44.5±1.4	4.8±0.[illegible]	1.0±0.2	1.3±0.2	[illegible]
23	Sw	44.7±1.3	53.7±3.4	2.6±0.3	1.6±0.2	1.6±0.2	44.[illegible]
	A	66					
24	Sw	69.0±2.1	56.7±4.4	8.6±1.5	[illegible]	[illegible]	[illegible]
	Fa	69					
	B	73					

APPENDIX 6 cont.

Plot No.	Species[a]	Age	Site index at 70yr (ft)[b]	Total volume per tree (ft^3)[c]	PAI per tree (ft^3)	Maximum PAI per tree (ft^3)	Age of maximum PAI
25	Sw	72.3 ± 1.2	59.5 ± 7.1	17.1 ± 6.6	4.1 ± 1.4	4.8 ± 1.8	57.3 ± 3.4
	A	73					
26	A	66	65				
	Pb			NO STEM ANALYSIS			
27	Sw	123.5 ± 1.3	49.0 ± 3.3	21.5 ± 6.2	3.4 ± 1.0	4.1 ± 0.9	115.2 ± 5.0
28	Pl	82.7 ± 1.0	56.2 ± 3.8	8.7 ± 2.0	1.5 ± 0.4	1.7 ± 0.4	64.3 ± 8.1
	Sb	86	40.5	3.8	1.2	1.2	79
29	Sb	207.7 ± 27.7	12.2 ± 3.1	3.6 ± 0.6	0.2 ± 0.1	1.2 ± 0.1	174.3 ± 25.9
30	Pl	85.8 ± 0.7	37.2 ± 1.5	3.4 ± 0.6	0.9 ± 0.2	1.1 ± 0.3	82.5 ± 3.2
31	Sb	76.0 ± 1.2	41.5 ± 1.8	4.8 ± 0.8	1.4 ± 0.2	1.4 ± 0.2	72.7 ± 3.6
	Pl	83					
32	Pl	211.4 ± 2.5	28.6 ± 1.7	8.2 ± 1.0	0.4 ± 0.0	1.3 ± 0.3	151.4 ± 24.5
33	Pl	179.8 ± 2.9	33.1 ± 2.0	14.0 ± 4.1	0.7 ± 0.2	3.4 ± 1.1	151.8 ± 6.0
	Fa	103					
	Sb	133	26.6	8.5	1.2	2.7	126
34	Pl	72.5 ± 0.7	54.4 ± 0.8	7.3 ± 0.5	1.9 ± 0.3	2.2 ± 0.2	65.8 ± 4.7

APPENDIX 6 cont.

Plot No.	Species[a]	Age	Site index at 70yr (ft)[b]	Total volume per tree (ft^3)[c]	PAI per tree (ft^3)	Maximum PAI per tree (ft^3)	Age of maximum PAI
35	Pl	74.2±0.8	56.6±2.0	13.4±1.9	1.6±0.3	3.3±0.5	48.2±3.5
	Sb	71	35.8	3.5	1.0	1.0	71
	A	71					
36	Pl	73.8±0.5	52.8±1.7	7.5±0.9	1.6±0.2	1.8±0.2	58.8±6.7
	Sb	64					
37	Pl	71.7±1.0	57.6±1.4	6.7±0.8	1.4±0.2	1.6±0.2	51.7±5.3
38	Pl	68.8±0.6	56.8±1.6	7.7±0.8	1.9±0.2	2.1±0.2	60.5±2.8
39	Pl	86.7±0.8	53.3±1.8	12.5±1.7	1.9±0.3	2.5±0.3	61.6±3.0
	Sb	52					
40	Pl	71.5±0.5	37.9±1.1	3.5±0.3	0.8±0.1	1.1±0.1	44.0±7.8
41	Pl	71.3±1.4	53.5±1.7	7.7±1.5	2.1±0.4	2.4±0.5	64.7±5.0
42	Pl	172.2±1.1	41.6±1.4	12.9±1.8	0.9±0.1	2.3±0.4	105.5±17.9
	Fa	123					
43	Pl	53.5±0.3	56.1±1.8	5.0±0.6	1.7±0.3	1.8±0.2	53.5±0.3
44	Sw	85.8±1.8	48.3±1.2	9.0±1.1	2.6±0.3	2.7±0.3	84.2±2.4
45	Sw	88.0±1.7	58.7±3.3	14.6±1.6	3.1±0.5	3.5±0.4	71.3±4.2
46	Sw	86.8±1.3	54.1±2.9	13.1±2.5	3.1±0.7	3.5±0.7	78.5±3.7
47	Sw	101.8±0.5	62.2±2.8	24.7±6.4	5.4±1.8	5.6±1.8	95.2±3.7
48	Sw	133.8±1.2	46.2±1.8	25.8±2.0	3.3±0.4	4.1±0.5	110.5±7.8

APPENDIX 6 cont.

Plot No.	Species[a]	Age	Site index at 70yr (ft)[b]	Total volume per tree (ft^3)[c]	PAI per tree (ft^3)	Maximum PAI per tree (ft^3)	Age of maximum PAI
49	Sw	175.0±1.9	42.1±2.9	29.9±4.6	1.6±0.4	4.8±0.6	160.0±4.4
50	Sw	218.5±1.6	30.1±2.6	24.3±2.9	1.0±0.2	2.3±0.1	193.5±5.3
51	Pl	72.3±0.8	52.9±1.0	7.5±0.8	2.1±0.2	2.1±0.2	69.0±3.8
52	Pl	181.0±3.0	50.9±1.2	27.5±5.1	1.5±0.2	2.3±0.4	131.0±16.4
53	Pl	188.8±0.8	43.5±2.0	17.1±1.6	1.0±0.1	1.5±0.2	177.2±11.4
54	Pl	70.3±0.8	40.3±1.0	4.5±0.5	1.3±0.1	1.3±0.2	70.3±0.8
55	Sb	129.7±2.6	17.9±1.0	2.1±0.0	0.3±0.0	0.3±0.0	123± 4.8
56	Pl	81.7±0.8	44.3±0.9	6.2±0.6	0.8±0.1	1.5±0.1	51.7±0.8
57	Sw	135.7±6.3	42.1±3.6	31.3±5.7	5.4±0.9	5.8±1.1	112.3±10.3
58	Pl	82.3±0.6	55.8±1.7	9.7±1.0	1.9±0.3	2.1±0.3	70.7±6.4
59	Sw	117.2±1.4	44.5±0.2	31.0±4.6	6.1±1.0	6.5±1.0	105.5±2.6
60	Pl	79.2±0.5	69.4±1.5	14.5±0.8	2.4±0.3	2.8±0.2	59.2±10.2
61	Sw	80.5±0.4	70.6±0.8	21.9±0.9	5.9±0.4	6.1±0.3	73.8±3.6
62	Pl	82.5±0.9	59.1±0.9	12.3±0.9	2.7±0.3	2.8±0.3	77.5±5.4
63	Sb	171.8±3.1	16.6±1.8	6.6±0.8	0.3±0.1	1.4±0.1	158.5±2.3
64	Pl	177.2±0.5	30.9±1.6	16.2±2.0	0.5±0.1	2.2±0.3	162.2±4.0
65	Sb	171.5±2.3	27.9±2.4	13.0±1.1	0.9±0.1	1.7±0.1	154.8±4.7
66	Pl	174.2±1.2	47.5±1.4	29.3±5.1	1.8±0.4	3.1±0.5	154.2±0.6

APPENDIX 6 cont.

Plot No.	Species[a]	Age	Site index at 70yr (ft)[b]	Total volume per tree (ft^3)[c]	PAI per tree (ft^3)	Maximum PAI per tree (ft^3)	Age of maximum PAI
67	Sb	176.2±1.7	16.6±1.1	4.0±0.5	0.2±0.0	0.6±0.0	159.5±5.0
68	Pl	83.7±0.4	74.5±1.6	25.4±1.0	4.3±0.2	5.1±0.2	62.0±1.8
69	Pl	174.6±1.2	50.7±1.6	28.2±2.1	1.2±0.2	3.6±0.4	158.6±6.0
70	Pl	176.3±1.8	33.6±2.2	13.1±2.2	0.8±0.1	1.8±0.4	176.3±1.8
	Sb	154.0±3.1	36.1±3.3	10.1±1.8	0.7±0.1	1.3±0.3	117.3±20.3
71	Pl	84.4±0.4	73.0±1.8	28.0±3.5	5.2±0.6	5.[illegible]±0.8	72.4±3.9
72	Pl	82.5±0.8	49.3±1.2	7.0±0.7	1.7±[illegible]	1.9±0.2	70.8±4.1
73	Sb	167.8±2.5	21.7±1.5	5.6±0.6	0.4±0.0	0.7±0.0	164.5±5.0
74	Pl	177.0±2.5	41.1±1.9	22.7±2.5	1.2±0.1	2.6±0.5	145.0±15.4
75	Sb	171.5±2.1	22.0±1.8	7.7±0.8	0.7±0.1	1.0±0.0	146.5±4.9
76	Pl	84.2±0.2	44.9±1.0	5.2±0.3	1.4±0.1	1.5±0.0	82.5±1.7
77	Pl	81.2±0.8	59.6±1.5	11.5±1.0	2.6±0.3	2.8±0.3	74.5±4.3
78	Sw	133.5±4.5	44.4±0.1	22.8±2.8	2.9±0.0	3.3±0.4	128.5±9.5
	Sb	135.3±10.9	31.9±5.9	11.3±0.6	1.6±0.2	1.9±0.1	115.3±11.2
79	Pl	76.2±0.4	44.7±0.6	6.5±0.5	1.9±0.2	1.9±0.2	62.2±4.2
80	Pl	144.2±4.1	38.8±2.3	11.7±0.8	1.4±0.1	1.7±0.2	76.2±3.3
81	Pl	120.6±2.1	39.2±1.3	12.0±1.4	1.8±0.2	1.9±0.2	82.6±2.8
82	Pl	127.2±0.7	39.6±0.6	9.2±0.7	1.0±0.1	1.5±0.2	117.2±6.4

APPENDIX 6 cont.

Plot No.	Species[a]	Age	Site index at 70yr (ft)[b]	Total volume per tree (ft^3)[c]	PAI per tree (ft^3)	Maximum PAI per tree (ft^3)	Age of maximum PAI
83	Pl	81.8±0.4	68.9±2.1	15.1±1.4	2.3±0.2	3.2±0.3	59.8±7.8
84	Pl	98.3±3.2	61.8±3.5	10.0±1.5	1.3±0.2	1.9±0.2	51.7±1.9
	Sb	94.3±0.7	40.3±3.1	4.2±1.0	0.7±0.1	1.1±0.1	84.3±9.7
85	A	66.3±2.0	77.4±0.5	13.4±1.9	4.8±0.8	4.8±0.8	66.3±2.0
86	Pl	95.0±1.5	64.9±2.2	20.1±1.3	2.4±0.2	3.8±0.1	55.0±1.5
	Sw	95.3±2.9	44.5±2.7	7.6±2.4	1.5±0.4	1.8±0.6	88.7±4.7
87	A	83.5±5.3	57.1±2.9	10.3±1.2	2.3±0.2	2.5±0.2	68.5±4.4
88	Pl	77.7±0.9	70.4±0.9	21.3±1.8	3.7±0.5	4.8±0.5	54.3±3.3
89	Pl	81.5±1.0	61.7±1.8	11.3±1.2	1.9±0.2	2.4±0.2	63.2±4.5
90	A	87.0±2.4	65.7±0.5	25.3±5.0	5.6±0.7	6.3±0.8	87.0±2.4
91	Sw	146.7±1.7	46.7±9.0	21.8±5.0	2.4±0.4	3.3±0.8	116.7±10.9
	Pl	149.3±3.2	65.1±2.8	41.0±7.3	3.7±0.2	4.9±1.0	112.7±20.9
92	Pl	83.4±1.3	72.2±2.0	27.6±3.6	5.1±0.5	5.3±0.5	71.4±6.8
93	Pl	80.8±0.2	57.4±2.1	11.7±1.3	2.2±0.3	2.7±0.3	62.8±4.9
94	Sw	138.6±4.2	39.8±6.0	36.2±10.7	5.4±1.4	7.5±1.8	124.3±6.2
95	Sw	94.2±9.5	61.7±5.8	29.3±9.5	5.6±1.7	6.2±1.9	72.2±4.6
96	Pl	75.6±3.4	71.4±1.3	16.6±3.1	3.0±0.8	3.8±0.5	53.6±8.2
97	Pl	86.2±0.4	69.3±0.7	20.1±1.4	3.4±0.4	4.1±0.4	66.2±6.7

APPENDIX 6 cont.

Plot No.	Species[a]	Age	Site index at 70yr (ft)[b]	Total volume per tree (ft^3)[c]	PAI per tree (ft^3)	Maximum PAI per tree (ft^3)	Age of maximum PAI
98	Pl	80.4±0.7	60.7±1.1	15.0±0.9	2.9±0.2	3.3±0.2	62.4±5.0
99	Pl	82.5±0.5	67.4±5.7	23.9±13.4	4.2±1.6	5.2±2.6	67.5±14.5
	Sw	79.8±0.5	72.2±3.1	20.7±3.3	5.3±1.1	5.5±1.0	74.8±5.3
100	A	50.4±1.9	75.1±4.0	3.4±0.3	1.6±0.1	1.5±0.1	50.4±1.9
101	Sw	154.6±0.5	28.7±2.0	16.0±1.5	1.3±0.1	3.1±0.3	142.6±4.5
102	Pl	83.0±0.8	54.4±1.3	9.9±0.8	2.4±0.3	2.6±0.3	83.0±0.8
103	Pl	82.4±0.5	69.6±2.0	20.5±3.4	3.7±0.7	4.0±0.6	64.4±6.5
104	Sb	70.7±0.9	51.9±1.4	6.3±0.5	1.9±0.1	2.0±0.0	67.3±4.2
	Pl	75.3±0.9	59.1±3.7	12.1±2.9	1.7±0.5	3.0±0.8	45.3±0.9
105	Pl	83.2±0.7	66.4±2.3	19.3±2.8	3.3±0.6	3.7±0.6	63.2±5.1
106	A	58.8±0.2	77.4±3.1	15.2±4.5	4.5±1.2	4.5±1.1	56.3±3.3
107	Pl	85.0±0.5	66.5±1.1	16.7±1.6	3.4±0.3	3.7±0.3	83.0±2.1
108	Pl	79.2±1.2	67.0±1.6	15.6±1.4	2.6±0.3	3.6±0.4	57.2±3.3
109	Pl	97.2±1.0	56.5±1.3	12.3±1.0	1.8±0.2	2.2±0.2	83.8±6.6
110	Pl	79.4±1.7	56.8±0.6	11.9±0.8	2.0±0.2	2.5±0.1	59.4±7.0
111	Pl	97.6±0.7	56.3±0.5	11.6±1.1	1.4±0.2	2.1±0.2	67.6±7.4
	Sw	99.0±0.0	41.4±0.9	5.6±1.7	1.3±0.5	1.4±0.6	89.0±0.0
112	Pl	81.4±0.4	57.7±0.8	9.8±0.7	1.8±0.2	2.2±0.2	57.4±2.2

APPENDIX 6 cont.

Plot No.	Species[a]	Age	Site index at 70yr (ft)[b]	Total volume per tree (ft^3)[c]	PAI per tree (ft^3)	Maximum PAI per tree (ft^3)	Age of maximum PAI
113	Pl	76.6 ± 0.7	58.8 ± 1.8	12.0 ± 1.0	3.3 ± 0.4	3.4 ± 0.4	70.6 ± 5.9
114	Pl	87.3 ± 4.3	53.4 ± 1.1	15.9 ± 1.9	2.6 ± 0.7	3.8 ± 0.4	64.0 ± 8.0
	Sw	81.0 ± 1.0	55.1 ± 0.8	12.0 ± 0.1	3.1 ± 0.4	3.2 ± 0.3	76.0 ± 4.0
115	Pl	81.8 ± 0.2	56.5 ± 0.5	10.5 ± 1.2	1.9 ± 0.3	2.4 ± 0.1	63.8 ± 5.8
116	Pl	83.2 ± 0.4	53.5 ± 1.3	8.4 ± 0.7	2.0 ± 0.2	2.2 ± 0.2	77.0 ± 3.9
117	Sw	90.7 ± 0.3	63.6 ± 3.1	21.6 ± 4.8	4.3 ± 0.1	5.5 ± 1.3	74.0 ± 4.9
118	Sw	113.3 ± 0.7	54.3 ± 4.3	25.7 ± 2.5	3.8 ± 0.7	4.8 ± 0.6	98.3 ± 8.3
	Pl	112	70.5	29.7	1.8	4.9	62
119	Pl	80.0 ± 0.6	58.0 ± 1.6	12.5 ± 1.6	3.1 ± 0.6	3.2 ± 0.5	76.4 ± 4.6
120	Pl	79.0 ± 0.6	75.1 ± 1.1	24.0 ± 3.0	3.8 ± 0.8	4.8 ± 0.7	62.3 ± 8.5
	Sw	79.3 ± 0.3	65.3 ± 2.1	15.7 ± 4.1	4.5 ± 1.2	4.9 ± 1.1	76.0 ± 3.0
121	Sw	111.0 ± 2.2	48.0 ± 3.1	17.2 ± 4.1	2.5 ± 0.6	3.2 ± 0.8	89.2 ± 4.2
122	A	68.8 ± 0.9	61.4 ± 2.5	7.0 ± 1.0	2.0 ± 0.4	2.1 ± 0.4	64.8 ± 4.7
123	A	87.4 ± 0.9	80.3 ± 1.0	25.8 ± 1.8	4.1 ± 0.4	5.2 ± 0.3	69.4 ± 8.9
124	Sw	80.0 ± 1.3	61.6 ± 2.3	16.0 ± 3.2	4.1 ± 0.7	4.7 ± 1.1	68.0 ± 4.7
125	Sw	114.0 ± 0.6	46.8 ± 0.5	11.6 ± 1.8	1.3 ± 0.2	2.2 ± 0.6	114.0 ± 0.6
	Pl	109.0 ± 2.5	61.8 ± 2.4	19.9 ± 3.1	2.2 ± 0.6	2.8 ± 0.2	69.0 ± 11.7

APPENDIX 6 cont.

Plot no.	Species[a]	Age	Site index at 70yr (ft)[b]	Total volume per tree (ft^3)[c]	PAI per tree (ft^3)	Maximum PAI per tree (ft^3)	Age of maximum PAI
126	Sw	130.8 ± 2.1	40.1 ± 1.4	25.2 ± 4.4	3.8 ± 0.5	4.1 ± 0.5	120.8 ± 4.4
	Pl	102.0 ± 2.0	52.2 ± 3.5	12.0 ± 1.7	1.5 ± 0.4	2.4 ± 0.3	72.0 ± 2.0
127	Pl	110.3 ± 1.5	53.3 ± 1.3	16.5 ± 3.6	2.1 ± 0.4	2.3 ± 0.5	63.7 ± 7.0
	Sw	113.3 ± 0.3	39.9 ± 1.8	13.9 ± 2.2	1.9 ± 0.3	2.8 ± 0.5	98.3 ± 4.9
128	Sw	117.0 ± 0.7	41.5 ± 1.0	22.7 ± 3.3	3.7 ± 0.6	4.3 ± 0.7	89.5 ± 4.5
	Pl	117.0 ± 3.0	42.2 ± 1.7	12.7 ± 3.7	2.3 ± 0.6	2.4 ± 0.6	82.0 ± 2.0
129	Sw	115.8 ± 0.5	47.7 ± 3.4	14.7 ± 4.6	2.8 ± 0.9	3.0 ± 0.9	105.8 ± 4.3
	Pl	114.5 ± 0.5	58.2 ± 2.0	19.5 ± 1.8	2.5 ± 0.1	2.7 ± 0.2	89.5 ± 5.5
130	Pl	82.3 ± 9.7	54.2 ± 1.1	11.2 ± 2.4	1.5 ± 0.3	2.5 ± 0.4	52.3 ± 6.2
	Sw	89.0 ± 4.2	53.9 ± 4.2	13.5 ± 4.3	3.1 ± 1.1	3.6 ± 1.2	69.0 ± 4.2
131	Pl	122.4 ± 2.6	54.9 ± 1.1	19.1 ± 2.2	2.1 ± 0.2	2.3 ± 0.2	90.4 ± 7.8
132	Pl	76.4 ± 1.2	54.0 ± 2.2	10.2 ± 0.8	1.8 ± 0.2	2.4 ± 0.2	56.4 ± 1.2
133	Sw	76.7 ± 3.2	62.9 ± 2.5	12.7 ± 3.1	4.0 ± 1.0	3.4 ± 1.0	73.3 ± 1.9
	Pl	73.8 ± 0.3	68.8 ± 1.7	19.4 ± 2.8	2.7 ± 0.4	4.6 ± 0.8	54.8 ± 4.4
134	Pl	79.2 ± 1.8	47.2 ± 0.7	6.3 ± 0.5	0.9 ± 0.1	1.5 ± 0.1	53.2 ± 3.6
135	Sb	115 ± 5.0	29.7 ± 1.2	5.8 ± 0.3	1.0 ± 0.1	1.1 ± 0.1	105 ± 5.0
	Sw	105.3 ± 2.8	31.1 ± 2.4	9.3 ± 1.0	2.4 ± 0.1	2.4 ± 0.2	100.3 ± 3.0

APPENDIX 6 cont.

Plot No.	Species[a]	Age	Site index at 70yr (ft)[b]	Total volume per tree (ft^3)[c]	PAI per tree (ft^3)	Maximum PAI per tree (ft^3)	Age of maximum PAI
136	Sw	177.8 ± 5.4	25.9 ± 1.1	13.4 ± 3.1	0.8 ± 0.2	2.1 ± 0.6	170.3 ± 6.7
	Sb	191.0 ± 3.0	23.6 ± 4.5	5.3 ± 0.3	0.4 ± 0.0	0.5 ± 0.0	171.0 ± 7.0
137	Pl	73.6 ± 2.0	58.4 ± 1.4	8.0 ± 0.3	1.7 ± 0.2	1.9 ± 0.1	51.6 ± 5.6

Footnotes

a Tree species abbreviations

- Pl - lodgepole pine
- Sw - white spruce
- Sb - black spruce
- Se - Engelmann spruce
- Fa - subalpine fir
- A - aspen
- Pb - balsam poplar
- B - white birch
- L - tamarack

b Volume in $m^3 = ft^3 \times 0.028$

c $m^3 ha^{-1} = ft^3 ac^{-1} yr^{-1} \times 0.070$

d mean ± standard error of mean

APPENDIX 7 Vascular plants identified in forested plots within the Wapiti map area, arranged by family.

POLYPODIACEAE

Dryopteris spinulosa (Muell.) Watt 7/T,28/T,33/T,34/T,41/T,62/T,63/T,83/T, 92/T,93/T,98/T,105/T,108/T,120/T[1]

Gymnocarpium dryopteris (L.) Newm.

EQUISETACEAE

Equisetum arvense L.

Equisetum scirpoides Michx.

Equisetum sylvaticum L.

Equisetum variegatum Schleich. 7/T,10/T,88/T

LYCOPODIACEAE

Lycopodium annotinum L.

Lycopodium clavatum L. 83/1, 92/1, 102/T, 114/T

Lycopodium complanatum L.

PINACEAE

Abies lasiocarpa (Hook.) Nutt.[2]

Larix laricina (DuRoi) K. Koch

Picea engelmannii Parry

Picea glauca (Moench) Voss

Picea mariana (Mill.) BSP.

Pinus contorta Dougl. var. *latifolia* Engelm.

GRAMINEAE

Agropyron repens (L.) Beauv. 18/T, 26/T

Calamagrostis canadensis (Michx.) Beauv.

Elymus innovatus Beal

Oryzopsis asperifolia Michx. 46/T, 90/1, 118/T

CYPERACEAE

Carex aenea Fern.

APPENDIX 7 cont.

Carex capillaris L.

Eriophorum vaginatum L. ssp. *spissum* (Fern.) Hulten 14/T

LILIACEAE

Disporum trachycarpum (S. Wats.) B+H. 94/1

Maianthemum canadense Desf. var. *interius* Fern.

Smilacina racemosa (L.) Desf. var. *amplexicaulis* (Nutt.) S. Wats. 25/T,27/T, 45/T,91/T,94/T,95/T,101/T,119/T,123/T,127/T

Streptopus amplexifolius (L.) DC.

Veratrum escholtzii A. Gray 33/T,36/T,40/1,41/5,42/T,43/3

ORCHIDACEAE

Calypso bulbosa (L.) Oakes 47/T,49/T,52/T,68/T,84/T,86/T,88/T,92/T,96/T, 97/T,98/T,106/T

Habenaria hyperborea (L.) R. Br.

Habenaria obtusata (Pursh) Torr. 44/T,59/T,61/T,67/T,78/T,85/T,97/T,98/T, 102/T,107/T,117/T,121/T

Listera cordata (L.) R. Br. 1/T,9/T,17/T,33/T,64/T,65/T,74/T,79/T,82/T, 125/T,128/T,130/T

SALICACEAE

Populus balsamifera L.

Populus tremuloides Michx.

Salix bebbiana Sarg.

Salix spp.

Salix scouleriana Barratt

BETULACEAE

Alnus crispa (Ait.) Pursh

Betula papyrifera Marsh

Betula pumila L. var. *glandulifera* Regel 1/T,15/T,29/T,31/T,35/T,37/T, 80/T,111/T

Corylus cornuta Marsh 45/T

APPENDIX 7 cont.

SANTALACEAE

Geocaulon lividum (Richards.) Fern. 28/T,29/T,45/T,60/1, 70/1,88/T,89/T, 91/T,96/T,104/T,114/T,121/T

RANUNCULACEAE

Actaea rubra (Ait.) Willd.

Anemone parviflora Michx. 2/T

Clematis verticellaris DC. var. *columbiana* (Nutt.) A. Gray 94/T

Delphinium glaucum S. Wats. 1/T, 5/T, 15/1, 18/T,31/T,50/T,55/T,61/T,118/T,135/T

Thalictrum venulosum Trel. 18/2, 19/T,46/T,123/T

SAXIFRAGACEAE

Mitella nuda L.

Ribes glandulosum Grauer 69/T

Ribes lacustre (Pers) Poir.

Tiarella trifoliata L. 34/T, 36/T, 41/1, 43/T, 93/10, 106/T

ROSACEAE

Amelanchier alnifolia Nutt.

Fragaria virginiana Duchesne var. *glauca* S. Wats.

Geum rivale L. 15/2,49/2,63/T,65/T,121/1

Prunus pensylvanica L.f. 79/T

Prunus virginiana L. 46/T

Rosa acicularis Lindl.

Rubus acaulis Michx. 1/1,15/1,78/T,84/T,130/T,135/T

Rubus chamaemorus L. 14/27,29/3,31/1,67/4,135/T

Rubus parviflorus Nutt. 25/1,34/1,68/T,92/1,103/1,105/T,107/1,123/1

Rubus pedatus J.E. Smith

Rubus pubescens Raf.

Rubus strigosus Michx.

Sorbus scopulina Greene

Spiraea lucida Dougl.

APPENDIX 7 cont.

LEGUMINOSAE

Lathyrus ochroleucus Hook.

Vicia americana Muhl. 10/1,12/T,18/1,19/1,85/T,87/T,90/T,96/T,100/T,106/T, 107/T,122/1,126/T,127/T

EMPETRACEAE

Empetrum nigrum L.

VIOLACEAE

Viola adunca J.E. Smith 91/T,117/T,122/T

Viola renifolia A. Gray

ELAEAGNACEAE

Shepherdia canadensis (L.) Nutt.

ONAGRACEAE

Epilobium angustifolium L.

ARALIACEAE

Aralia nudicaulis L.

Opplopanax horridum (Sm.) Miq. 24/T,59/T,71/1,93/T

UMBELLIFERAE

Heracleum lanatum Michx. 1/T,5/T,41/1,61/T,78/T,126/T,127/T,130/T

Osmorhiza depauperata Philippi

CORNACEAE

Cornus canadensis L.

Cornus stolonifera Michx.

PYROLACEAE

Moneses uniflora (L.) A. Gray 2/T,4/T,6/T,17/T,22/T,59/T,61/T,81/T,99/T,114/T, 124T,130/T

Pyrola asarifolia Michx.

Pyrola secunda L.

Pyrola virens Schweigg. 13/T,112/T,124/T,127/T,132/T,133/T

APPENDIX 7 cont.

ERICACEAE

Arctostaphylos rubra (Rehder and Wills.) Fern. 135/T

Arctostaphylos uva-ursi (L.) Spreng. 10/T,16/T,19/T,23/T,30/T,44/T,87/T, 89/T,133/T

Gaultheria hispidula (L.) Bigel.

Ledum groenlandicum Oeder

Menziesia glabella A. Gray

Oxycoccus microcarpus Turcz. 14/2,29/1,31/T,67/T

Phyllodoce empetriformis (Smith) D. Don 2/T,11/T

Rhododendron albiflorum Hook

Vaccinium caespitosum Michx.

Vaccinium membranaceum Dougl.

Vaccinium myrtilloides Michx.

Vaccinium vitis-idaea L. var. *minus* Lodd.

BORAGINACEAE

Mertensia paniculata (Ait.) S. Don

SCROPHULARIACEAE

Castilleja miniata Dougl. 19/T,83/T,85/T,87/T,100/T,106/3,122/1

Pedicularis bracteosa Benth. 2/T,6/T,9/T,15/T,16/T,127/T,130/T,[illegible]T

RUBIACEAE

Galium boreale L.

Galium triflorum Michx.

CAPRIFOLIACEAE

Linnaea borealis L. var. *americana* (Forbes) Rehd.

Lonicera dioica L. var. *glaucescens* (Rydb.) Butters 45/T,47/T,84/T,85/T, 90/T,91/T,95/T,~~121/T~~

Lonicera involucrata (Richards.) Banks

Symphoricarpos albus (L.) Blake 25/T,26/T,44/T,45/T,101/T,118/T,121/1

Viburnum edule (Michx.) Raf.

APPENDIX 7 cont.

COMPOSITAE

Achillea millefolium L.

Antennaria neglecta Greene 9/T

Arnica cordifolia Hook.

Arnica latifolia Bong. 3/T,80/1,81/4,125/T

Aster ciliolatus Lindl.

Aster conspicuus Lindl.

Petasites palmatus (Art.) A. Gray

Petasites sagittatus (Pursh) A. Gray 18/T

Solidago decumbens Greene 26/1,86/T

1 Plot number/percent cover follows species with > 20% plot presence not shown in table 1. T = less than 0.5% cover

2 Plot occurrence of tree species obtainable from Appendix 5.

APPENDIX 8 Non-vascular plants indentified in forested plots within the Wapiti map area, arranged by family.

AULACOMNIACEAE

Aulacomnium palustre (Hedw.) Schwaegr. 31/T*

BRACHYTHECIACEAE

Tomenthypnum nitens (Hedw.) Loeske 15/15

DICRANACEAE

Dicranum spp. includes predominantly *D. polysetum* Sw. and *D. undulatum* Brid.

DITRICHACEAE

Ceratodon purpureus (Hedw.) Brid. 15/16,86/T

ENTODONTACEAE

Pleurozium schreberi (Brid) Mitt.

HYLOCOMIACEAE

Hylocomium splendens (Hedw.) B.S.G.

HYPNACEAE

Ptilium crista-castrensis (Hedw.) DeNot.

MNIACEAE

Mnium spp. includes predominantly *M. cuspidatum* Hedw. and *M. spinulosum* B.S.G.

POLYTRICHACEAE

Polytrichum commune Hedw.

SPHAGNACEAE

Sphagnum spp. includes predominantly *S. fuscum* (Schimp.) Klinggr. and *S. warnstorffii* Russ

MARCHANTIACEAE

Marchantia polymorpha L. (liverwort) 4/2,105/2

LICHENS

PELTIGERACEAE

Peltigera spp. includes predominantly P. *aphthosa* (L.) Willd. with lesser amounts of *P. canina* (L.) Willd.

APPENDIX 8 cont.

"Other lichen" includes predominantly species of the *Cladoniaceae*, especially *Cladina mitis* (Sandst.) Hale and W. Culb., *C. rangiferina* (L.) Wigg., plus other *Cladonia* species. *Stereocaulon tomentosum* Fr. also often contributes significantly to the generally very small "other lichen" cover category in Table 1.

* Plot number/percent cover follows species with < 20% plot presence not shown in table 1. T = less than 0.5% cover.

APPENDIX 9 Canada Land Inventory Mean Annual Total Volume Increment Classes

CLI Class	MAI (ft^3 $acre^{-1}$ yr^{-1})	MAI (m^3 ha^{-1} yr^{-1})
1	greater than 111	greater than 7.8
2	91 - 110	6.4 - 7.8
3	71 - 90	5.0 - 6.3
4	51 - 70	3.6 - 4.9
5	31 - 50	2.2 - 3.5
6	11 - 30	0.8 - 2.1
7	less than 10	less than 0.8