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NAME OF AUTHOR/*NOM DE L'AUTEUR* GLENN BROWN

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DATED/*DATÉ* March 10, 1977 SIGNED/*SIGNÉ* Glenn Brown

PERMANENT ADDRESS/*RÉSIDENCE FIXE* 550 SANFORD AVE
ST. LAMBERT
QUEBEC

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THE UNIVERSITY OF ALBERTA

# VEGETATION - LANDFORM RELATIONSHIPS IN THE LOWER ROCK CREEK VALLEY, WEST CENTRAL ALBERTA

BY

© GLENN BROWN

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

DEPARTMENT OF GEOGRAPHY

EDMONTON, ALBERTA

FALL, 1976

THE UNIVERSITY OF ALBERTA

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 VEGETATION - LANDFORM RELATIONSHIPS IN THE LOWER ROCK CREEK VALLEY, WEST CENTRAL ALBERTA, submitted by GLENN BROWN in partial fulfillment of the requirements for the degree of Master of Science.

Supervisor

Date August 5 1976

## ABSTRACT

The vegetation patterns in the lower Rock Creek Valley in west central Alberta were described and the ecological bases of their apparent correlation with alluvial landforms there were investigated. High water levels are maintained on the nearly level valley floor by normal basin drainage and by local and regional groundwater input from numerous springs. The seasonal high level of standing water closely matches the line of division between the valley's two very different basic vegetation types. Better drainage provided by the more elevated landforms permits a *Picea* and *Salix* dominated species-rich vegetation type to develop upon them. A depauperate flora of mostly *Carex* and low *Salix* species is maintained in the often flooded interchannel basins.

Both basic vegetation types were divided into two subtypes. Of the two more complex higher ground types, one is of somewhat richer flora and taller growth form than the other. The former vegetation type occupies the higher creekbanks, the latter appears in lower positions on the levee backslopes, or on creekbanks with lower relief or consistently higher water levels for at least part of the year.

The two vegetation types in the lower, wetter areas differ mostly in the presence or absence of several *Salix* species, whose downslope distribution may be limited by increasingly long periods of standing water and diminishment of their competitive ability.

Vegetational degeneration along an abandoned channel seems likely to represent levee subsidence. A groundwater-fed stream, possessing no levees, is bordered by more complex vegetation in upstream areas where it has incised itself to about 1 m below the land surface, providing a local depression of the groundwater table. Downstream the creek approaches a local base level, the water surface is closer to the ground surface, and wet site vegetation consequently grows beside it.

The presence of several types of permafrost does not appear to control landscape vegetation patterns. Available soil nutrients do not seem to control plant distributions in the valley.

## ACKNOWLEDGMENTS

The completion of this project would have been impossible without the cooperation of a number of people and institutions, whose help I am pleased to acknowledge. To the friends who assisted me in the field - Lorna Allen and Bill Reynolds in the rainy summer of 1975, and Dave Bernard and Linda Hannah in the equally hectic summer of 1976 - I owe heartfelt thanks for their understanding, encouragement and long hours of work. Without their help the job could not have been done. Clifford and Rose Henson and John and Winnie Elaniak, Alberta Forestry Service personnell at the Rock Lake Ranger Station in 1975 and 1976, respectively, provided many kindnesses (including many a warm meal) and were our connection with the "outside world." Their good will made rough conditions more bearable.

The analysis of soil samples was done by the Alberta Department of Agriculture Soil and Feed Testing Laboratory. The Alberta Research Council and the University of Alberta Zoology Department provided several hydrochemical analyses of spring water. The use of the soil laboratory facilities of the University of Alberta Botany Department and the Alberta Soil Survey was appreciated, as was the advice and help in the field of A.S.S. staff member Tom Peters. Essential field equipment was borrowed from Dr. Don

Gill of the University of Alberta Geography Department, the Geography Department, the Botany Department and Dr. Michael Hickman thereof, and the Zoology Department Water Laboratory run by Gertie Hutchinson. Much help with the identification of plant specimens and the determination of range extensions was provided by Madeline Dumais of the Botany Department Herbarium. Richard Barnes of the Alberta Research Council was helpful in providing information about groundwater movement. I appreciated the comments and criticisms of Drs. Don Gill and George La Roi of my supervisory committee. Technical assistance was provided by Jack Chesterman, Gail Glende, and Linda Hannah. Lorrie Jamieson and Joyce Hipskind graciously typed successive drafts of the thesis on short notice. Help with administrative details was provided by the staff of the Boreal Institute for Northern Studies. Financial support was provided by two grants-in-aid of research from the Boreal Institute, by my father, Jim Brown, by an intersessional bursary from the Geography Department in 1975, and from Dr. Gill's 1976 National Research Council Grant No. A8700.

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# CHAPTER 1: INTRODUCTION

## 1. INTRODUCTION

An inspection of the environment in the lower Rock Creek Valley (Plates 1-7) reveals two things: the striking spatial patterns of the vegetation and their apparent correlation with the alluvial landforms of the valley bottom. This study represents an attempt to describe the vegetation patterns present there and to discover the extent of, and the ecological bases for, the observed correlations between landforms and plant distributions.

Vegetational patternings much like those in the study area have been observed on similar landforms in many other locations, such as Sweden (Dahlskog 1966), Saskatchewan (Dirschl and Coupland 1972), Canada's Northwest Territories (Gill 1971), Mexico (Thom 1967), and Venezuela (Vann 1959). Although many common features were observed, the important controlling ecological factors were variously claimed to be sedimentation and annual flooding patterns (Dahlskog 1966, Gill 1971); gradients of moisture, nutrients and pH (Dirschl and Coupland 1972); salinity of water, tide level, drainage and soil texture (Vann 1959); landform changes due to sedimentation and subsidence, and the influence of salt water (Thom 1967). That there are some differences in these reports reflects different geomorphic environments more than conflicts in data interpretation. Similarly, in the case of the Rock Creek Valley

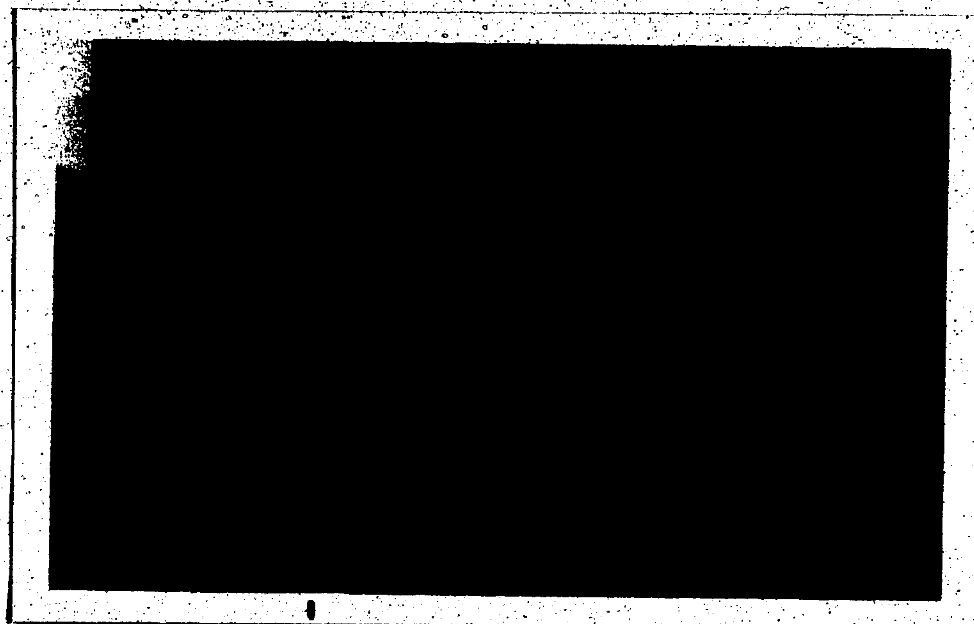


Plate 1: Eastern quarter of study area and Rock Lake as seen from northeast hillside. 5 July 1975.

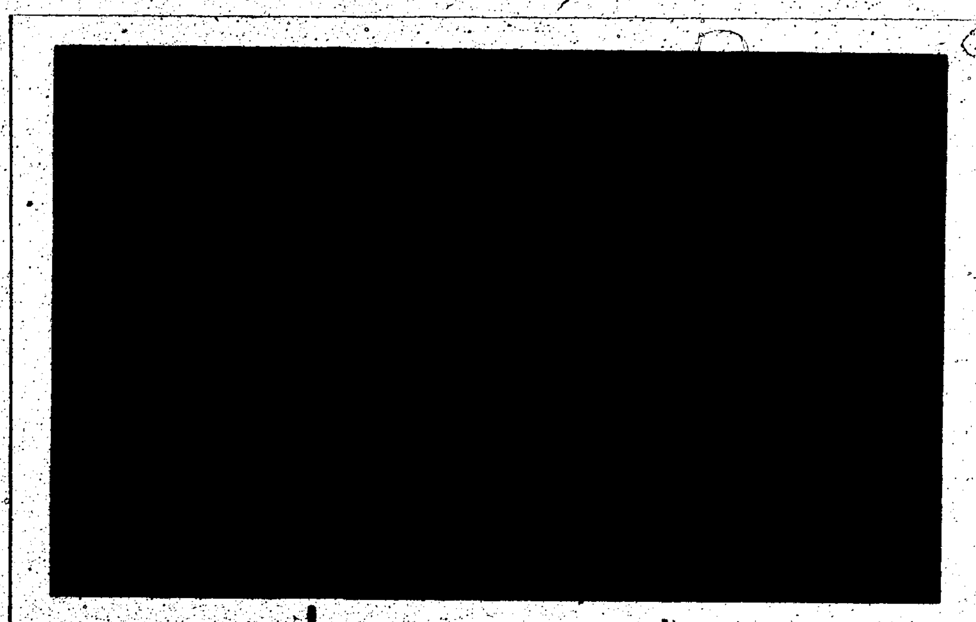


Plate 2: Portion of eastern end of study area as seen from northeast hillside. 5 July 1975.

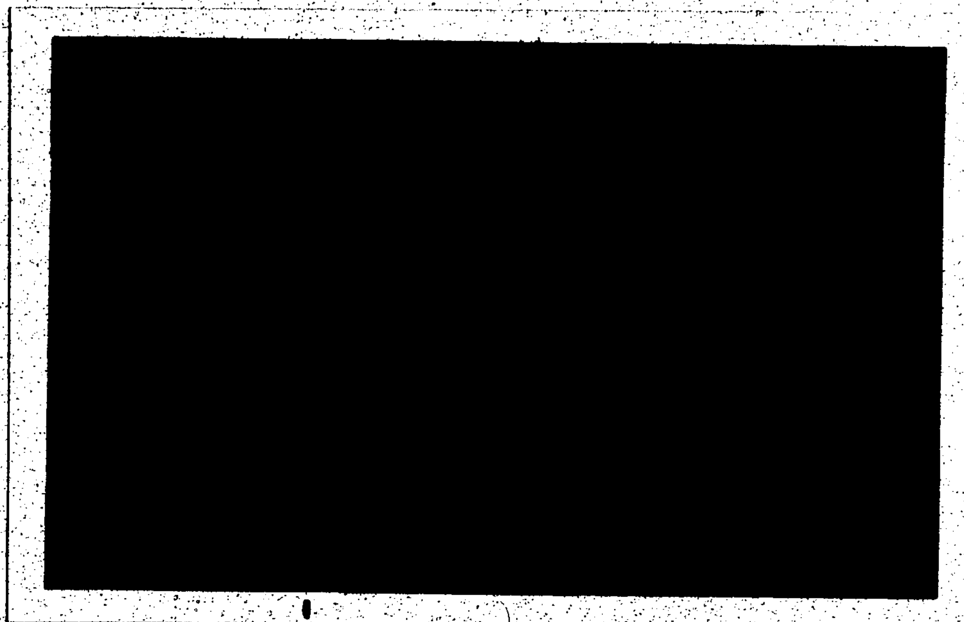


Plate 3: Portion of eastern end of study area as seen from northeast hillside. 5 July 1975.

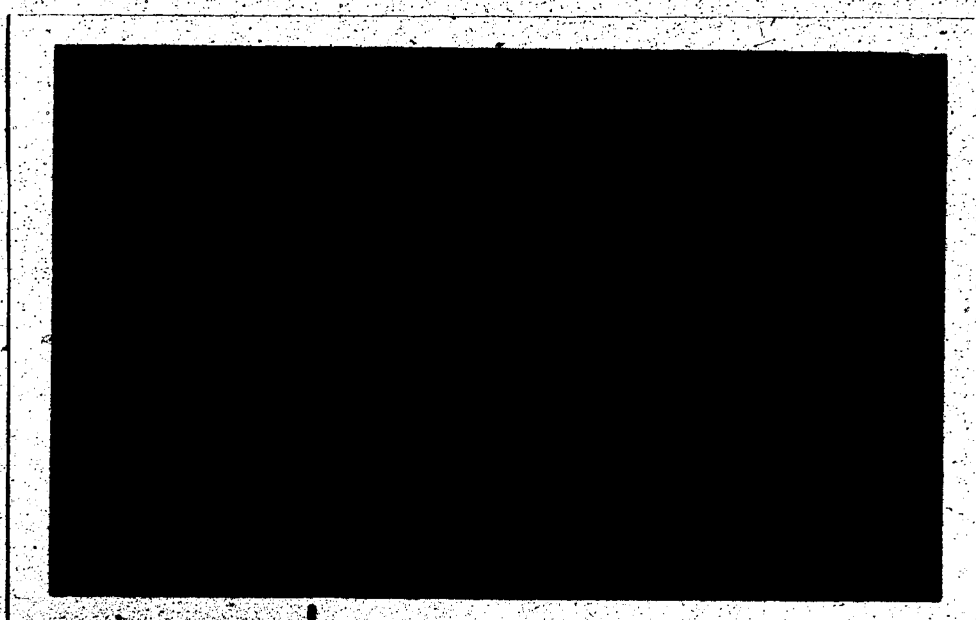


Plate 4: Portion of central part of study area as seen from northeast hillside. 5 July 1975.

the factors of the "directly acting" or "effective" environment (<u>sensu</u> Walter 1960, quoted in Waring and Major 1964) that seemed likely to vary significantly at the landform scale in question were soil moisture and soil nutrients. These were examined directly. Also studied were those features of the local environment that may influence those factors indirectly: local topography; soil texture, organic matter content and pH; ground water table levels; and soil frost patterns.

Many authors (e.g. Drury 1956, Hack and Goodlett 1960, Heinselman 1970) have emphasized the importance of active geomorphic processes in influencing vegetation patterns. While ongoing or irregularly occurring events may bear an important role in determining the distribution patterns of plant species in the study area, the main thrust of the present investigation was to obtain information relating to the current or static relationships between plants and landforms. This provides the necessary first step toward an understanding of the dynamic ecosystem of the valley.

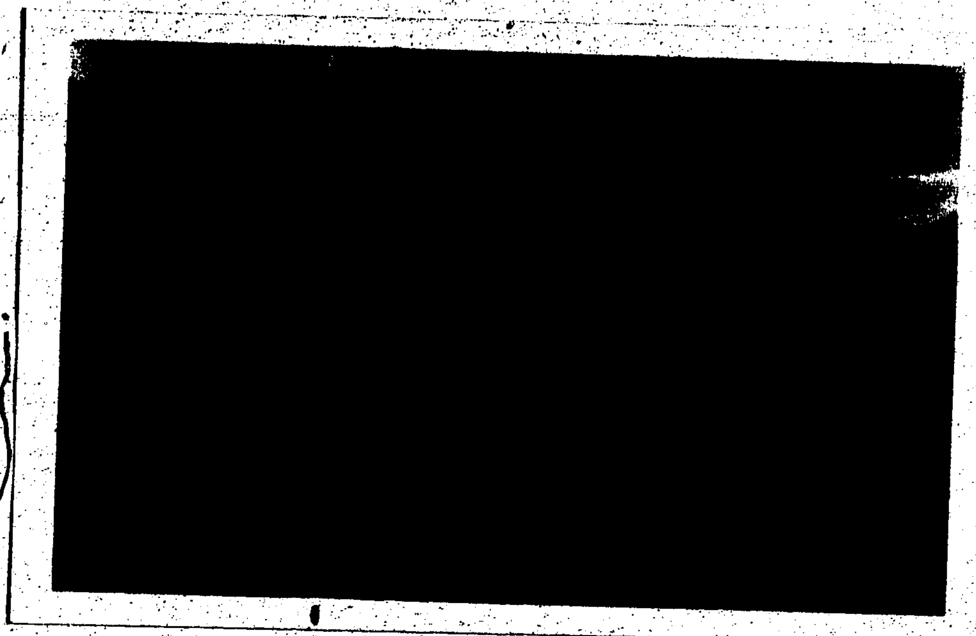


Plate 5: Western half of study area, Rocky Mountains and Snake Indian Valley as seen from northeast hill-side. 5 July 1975.

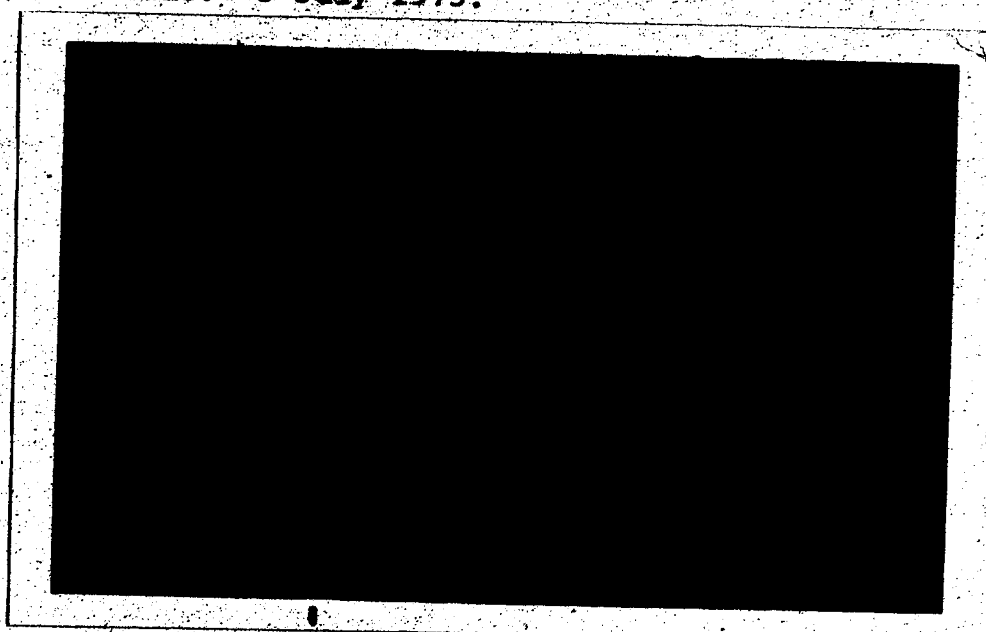


Plate 6: Eastern three-quarters of study area as seen from west. 21 July 1975.

Plate 7: Aerial photograph of lower Rock Creek Valley. 15 August 1974. Approx. 1:21, 100 (AS 1343 No. 226)

# CHAPTER 2 : THE NATURAL ENVIRONMENT OF THE STUDY AREA

# 2. THE NATURAL ENVIRONMENT OF THE STUDY AREA

## 2.1 Location and Size

The area of study is the alluvial valley of the lowest section of the Rock Creek Valley in the Western Foothills of west central Alberta. It is just east of the northeastern boundary of Jasper National Park at an elevation of about 1400 m (Figure 1). The site is about 4 km long and 0.9 km wide at its widest point, an area of approximately 3.3 $km^2$. It is bounded on the northwest and southeast by mountainsides and several small alluvial fans, and to the east by Rock Lake. The western boundary is arbitrarily delimited as indicated in Figure 2, based upon the presence of fluvio-glacial deposits at or near (within 2 m) the ground surface. The exact pattern of the outwash deposits was not determined but the study area included areas of finer alluvial deposits and excluded areas of known outwash.

## 2.2 Climate

The lower Rock Creek Valley experiences a generally cold continental climate with long, cold winters and short cool summers. While weather and climate can vary considerably in a mountain region, data from the year-round weather station at Grande Cache (at an elevation

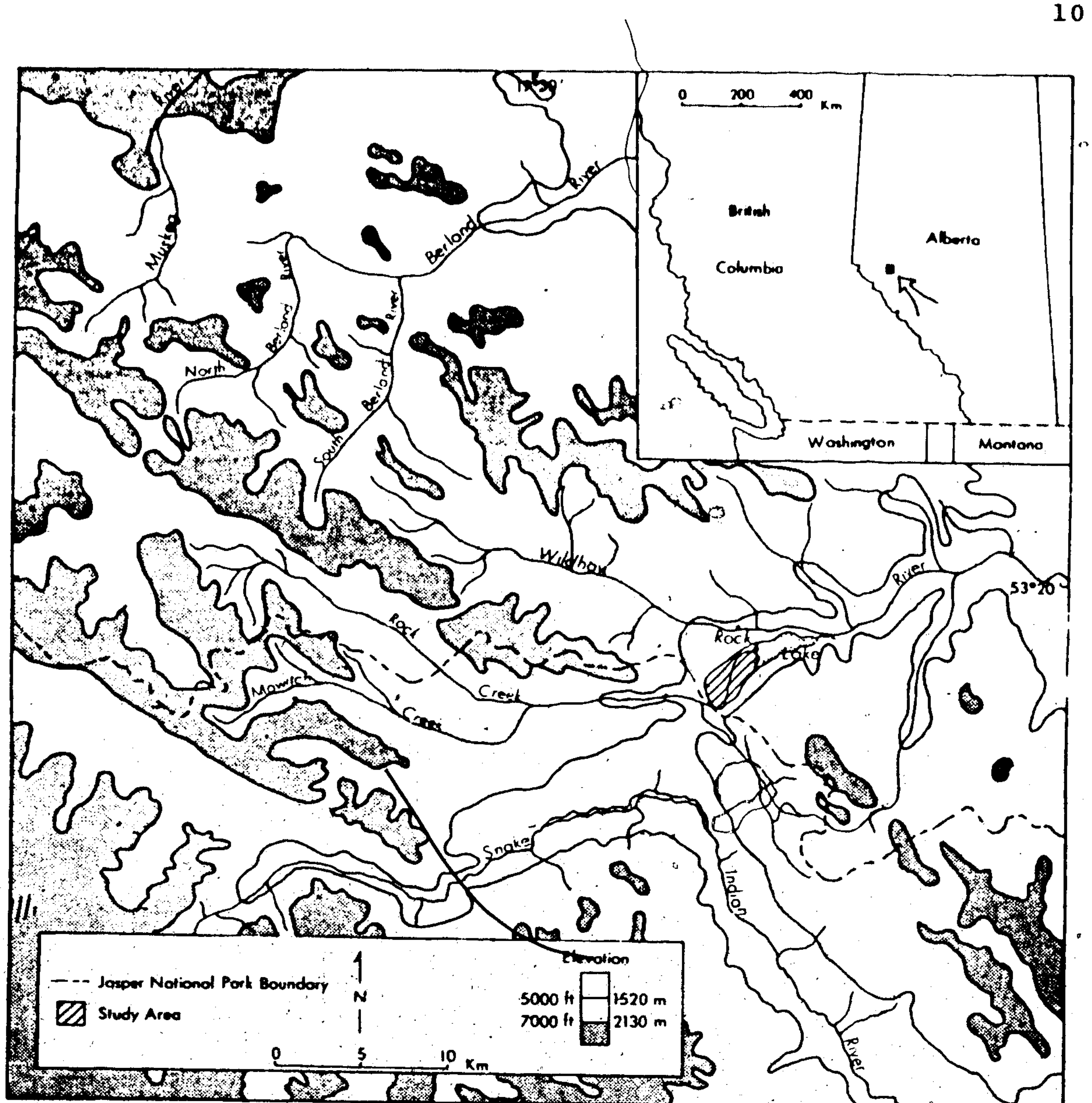
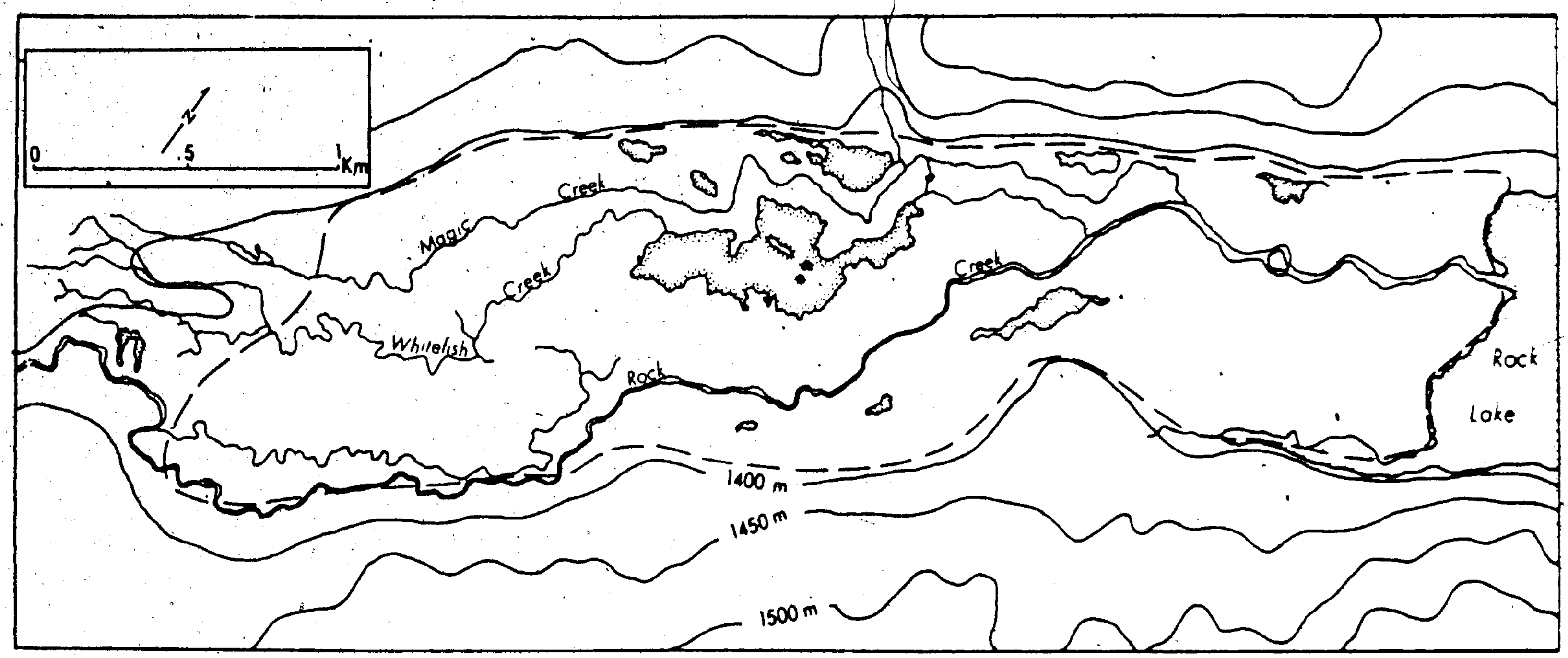



Figure 1: Location of Study Area




— — Approximate Boundary of Study Area

Figure 2. Study Area

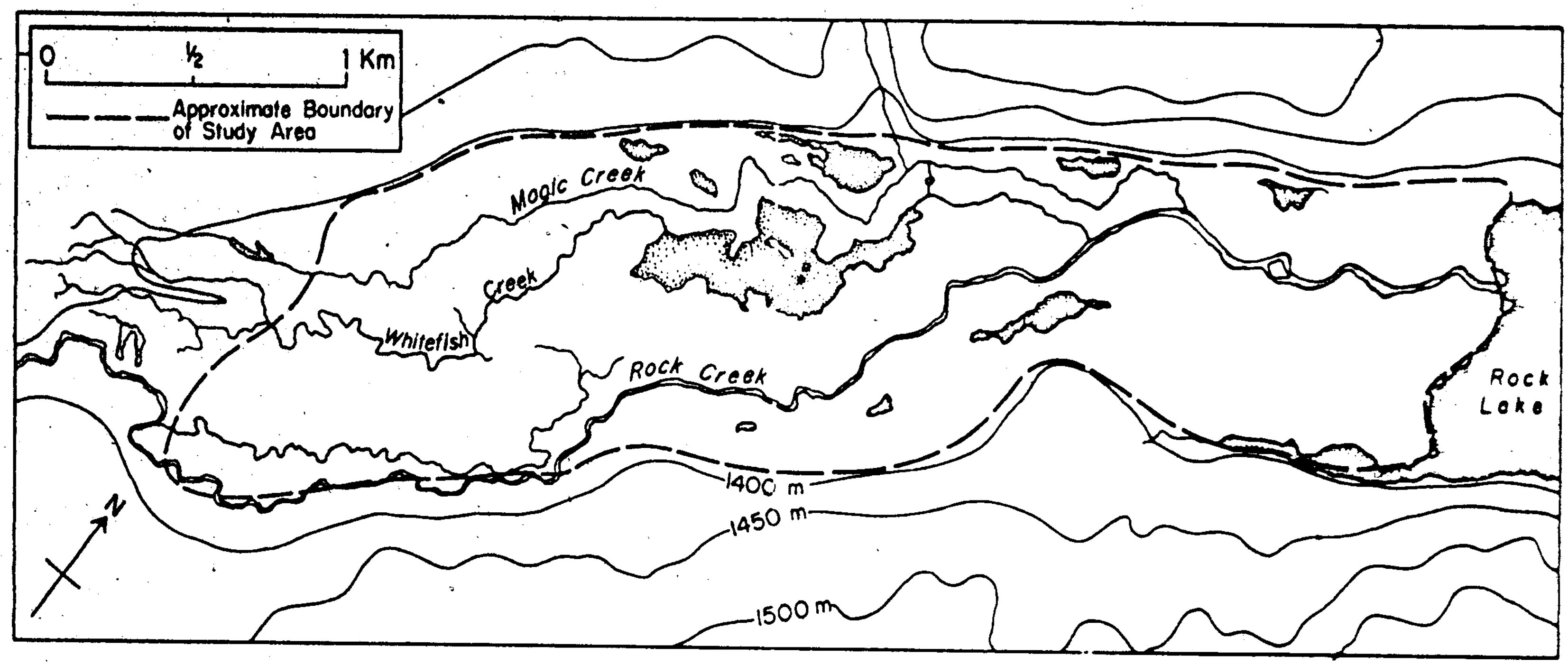



Figure 2. Study Area.

of 1200 m, 70 km to the northwest) and summer records from hilltop forestry lookout towers at Adams Creek (2200 m, 35 km NNW) and Moberly (1650 m, 20 km ENE) give an indication of the regional climate (Figures 3-5). Within the study area, daily temperature maxima and minima were recorded (1.5 m from the ground at a shaded site) for the duration of the field season, in the summer of 1975 (Figure 6). Precipitation in the valley is probably similar to that recorded at the weather stations but the often strong west winds during winter undoubtedly blow away or sublimate much of the snowfall.

## 2.3 Bedrock Geology

The study area is located within the Western Foothills about 1.5 km east of the Rocky Pass thrust fault which defines the eastern edge of the Rocky Mountains in this area (Mountjoy 1962). The site is underlain by mixed mudstones, siltstones and sandstones of the same Mezozoic formations as make up the foothills to the northwest and southeast (Mountjoy 1962). Two or three faults associated with the Miette thrust fault pass directly beneath the study area (Mountjoy 1962). Upstream, in the Eastern Ranges of the Rockies, Rock Creek and its tributaries drain areas composed mostly of Triassic siltstones, sandstones, limestones, mudstones and shales, with limited exposures

# CLIMATIC DATA

## Monthly Precipitation Totals (mm) and Mean Temperature (°C)

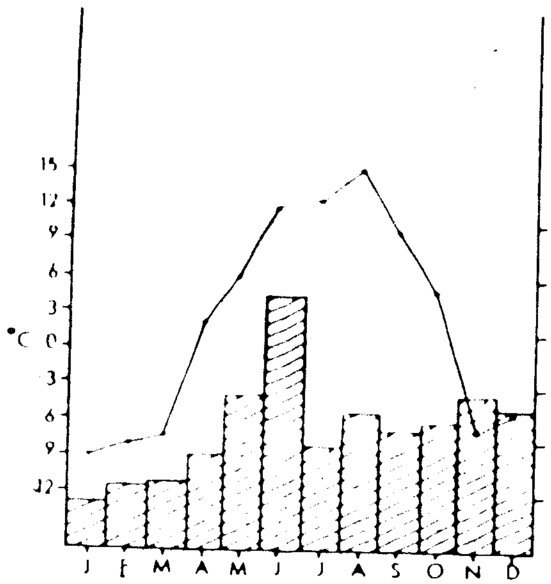



Figure 3: Grande Cache

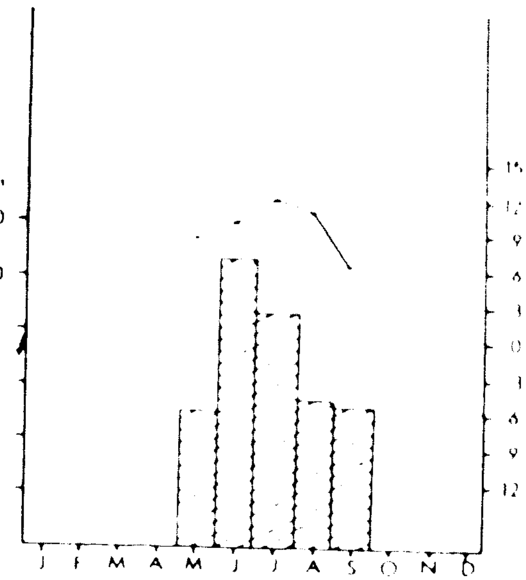



Figure 4: Moberly

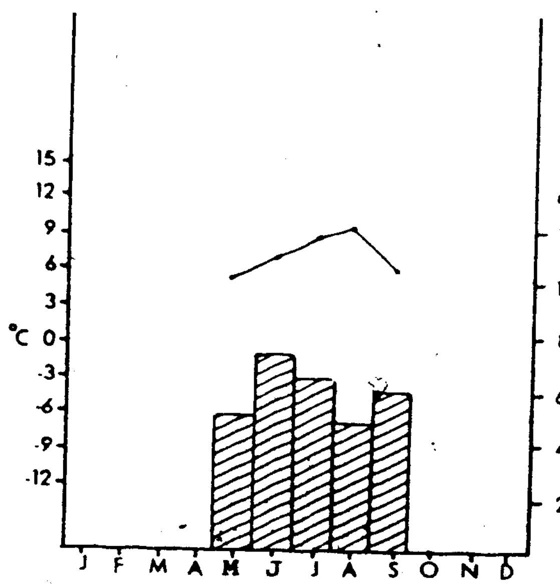



Figure 5: Adams Creek

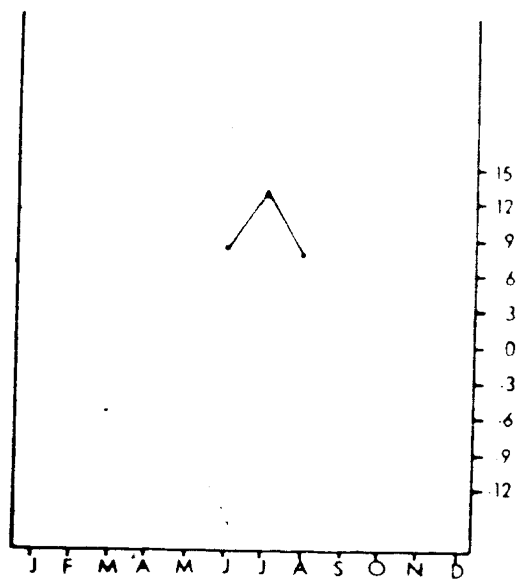



Figure 6: Rock Creek

Sources: Alberta Environment 1972 1973
Canada Department of Transport 1965
Environment Canada 1971 1975
Powell, J and D.C. MacIver 1976
Stashko, E 1971

of Paleozoic shales, limestones and dolomites (Mountjoy 1962, Irish 1965). The regional geology is further discussed by Irish (1968) and Edmonton Geological Society (1960).

## 2.4 Local Topography

The valley floor study area is broad and nearly flat, sloping gently downstream at an average of about 0.6 m/km. The most abrupt changes in local relief are provided by the levees of present and former stream channels. These asymmetric features rise steeply from beside the stream channel and slope gently in the direction away from the water course. The maximum relief from stream to levee crest is over 2 m in the upstream areas of Rock Creek. This diminishes to about 0.5 m near the river's mouth. The main stream does not at present divide until it enters Rock Lake, but the two small tributary streams which pass across the valley floor (Figure 2) contribute to a somewhat "deltaic" surface environment of water courses and "backswamps." The relief of their banks is much less than that of the Rock Creek levees presumably since they are groundwater fed (section 2.6.3) and carry very small sediment loads. There are thirteen small lakes in interchannel basins or between streams and the hillsides. Past shifting of stream channels and distributaries of Rock Creek have left abandoned channels in several locations in the valley, adding variation to the local relief.

## 2.5 Surficial Deposits and Soils

### 2.5.1 Geomorphological History

The valley containing the lower Rock Creek, Rock Lake, and the nearby section of the Wildhay River shows the U-shape (Plate 6) derived from its occupation by valley glaciers during the Pleistocene (Irish 1965). Direct glacial deposits, water laid sediments from melting glaciers, and more recent alluvial deposits have filled the Snake Indian River Valley and the lower Rock Creek Valley above Rock Lake (Mountjoy 1962). In those areas, such deposits roughly correspond to and are therefore indicated by the 1520 m contour of Figure 1. Field observations of surficial materials and creekbed deposits corroborate Bayrock and Reimchen's (1975) interpretation that valley train materials occupy the lower Rock Creek Valley just east of the Jasper National Park border. These have been overlain, since deglaciation, by finer alluvial deposits which make up the topmost surficial material extending from near the Park border to Rock Lake.

### 2.5.2 Deltaic Deposits

It is obvious that deltaic deposition is currently underway at the mouth of the present-day Rock Creek (Plate 7), albeit slowly. (Aerial photos show that the levees are only about 10 m longer in 1974 than in 1952, and the channel mouth bar is only of about 1/3 (10 m) greater length.) Without numerous deep core samples, a project beyond the scope of this study, the exact nature of the valley fill of the study area cannot be determined. It is reasonable to assume, however, that Rock Creek has deposited materials, first on top of a downstream-sloping surface of outwash materials, and then progressively filling in the Rock Lake basin up to its present delta front. The study site is probably underlain by at least 30 m of sediments, since this is the maximum depth of the symmetrical basin of the present Rock Lake (Government of Alberta 1969, Lane 1969). The surface environment of distributary channels and lakes (especially of the lower third of the study area) is strongly similar to that of those mountain deltas described by Dahlskog (1966) and Axelsson (1967). These factors suggest that much of the valley fill is of deltaic origin.

### 2.5.3 Alluvial Deposits

Within an active delta, or on the floodplain surface of a deltaically-filled valley, the parent stream continues to flow and to perform its geomorphic work of erosion, transportation and deposition. Thus the surfical alluvium of the Rock Creek delta/floodplain is, as in any floodplain, a complex mixture of lateral and vertical accretionary deposits (Allen 1965). The study site demonstrates most of the normally characteristic alluvial landforms described, for example, by Leopold, Wolman, and Miller (1964), and Axelsson (1967). Many of them are visible in Plates 1-7.

In the study area, there are three active stream channels, Rock Creek, Whitefish Creek, and Magic Creek, and numerous abandoned channel reaches. Many of the abandoned channels are in the lower portion of the valley, but a large one is conspicuous in the southwest sector of the study site (Plate 7). A channel in the northwest corner of the study site has been abandoned by its formative stream, but is now occupied for most of its length by Magic Creek, an underfit stream of spring origin (6.3.2) (cf. Plate 6). Comparison of 1952 and 1974 aerial photography shows that the active channels have been very stable over that time period, with only a few changes of no more than 2 m having occurred near some meanders of Rock Creek. The lakes also show little change in configuration over twenty-four years.

Soil pits and bank exposures showed the stratified sediment pattern that Leopold, Wolman, and Miller (1964) claim as being a common feature of laterally accreting floodplains. Soil samples from lake bottoms also showed the silt loam texture found in many of the streamside strata examined. The nature of the overall balance between lateral and vertical accretionary forces in the valley is not known.

### 2.5.4 Soils

All of the soils observed within the study area were immature and showed the mottling effects of prolonged high water tables: all were Rego Gleysols (Canada Department of Agriculture 1974). These are young soils with no developed horizons. Two typical soil profile descriptions, from transect 3 (the 2 higher sites in Figure 13) are listed in Appendix 1. One of these profiles also shows the layers of organic material which were typical of many soil pits examined. Soil profiles were not described on lower ground because high water tables and soil frost precluded pit digging. Such sites possess Cryic Gleysols (Canada Department of Agriculture 1974).

## 2.6 Drainage and Hydrology

### 2.6.1 Basin Description

At Rock Lake, Rock Creek drains a relatively small basin of about 340 $km^2$ (Figure 1). When entering the study area, it carries runoff from its own basin (180 $km^2$), the Mowitch Creek basin (97 $km^2$) and the basin of a small unnamed stream to the south (37 $km^2$). Within the study area, drainage is received from the slopes between the hillcrests to the north and south, areas of 14 and 9 $km^2$ respectively. Two permanent streams, Whitefish and Magic Creeks (Figure 2), transport some of the local runoff, the rest being carried by intermittent streams, springs and underground seepage.

### 2.6.2 Flow Regime of Rock Creek

Records were kept of river levels from 20 June to 30 August 1975 (Figure 7). Field observations in April and May of 1975 and 1976 added information about water levels at break up. The ice melted out at low water levels, which carried little sediment. In 1976, the water level continued to drop after break up. In neither year did the creek overtop its banks. Thus the high waters recorded during June and July, corresponding to the main period of snowmelt in the mountains, are believed to represent the annual period of high water.

Discharge data for 1975 from the Wildhay River (basin area about 950 $km^2$), recorded about 13 km downstream from Rock Lake, show patterns similar to those seen in Rock Creek in that year (Water Survey of Canada 1976). The 1975 data are similar to those of other years since 1963, when the Wildhay station was established, although the total discharge is below average and the time of peak flow (4 July) later than the norm. It is therefore assumed that the regime of Rock Creek has been similar to the pattern recorded there in 1975, during those other years (i.e., little or no flooding has occurred).

### 2.6.3 Groundwater Springs

A number of springs (Figure 8) were discovered at the western end of the study area and along

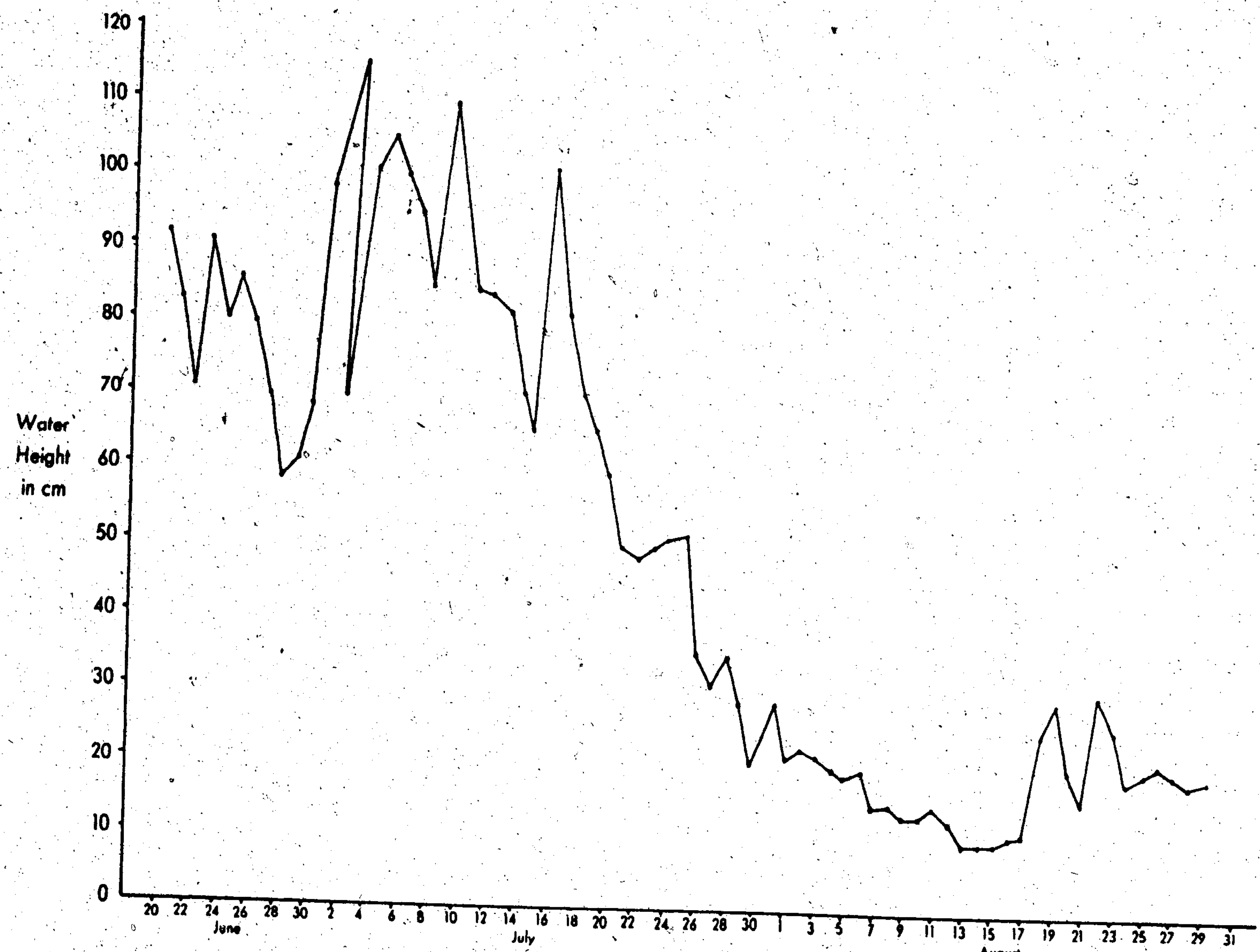



Figure 7: Daily Mean Water Levels of Rock Creek with respect to arbitrary datum, Summer 1975

the northern and southern sides. They provide most of the water for Whitefish Creek and Magic Creek, and also flow overland, downslope through the sedge meadows, eventually into water channels and Rock Lake.

A water sample from one of the springs at the west end of the study site was analyzed by the Alberta Research Council (Appendix 2). Its low level of total dissolved solids suggests that this water is mostly from local groundwater flow, which follows topographic gradients through coarse hillside and valley fill materials. The relatively high sulphate content suggests that it also contains some water from regional systems which has moved through pyrite ($FeS_2$) containing ironstones of shale and mudstone bedrock formations (pers. comm. Richard Barnes, Alberta Research Council hydrogeologist). Both types of flow system could also be discharging through any of the other springs although most of them are probably of local origin. The regional flow is probably being concentrated in the valley area, along topographic gradients, by the Miette faults in the manner discussed by Everdingen (1972).

## 2.7 Soil Frost and Permafrost

The soil surface is frozen to about 1 m durin the winter and thaws progressively during the summer, t thawing front moving from the stream banks and pond edge

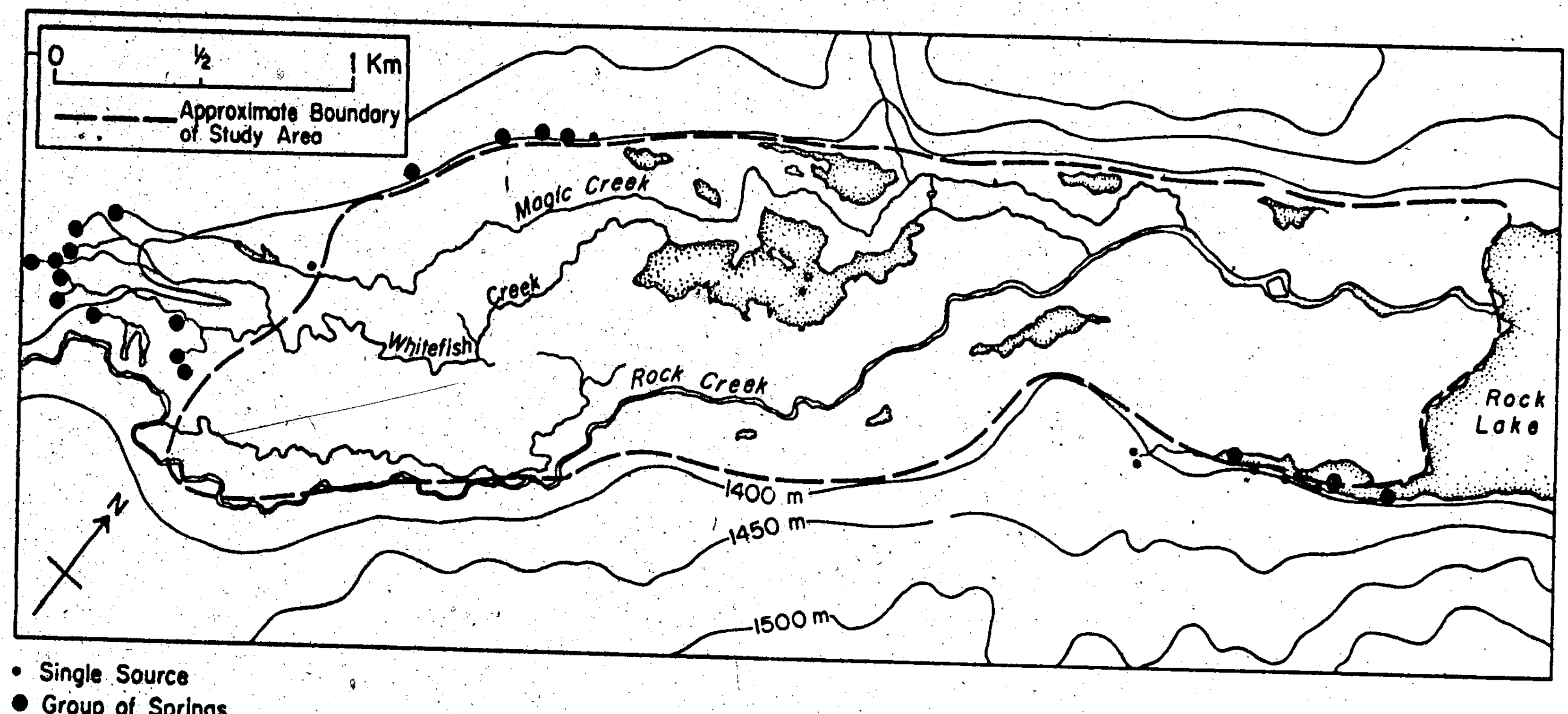



Figure 8: Location of Ground Water Springs

inland. Regular inspection (see section 4.2) showed that by September of 1975 the frost had not thawed out completely from under the middle of several areas of sedge and sedge/willow. While nothing is known about the long term persistence of such conditions, one summer's endurance of soil frost is sufficient to classify this as permafrost (Brown 1973) and thus the known range of nonalpine permafrost has been extended southward considerably (cf. Brown 1973). Other localized permafrost features - different types of mounds containing continually frozen materials - were seen at several locations in the study site. Many of these are believed to be palsas. These features, which are not all present on 1952 photographs, occur in both more developed and seemingly "incipient" forms.

## 2.8 Natural Vegetation

The study area lies within a zone of vegetational transition, being just within the area designated as the East Slope Rockies section of Rowe's (1972) Subalpine Forest Region. The Upper Foothills section of the Boreal Forest region lies to the east (Rowe 1972). The lower Rock Creek Valley does not possess, however, the broad forested cover of the upland sites that Rowe describes, as it is mostly sedge meadow and willow-sedge thicket, with smaller areas of structurally more complex vegetation which includes spruce (Plates 1-7).

A list of the 115 terrestrial vascular plant species that were found in the study area is included in Appendix 3. Voucher specimens are deposited in the University of Alberta herbarium. Taxonomy follows Moss (1959).

## 2.9 Influence of Animals Upon Vegetation

An inventory of the fauna of the study site was not attempted, but the presence and activities of three groups - beavers, ungulates and humans - have had obvious local influences upon the spatial patterns of the vegetation. There were six active beaver (*Castor canadensis*) lodges observed during the summer of 1975 and evidence suggests that past years have experienced similar activity. The cutting of willows and spruce for food and construction materials clearly affects the vegetation but the flooding behind dams is probably of greater significance. Ungulates, primarily wapiti (*Cervus canadensis*), moose (*Alces alces*) and mule deer (*Odocoileus hemionus*) have influenced the valley vegetation in two ways - by grazing and browsing upon the living plants and through the creation of trails with lower relief, more compacted soil, and different vegetation from the surrounding areas. Horses (*Equus equus*) are believed to have grazed in the valley at different times in the past and have also contributed to these effects. Trappers and camper/hikers have, every year, helped to maintain animal-initiated trails and have cut several small clearings for tent sites and for camp fires. The extent of the influence of all these activities was not studied, but it was presumed to have been quite localized.

# CHAPTER 3: METHODS

# 3. METHODS

## 3.1 Vegetation Classification and Mapping

A first step in attempting to discover ecological bases for vegetation patterns is to obtain an objective description of these patterns. In this study, I used the theoretically sound and empirically proven method of information analysis (Lambert and Williams 1966, Goodall 1973, Frenkel and Harrison 1974, and others) (IA, a polythetic clustering technique) to classify species presence data from vegetation quadrats.

The vegetation of the study area was first subjectively divided into three broad classes based upon dominant growth forms visible from a distance and on air photos: communities containing large spruce, a willow shrub type, and sedge meadows. Based upon field estimates of presence, abundance and growth habit of easily observed species, these were further separated into fifteen types (listed in Appendix 4). Fifteen transects were chosen (Figure 9) such that each of the previous tentatively identified vegetation patterns was sampled and such that most areas of the study site were examined.

A series of nested quadrats were set out in different types of vegetation that seemed to vary from simple (sedge meadows) to complex (spruce wood, mixed shrub/herb community). Following Mueller-Dombois and Ellenberg's

(1974) description of Cain's (1938) method of minimal area determination, it was found that a quadrat size of 8.8 $m^2$ would sample 90 percent of the species of the most complex community present (which possessed only 32 species). Hence the size of the plots used was 9 $m^2$. (This small value resulted from an error discovered following the field season. The actual minimal area for the most complex vegetation sampled is 16 $m^2$; 8$m^2$ was adequate for a species-rich thicket area, classified as vegetation type 2, in the description below. The implications and consequences of this are discussed in Chapter 5.)

Quadrats were set out along the chosen transects at 10 m intervals in the more species-rich vegetation and at 25 m intervals in the extensive areas of simple vegetation (Figure 9). Slight variations were made in interplot distance to avoid sampling the overlap of distinguishably sharp ecotones or within entrenched animal trails. All vascular plant species rooted in each quadrat or projecting above it were recorded. The vegetation transects were completed between 22 July and 3 August, 1975.

The data from the sample plots (Appendix 5) were classified using the information analysis option within the Clustan 1C program package of the University College, London, available from the University of Alberta Computing Service. The dendrogram which displays the calculated data clusters was arbitrarily "stopped" at three positions (Figure 10) and those classifications were considered. Vegetation maps were made to show the distribution of the 2 and 4 unit classes by plotting the quadrat locations on base maps by vegetation type. These known points were then grouped with similar vegetation recognized in the field and from 1974 aerial photographs and the vegetation types were then mapped.

## 3.2 Environmental Measurements

Environmental data were gathered from sites within each visually distinguishable vegetation type which occurred along five representative transects, selected from the fifteen chosen for vegetation quadrat sampling (Figure 9).

A soil pit was dug within each vegetation type, to 1 m deep or to the level of the water table, whichever was shallower. The soil profile was described following Canada Department of Agriculture (1974). Since no developmental soil horizons existed, soil samples were taken, in early August, from the top 15 cm of the profile and from each textural stratum above 1 m or the water table. In places with frozen soils, augered samples from 0-15 cm and 15 cm to ice were used. All samples were analyzed by the Alberta Department of Agriculture's Soil and Feed Testing Laboratory for pH, conductivity, free

$CaCO_3$, organic matter content, soil textural class and for plant available N, P, K, Na, and S, using standard methods as described in Alberta Agriculture (undated).

In mid-July, five replicate soil samples were taken from each of the same pit strata as were sampled for nutrients. Soil moisture content was determined gravimetrically using standard methods (Slatyer 1967), the wet weight being measured in the field on an Ohaus triple-beam balance.

Standpipes of 1.25 cm internal diameter polyvinyl chloride pipe, scored at approximately 10 cm intervals, were inserted into holes augered into the ground at each site. About every two weeks, measurements of the depth to the ground water table were made with a sounding weight.

A metal probe was used to test for the persistence of solid frozen soil beneath the surface at each site. On the same day as water levels were measured, the depth of the unfrozen soil was recorded at those locations where soil frost was located.

A transit and stadia rod were used to measure the elevation of each site with respect to the surface of Rock Creek. All surveys were done between 19 and 22 August, 1975, when the creek water level was relatively constant (Figure 7).

## 3.3 Analysis of Vegetation-Landform Relationships

The vegetation classification produced 4 units (see Chapter 4) which are visually distinguishable in the field and which demonstrate the spatial patterns and apparent landform correlations that this study undertook to examine. The ecological investigations therefore deal with those four vegetation types.

Environmental data were gathered from each visually distinguishable vegetation type along 5 of the 15 vegetation sampling transects (Figure 9). Subsequent classification of quadrats showed that data had been collected from four sites in vegetation type 1, four type 2 sites, four type 3 sites, and six type 4 sites. The data from the analyses were assembled according to the vegetation type of the site where the pits were located (Table II). The full data from the groundwater and frozen soil depth measurements are presented in Appendices 6 and 7, respectively. Table II shows partial statistics useful for comparison by vegetation type: the depth of the water table on 15 July, 1975, 12 August, 1975, and 16 August, 1976 (mid-growth season, and dates of deepest and highest recorded water levels, respectively), and the last recorded date of frost presence. Soil moisture contents are shown by soil strata sampled, the moisture contents of strata which were below the water table at the time of sampling

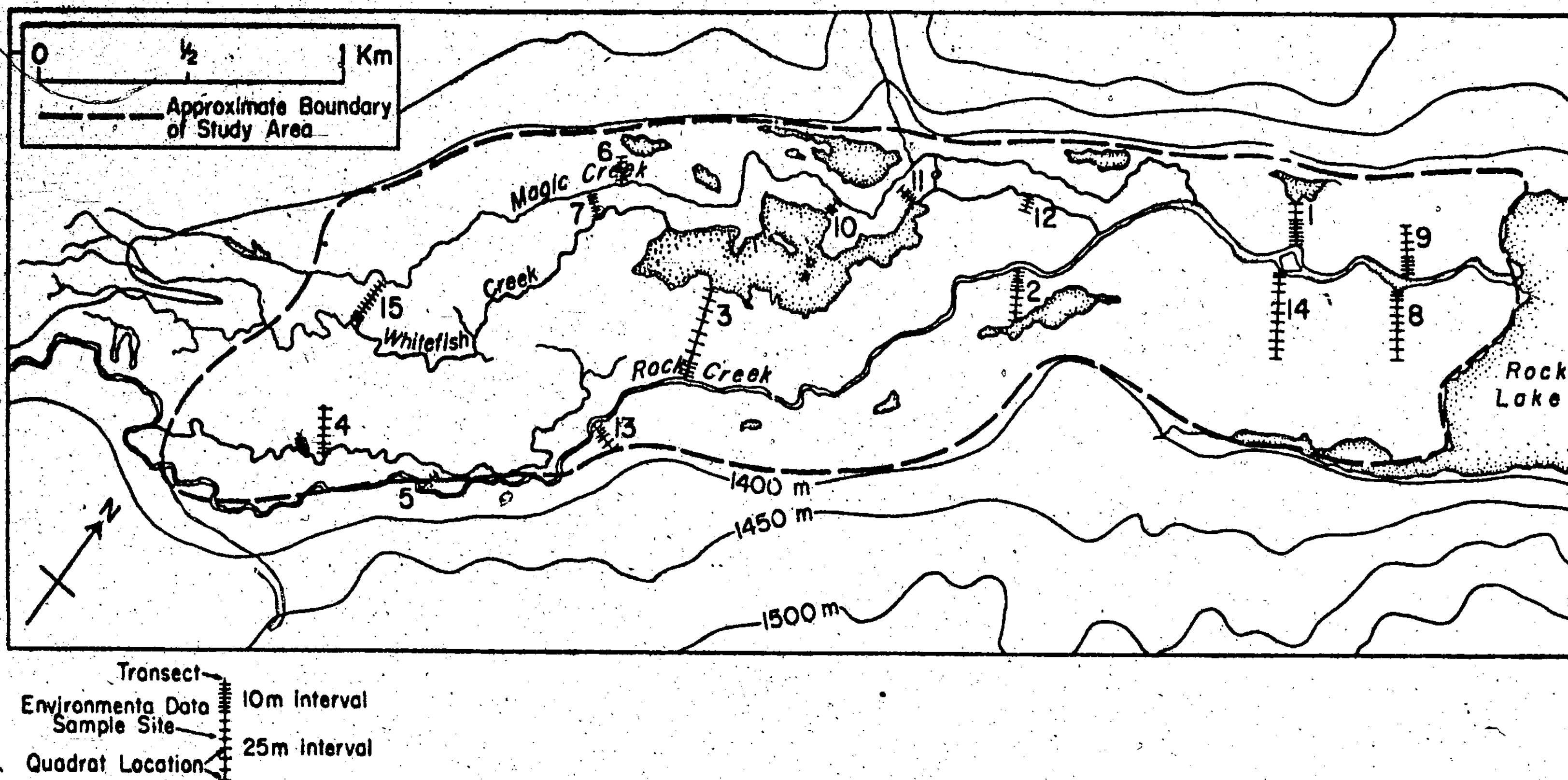



Figure 9: Location of Transects, Vegetation Quadrats, and Environmental Data Sampling Sites

are recorded as S (saturated). The surveyed elevation of each site above the level of Rock Creek is also listed.

The numerical environmental data in Table II were examined and those obviously having no variation with vegetation type were ignored. The others - K, Na, S, 15 July water level (of similar pattern to other recorded values which were therefore not specifically tested), and elevation above creek level - were examined by an analysis of variance (Anova) to determine if there was any significant difference in factor values between vegetation types. The two factors showing significant differences were further analyzed, using the Newman-Keuls multiple range test, to determine which sites were the sources of the variation. The coefficient of correlation between them was calculated. Only soil nutrient values for the top 15 cm of the soil were used. They seemed representative of other strata and were the only data available, and hence comparable, for all sites. The other environmental data in Table II were evaluated qualitatively.

# CHAPTER 4: RESULTS

# 4. RESULTS

## 4.1 Vegetation Classification and Mapping

The classification that was produced by information analysis of the data from the sample quadrats is displayed in the dendrogram of Figure 10. (As Lambert and Williams (1966) point out, agglomerative classifications are built "upwards" but they are commonly and meaningfully read "downwards," as shall be done here.) The data set was first divided into two strongly distinct groups, labeled A and B in Figure 10. A total of 70 different species were present in one or more of the sample plots. Inspection of the species present in the quadrats that were classified into the different divisions (Appendix 5, summarized in Table I) reveals the floristic characteristics of the vegetation types that were identified.

The A type, also referred to hereafter as the species-rich division, contains plots which have many species as compared to the B type - the species-poor division. Certain species are found in plots in both vegetation types. Only occasionally do any two different plots contain exactly the same flora. While some other species also appear, the species-impoverished class can clearly be associated with eight characteristic species: Calamagrostis neglecta, Carex aquatilis, C. vesicaria, Salix glauca, S. interior, Rumex occidentalis, Stellaria longipes, and Epilobium leptophyllum.

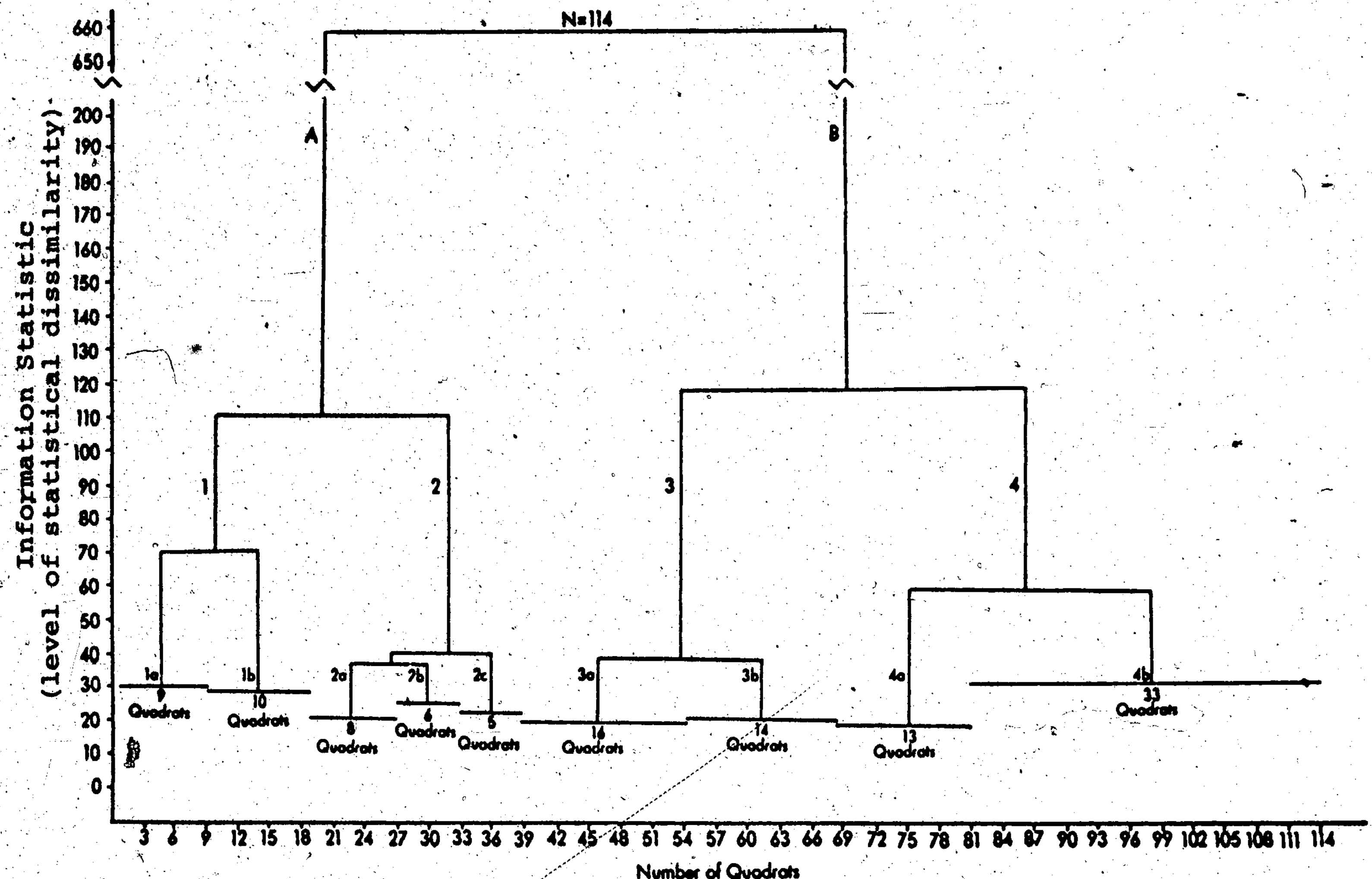



Figure 10: Information Analysis Classification of Vegetation Quadrat Data

Table I. Plant Species Present in Different Vegetation Types

1 = present in at least 1 quadrat
2 = present in >50% of quadrats
3 = present in all quadrats

| Code No. as in Appendix 3 | Species | TYPE A | | | | | TYPE B | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Type 1 | | Type 2 | | | Type 3 | | Type 4 | |
| | | a | b | a | b | c | a | b | a | b |
| 1 | *Equisetum arvense* | 3 | 3 | | 2 | 2 | 1 | | 1 | |
| 3 | *Equisetum scirpoides* | 2 | 2 | | 2 | 1 | 1 | 1 | | |
| 4 | *Equisetum variegatum* | 2 | 2 | 1 | | 1 | 1 | 1 | | |
| 6 | *Picea* glaucax engelmannii | 3 | 2 | | 1 | 2 | 1 | 1 | | |
| 8 | *Agropyron dasystachyum* | 1 | 1 | | | 2 | | | | |
| 11 | *Calamagrostis neglec*[illegible] | | 1 | | 1 | 1 | 1 | 1 | 3 | 1 |
| 12 | *Deschampsia caespitosa* | | 1 | 1 | 2 | 1 | 1 | | 1 | |
| 15 | *Hierochloe odorata* | | 1 | | | 1 | | | | |
| 17 | *Poa alpina* | 1 | | | 1 | | | | | |
| 20 | *Poa leptocoma* | 1 | 1 | 1 | | 2 | | | 1 | |
| 21 | *Trisetum spicatum* | 1 | 1 | | 1 | | | | | |
| 22 | *Carex aquatilis* | 2 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 23 | *Carex aurea* | 1 | 2 | 1 | 1 | 2 | | | | |
| 24 | *Carex capillaris* | | 1 | | | | | | | |
| 25 | *Carex gynocrates* | | | | | | | 1 | | |
| 26 | *Carex vesicaria* | | | | 1 | 1 | 1 | 1 | 2 | 2 |
| 27 | *Eriophorum brachyantherum* | | | | 1 | | | 1 | | |
| 28 | *Juncus balticus* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | |
| 32 | *Habenaria hyperborea* | 1 | 2 | 1 | | 1 | | | | |
| 33 | *Spiranthes romanzoffiana* | | 1 | | 1 | | | | | |
| 34 | *Populus balsamifera* | 1 | 2 | | | 1 | | | | |
| 35 | *Populus tremuloides* | 1 | | | | | | | | |
| 36 | *Salix arbusculoides* | 2 | 3 | 2 | 1 | 2 | 2 | 1 | 2 | 1 |
| 37 | *Salix candida* | | | | | | 1 | | 1 | |
| 38 | *Salix glauca* | 3 | 2 | 3 | 3 | 3 | 2 | 3 | 2 | 1 |

Table I. Continued

| Code No. as in Appendix 3 | Species | TYPE A Type 1 a | b | Type 2 a | b | c | TYPE B Type 3 a | b | Type 4 a | b |
|---|---|---|---|---|---|---|---|---|---|---|
| 39 | *Salix interior* | | | | | 1 | | | | |
| 40 | *Salix mackenzieana* | 3 | 3 | 3 | 3 | 3 | 2 | 2 | | |
| 41 | *Betula pumila* | 1 | 1 | | 1 | 1 | 1 | 3 | | |
| 42 | *Polygonum viviparum* | 1 | 1 | | 1 | 1 | | 1 | | |
| 43 | *Rumex occidentalis* | | | | | | 1 | | 2 | 1 |
| 46 | *Stellaria longipes* | | | 1 | | | 1 | 1 | 2 | 1 |
| 47 | *Anemone multifida* | 1 | | | | | | | 1 | |
| 49 | *Ranunculus gmelinii* | | | | | | | | | 1 |
| 53 | *Cardamine pensylvanica* | | | | | | | | | 1 |
| 58 | *Parnassia montanensis* | | 2 | 1 | 1 | 1 | | | | |
| 62 | *Fragaria virginiana* | 2 | 2 | 1 | 1 | 3 | | | 1 | |
| 63 | *Geum macrophyllum* | | 1 | 1 | | 1 | | | 2 | 1 |
| 64 | Potentilla fruticosa | | 1 | | | 1 | | | | |
| 66 | *Rosa acicularis* | 1 | | | | | | | | |
| 67 | *Rubus acaulis* | | 1 | 1 | 1 | 1 | 1 | 1 | | 1 |
| 69 | *Astragalus eucosumus* | 1 | | 1 | | 1 | | 1 | | |
| 70 | *Astragalus frigidus* | | 1 | | | 1 | | | | |
| 71 | *Hedysarum alpinum* | 2 | 1 | | | | | | | |
| 72 | *Lathyrus ochroleucus* | 1 | | | | | | | | |
| 73 | *Oxytropis deflexa* | 1 | | | | | | | | |
| 76 | *Vicia americana* | | 1 | | | 1 | | | | |
| 78 | *Shepherdia canadensis* | 1 | 2 | | | | | | | |
| 79 | *Epilobium angustifolium* | 1 | 2 | | 1 | 1 | | | | |
| 82 | *Epilobium leptophyllum* | | | 1 | | 2 | 2 | 1 | 3 | 2 |
| 83 | Moneses *uniflora* | 1 | | | | | | | | |
| 84 | *Pyrola asarifolia* | 2 | 3 | 1 | 1 | 2 | | 1 | | |
| 85 | *Pyrola secunda* | 1 | 2 | | 1 | | | | | 1 |
| 87 | *Arctostaphylos uva-ursi* | 1 | | | | | | | | |

Table I. Continued

| Code No. as in Appendix 3 | Species | TYPE A: Type 1 a | Type 1 b | Type 2 a | Type 2 b | Type 2 c | TYPE B: Type 3 a | Type 3 b | Type 4 a | Type 4 b |
|---|---|---|---|---|---|---|---|---|---|---|
| 89 | *Gentianella amarella* | 1 | 1 | | | 1 | | | | |
| 91 | *Mertensia paniculata* | 1 | | | 1 | | | | | |
| 93 | *Castilleja occidentalis* | 2 | 2 | 1 | 1 | 2 | | | | |
| 95 | *Pedicularis groenlandica* | 1 | 3 | | 1 | 3 | | 1 | | |
| 96 | *Rhinanthus crista-galli* | | 1 | | | | | | | |
| 99 | *Linnaea borealis* | 1 | | | | | | | | |
| 100 | *Valeriana septentrionalis* | | 1 | | | | | | | |
| 102 | *Achillea millefolium* | 3 | 3 | 1 | 1 | | | | | |
| 104 | *Antennaria pulcherrima* | 1 | 2 | | 1 | 1 | | | | |
| 105 | *Antennaria rosea* | 2 | 1 | 1 | | 1 | | | | |
| 107 | *Aster foliaceus* | 1 | 1 | 1 | | | | | | |
| 109 | *Aster sibericus* | 1 | | | | | | | | |
| 110 | *Erigeron lonchophyllus* | 1 | 2 | 2 | 1 | 3 | 1 | | 1 | |
| 111 | *Petasites vitifolius* | | | | 1 | | | | | |
| 112 | *Senecio pauperculus* | 2 | 2 | 3 | 1 | 3 | 1 | | 1 | |
| 114 | *Taraxacum ceratophorum* | 1 | | 1 | | 1 | | | | |
| 115 | *Taraxacum officinale* | 1 | | | | 2 | 1 | | | |

Also common are Salix mackenziana, Geum macrophyllum, and Betula pumila.

The quadrats of the A type tend to be floristically richer and more variable than those of B type (Appendix 5). The most common species are Equisetum arvense, E. scirpoides, E. variegatum, Picea glauca X engelmannii, Carex aquatilis, Carex aurea, Salix arbusculoides, Salix glauca, S. mackenziana, Fragaria virginiana, Epilobium angustifolium, Pyrola asarifolia, Castilleja occidentalis, Pedicularis groenlandica, Achillea millefolium, Erigeron lonchophyllus, and Senecio pauperculus. Also frequently occurring are Agropyron dasystachyum, Deschampsia caespitosa, Poa leptocoma, Trisetum spicatum, Juncus balticus, Habenaria hyperborea, Populus balsamifera, Betula pumila, Polygonum viviparum, Parnassia montanensis, Rubus acaulis, Shepherdia canadensis, Pyrola secunda, Antennaria pulcherrima, and A. rosea. Although most of the species-rich plots contain Carex aquatilis and the three Salix species mentioned, they rarely possess the other type B species.

The two groups are not as easily mapped from air photos as their clear floristic differences would suggest since the region of division was almost always at a type 2-type 3 boundary (see below). Especially near their division, these two types possess physiognomically almost identical upper strata of willows with some birch - indeed, such areas were originally identified as parts of a single community. The distinction between the two was made using both the knowledge of which vegetation type each quadrat along the transects was assigned to, and the clear differentiability of the two types in the field. The result is the map in Figure 11.

The two primary vegetation types are each divided, at similar levels of statistical similarity, into two further vegetation classes, designated 1 and 2, 3 and 4 on Figure 10 and Table I (Plates 8-11). Comparison of the quadrats in each pair of the subdivisions shows that while many of the species in one subtype can occur in the other, clear distinctions between them do exist. The species-poor type is now divided into a *Carex* dominated class (4), which possesses herb species but rarely *Salix*, and a *Salix* and *Carex* dominated group (3) that always has one or more *Salix* species present and often the physiognomically similar *Betula pumila*. The small stature and scattered distribution of the few willows in type 4 areas makes them quite easily distinguishable from type 3 areas and hence reliably mappable.

Although their overall floras are similar, the two subgroups of A are distinguishable by the greater number of species in most type 1 quadrats as compared to type 2 ones (Table I). Also, there are a number of species in

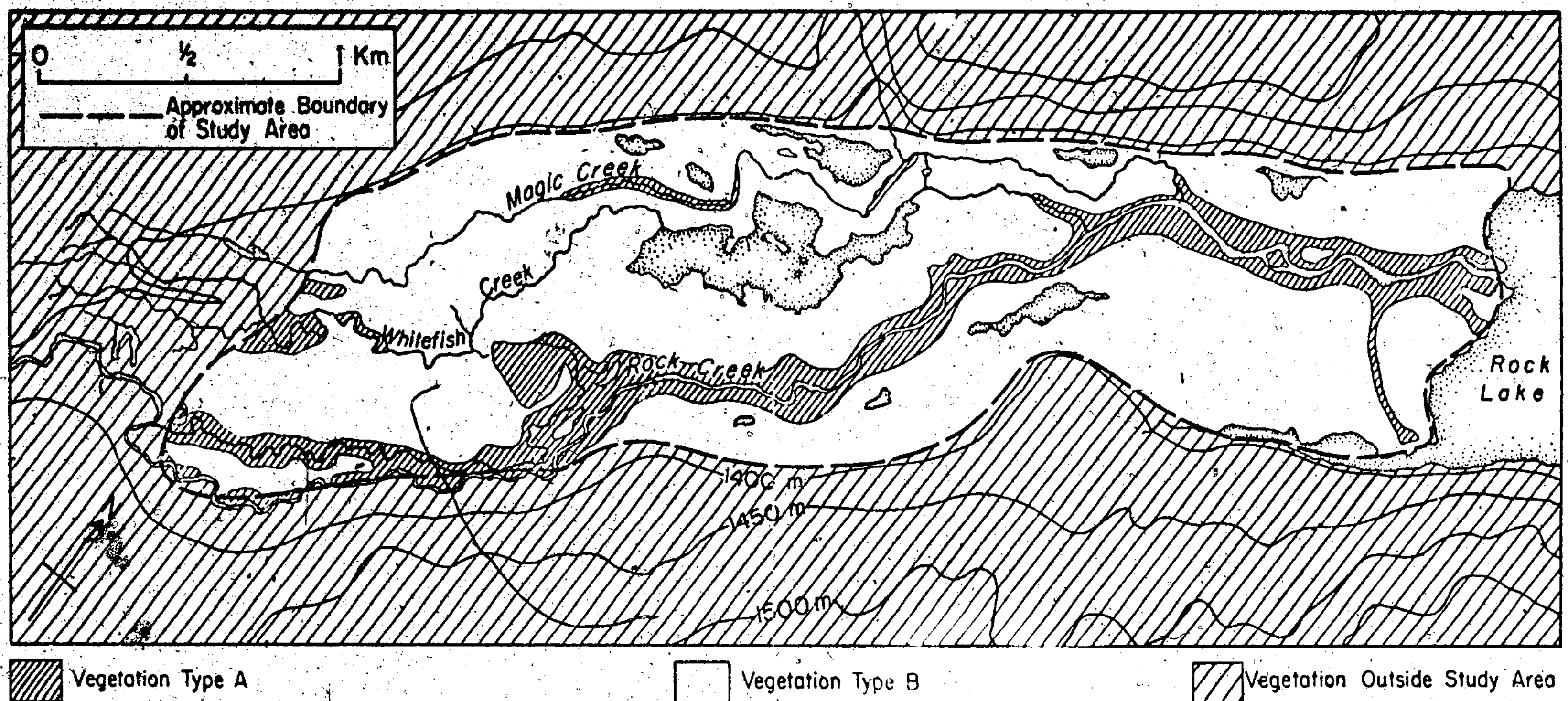



Figure II: Two Unit Vegetation Classification

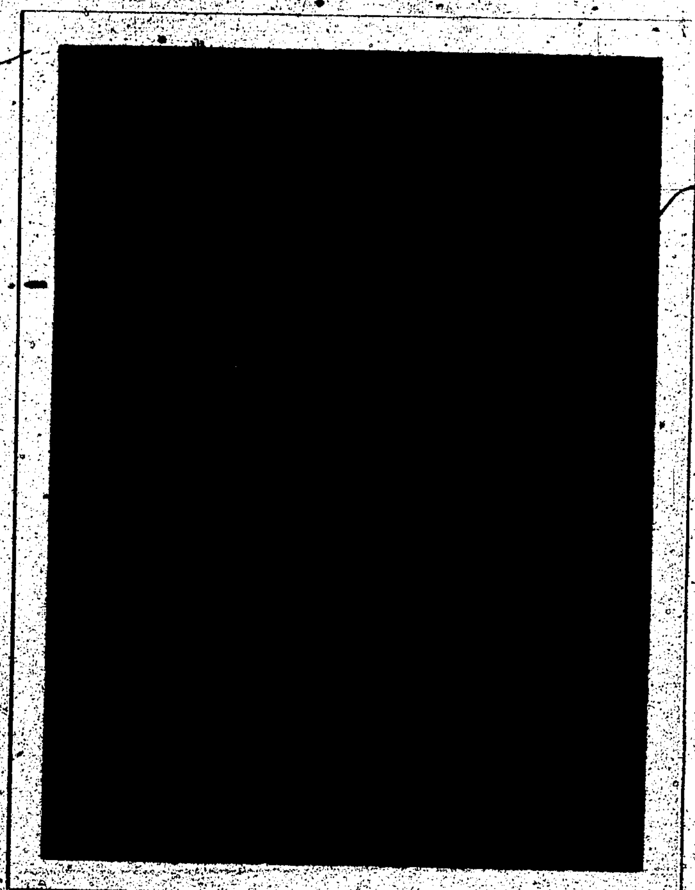


Plate 8: Example of vegetation type 1.

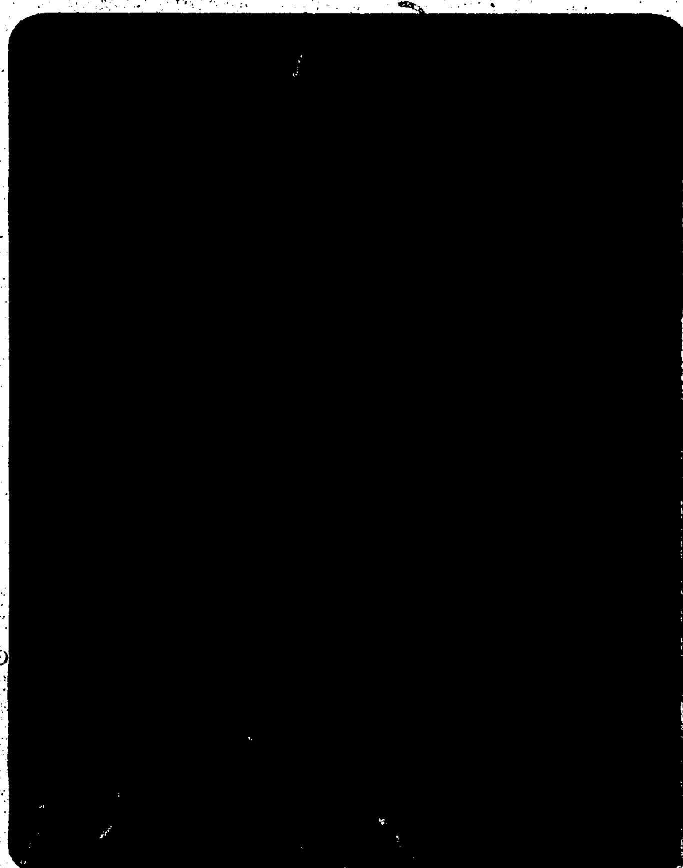


Plate 9: Example of vegetation type 2.

type 1 quadrats not present or seldom found in type 2 ones, and vice versa. The most common of those exclusively occurring in the richer vegetation class are *Hedysarum alpinum*, *Shepherdia canadensis*, and *Aster sibericus*. Occasionally *Carex capillaris*, *Populus tremuloides*, *Anemone multifida*, *Rosa acicularis*, *Lathyrus ochroleucus*, *Oxytropis deflexa*, *Moneses uniflora*, *Arctostaphylos uva-ursi*, *Rhinanthus crista-galli*, and *Linnea borealis* are present there. Species which are commonly found in type 1 vegetation but which occasionally appear in type 2 areas are *Equisetum variegatum*, *Habenaria hyperborea*, *Populus balsamifera*, *Parnassia montanensis*, *Potentilla fruticosa*, *Pyrola secunda*, *Achillea millefolium*, and *Antennaria pulcherima*. There are no species commonly occurring in type 2 vegetation that do not appear in some type 1 quadrats. Less common species found in type 2 but not type 1 plots are *Eriophorum brachyantherum*, *Stellaria longipes*, and *Epilobium leptophyllum*. *Deschampsia caespitosa*, *Carex aquatilis*, *Geum macrophylum*, and *Taraxacum officinale* are distinctly more common in type 2 areas, although they are present in come type 1 plots.

While reasonably distinguishable in the field, mapping these two types by extrapolation from aerial photographs was occasionally difficult due to the constancy of the distinctive spruce and willow species in both types, although type 1 vegetation is typically more densely wooded.

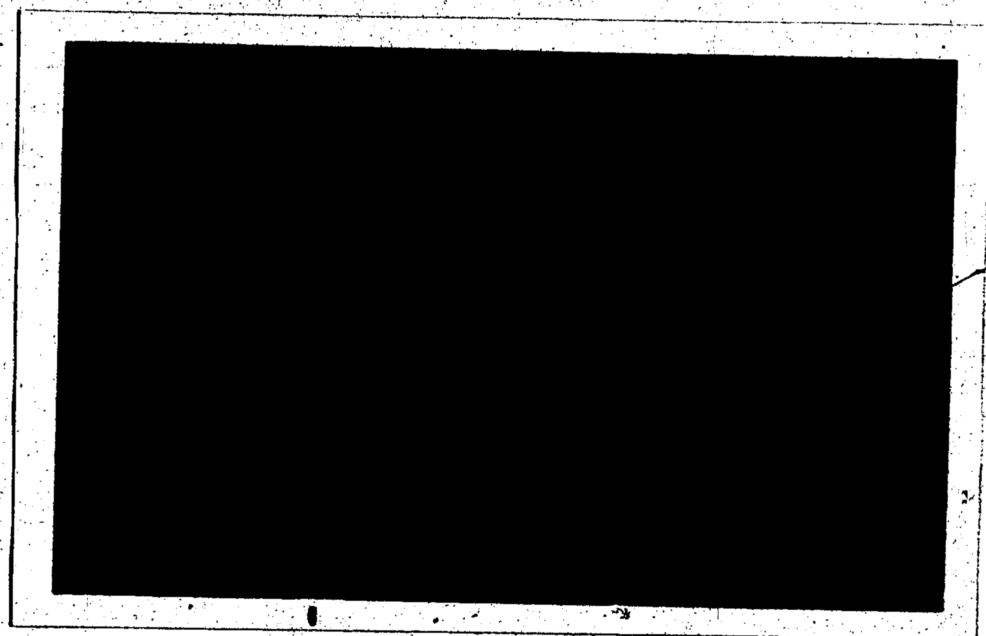


Plate 10: Example of vegetation type 3.

Plate 11: Example of vegetation type 4.

As in Figure 11, separating type 2 and type 3 vegetation areas was difficult. The distribution of the four vegetation types is mapped in Figure 12.

The third level of classification considered shows 9 vegetation classes (Figure 10, Table I). The distinctions between these units, both in the table and in the field are not as consistently clear as the nearly equal levels of statistical similarity of the divisions would suggest. Types 4(a) and 4(b), and 3(a) and 3(b), differ quite simply and detectably in species richness per plot and in species present. They are readily distinguishable in the field. The 1(a)-1(b) and 2(a)-2(b)-2(c) breakdowns, with larger floras, more complexly partitioned, are not easily separable in the field. Since even those types which can be identified on the ground (4(a)-4(b) and 3(a)-3(b)) are characterized by differences in herbaceous plants, it is not possible to interpret these community distinctions from photographs. This level of classification was not mapped or considered further.

4.2 Analysis of Environmental Data

The data presented in Table II clearly show that there is no variation between sites in the amounts of nitrogen and phosphorous available: they are uniformly very low. The conductivity values likewise show small variations. There are several sites or strata which show

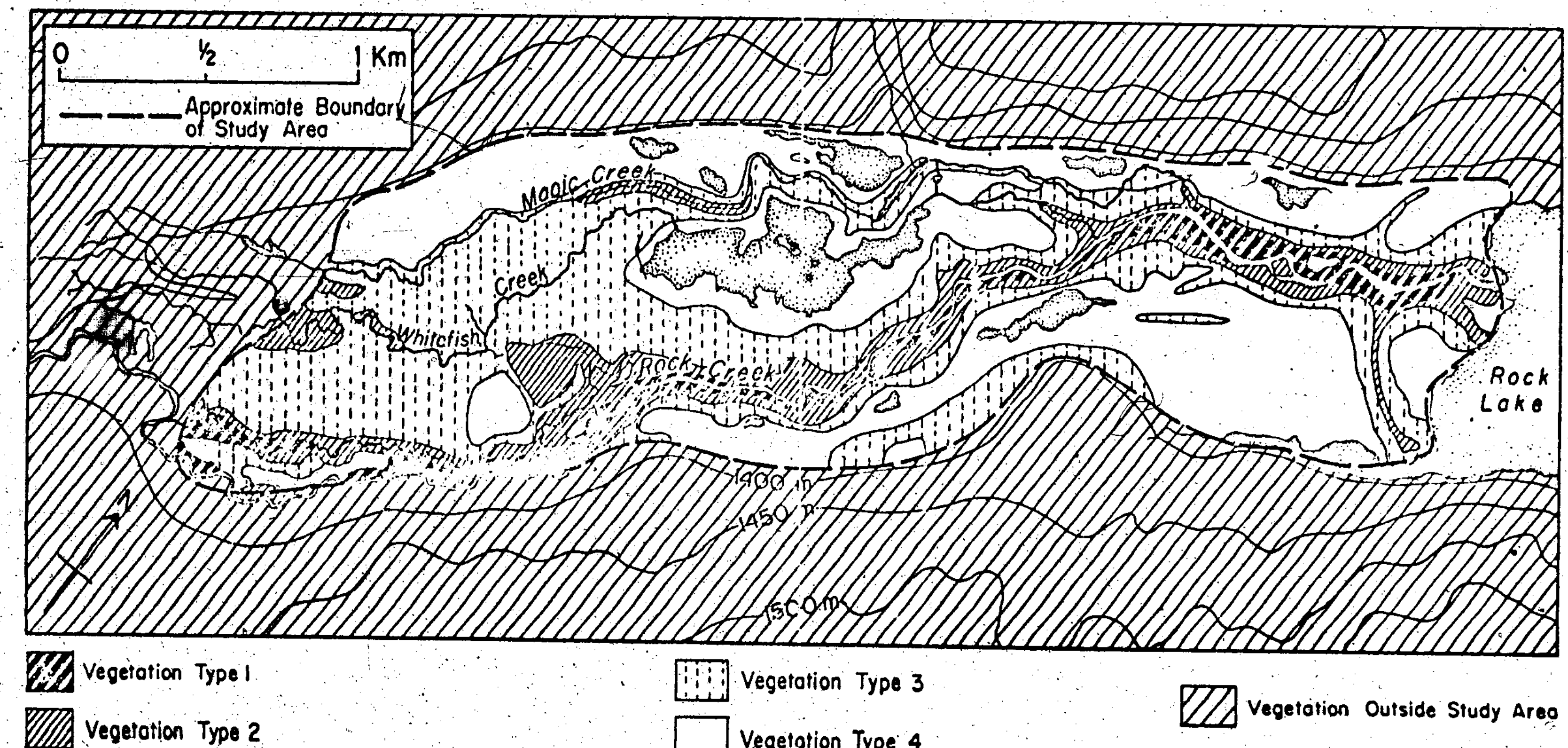



Figure 12: Four Unit Vegetation Classification

Table 11. Results of Measurements of Environmental Variables

| Vegetation Type | Transect Site Location | Elevation Above 31/22/VIII Level of Rock Creek in cm | Soil Stratum Depth, in cm | Soil Nutrients in ppm. N | P | K | Na | S | pH | Conductivity in mmhos | Organic Matter Contents by Class[1] | Free $CaCO_3$ by Class[2] | Soil Texture by Class[3] | Mid-July Soil Moisture Content as % Dry Weight | Depth to Ground Water Table 16/VIII/76 | 15/VII/75 | 13/VIII/75 | Last Recorded Date of Soil Frost Presence |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1,1 | 104 | (0-15) | 0.5 | 0 | 50 | 20 | 20 | 8.3 | 0.6 | L+ | H+ | 4 | 34 | 27 | 72 | 106 | Not found at 1st sampling 15/VI |
| | | | (15-41) | 0.5 | 0 | 65 | 25 | 24 | 8.3 | 0.4 | L+ | H+ | 4 | 38 | | | | |
| | | | (41-100) | 0.5 | 0 | 85 | 20 | 6 | 8.8 | 0.3 | L | H+ | 1 | 36 | | | | |
| 1 | 2,1 | 123 | (0-15) | 0.5 | 0 | 18 | 25 | 13 | 8.6 | 0.3 | L+ | H+ | 4 | | 67 | 114 | 131 | Not found at 1st sampling 17/VI |
| | | | (15-52) | 0.5 | 0 | 12 | 25 | 8 | 8.7 | 0.3 | L+ | H+ | 4 | | | | | |
| | | | (52-69) | 0.5 | 0 | 15 | 15 | 7 | 8.5 | 0.3 | L+ | H+ | 4 | | | | | |
| | | | (69-100) | 0.5 | 0 | 10 | 15 | 6 | 8.5 | 0.4 | L+ | H+ | 4 | | | | | |
| 1 | 3,1 | 210 | (0-15) | 0.5 | 0 | 52 | 15 | 5 | 8.4 | 0.3 | L+ | H+ | 4 | 40 | 115 | 176 | 216 | Not found at 1st sampling 18/VI[4] |
| | | | (15-42) | 0.5 | 0 | 25 | 20 | 11 | 8.5 | 0.3 | L+ | H+ | 4 | 22 | | | | |
| | | | (42-100) | 0.5 | 0 | 27 | 25 | 6 | 8.6 | 0.3 | L | H+ | 4 | 36 | | | | |
| 1 | 5,1 | 204 | (0-11) | 0.5 | .5 | 27 | 20 | 65 | 8.5 | 0.4 | L+ | H+ | 4 | 34 | 140 | 173 | 212 | Not found at 1st sampling 16/VI |
| | | | (11-61) | 0.5 | 0 | 25 | 15 | 24 | 8.6 | 0.3 | L+ | H+ | 2 | 18 | | | | |
| | | | (61-100) | 0.5 | 0 | 22 | 25 | 66 | 8.6 | 0.3 | L+ | H+ | 4 | 33 | | | | |
| 2 | 3,2 | 130 | (0-15) | 0.5 | 0 | 37 | 25 | 10 | 8.4 | 0.4 | L | H+ | 4 | | +3 | 66 | 115 | Not found at 1st sampling 18/VI |
| | | | (15-38) | 0.5 | 0 | 32 | 20 | 8 | 8.4 | 0.3 | L | H+ | 4 | | | | | |
| | | | (38-100) | 0.5 | 0 | 60 | 10 | 22 | 8.2 | 0.4 | L+ | H+ | 4 | | | | | |
| 2 | 4,1 | 127 | (0-15) | 0.5 | 0 | 35 | 70 | 33 | 8.5 | 0.4 | L | H+ | 4 | 30 | 77 | 132 | 155 | 1/VII |
| | | | (15-55) | 0.5 | 0 | 22 | 50 | 13 | 8.7 | 0.3 | L+ | H+ | 2 | 22 | | | | |
| | | | (55-100) | 0.5 | 0 | 30 | 45 | 8 | 8.6 | 0.3 | L+ | H+ | 4 | 36 | | | | |
| 2 | 4,2 | 78 | (0-18) | 0.5 | 0 | 20 | 20 | 12 | 8.6 | 0.4 | L | H+ | 4 | 35 | +4 | 74 | 107 | 1/VII |
| | | | (18-51) | 0.5 | 0 | 20 | 20 | 4 | 8.6 | 0.3 | L+ | H+ | 2 | 24 | | | | |
| | | | (51-100) | 0.5 | 0 | 22 | 15 | 14 | 8.5 | 0.3 | L+ | H+ | 4 | S* | | | | |
| 2 | 5,2 | 136 | (0-15) | 0.5 | 0 | 60 | 45 | 83 | 8.5 | 0.4 | L+ | H+ | 4 | 35 | +10 | 121 | 203 | Not found at 1st sampling 16/VI[4] |
| | | | (15-20) | 0.5 | 0 | 70 | 40 | 35 | 8.1 | 0.4 | L+ | H+ | 4 | 13 | | | | |
| | | | (20-37) | 0.5 | 0 | 27 | 30 | 34 | 8.3 | 0.3 | L+ | H+ | 4 | | | | | |
| | | | (37-40) | 0.5 | 0 | 45 | 45 | 30 | 8.3 | 0.3 | L+ | H+ | 4 | 30 | | | | |
| | | | (40-45) | 0.5 | 0 | 65 | 40 | 55 | 8.2 | 0.4 | L+ | H+ | 4 | | | | | |
| | | | (45-100) | 0.5 | 0 | 40 | 35 | 100 | 8.2 | 0.5 | L+ | H+ | 4 | 34 | | | | |
| 3 | 2,2 | 90 | (0-14) | 0.5 | 0.5 | 120 | 40 | 18 | 7.8 | 0.5 | L+ | H+ | 4 | | 0 | 41 | 70 | Not found at 1st sampling 17/VI |
| | | | (14-44) | 0.5 | 0 | 27 | 20 | 17 | 7.5 | 0.4 | L+ | H+ | 2 | | | | | |
| | | | (44+ ) | 0.5 | 0.5 | 35 | 25 | 14 | 7.9 | 0.5 | L+ | H+ | 4 | S | | | | |
| 3 | 3,3 | 62 | (0-15) | 0 | 0 | 32 | 25 | 13 | 8.2 | 0.5 | L | H+ | 4 | S | +4 | 11 | 32 | 1/IX(patches) |
| | | | (15+ ) | 0.5 | 0 | 38 | 25 | 10 | 8.0 | 0.4 | L+ | H+ | 4 | S | | | | |
| 3 | 4,3 | 64 | (0-15) | 0 | 0 | 25 | 15 | 13 | 8.0 | 0.4 | L+ | H+ | 4 | S | +6 | +3 | 37 | 24/VII |
| | | | (15-50) | 0.5 | 0 | 22 | 15 | 24 | 8.1 | 0.5 | L+ | H+ | 3 | S | | | | |
| | | | (50-100) | 0.5 | 0 | 25 | 10 | 24 | 7.9 | 0.4 | L+ | H+ | 4 | S | | | | |
| 3 | 4,4 | 61 | (0-15) | 0.5 | 0 | 15 | 30 | 22 | 8.1 | 0.5 | L+ | H+ | 4 | S | +10 | +5 | 0 | 1/IX |
| | | | (15+ ) | 0.5 | 0 | 17 | 30 | 200 | 8.1 | 0.7 | M | H+ | 4 | S | | | | |
| 4 | 1,2 | 56 | (0-15) | 0.5 | 0 | 35 | 25 | 9 | 8.3 | 0.6 | L+ | H+ | 4 | 57 | 0 | 12 | 52 | 11/VII |
| | | | (15-25) | 0.5 | 0 | 35 | 25 | 6 | 8.4 | 0.3 | L | H+ | 4 | S | | | | |
| | | | (25-46) | 0.5 | 0 | 20 | 20 | 10 | 8.3 | 0.4 | L+ | H+ | 4 | S | | | | |
| | | | (46-62) | 0.5 | 0 | 65 | 25 | 20 | 8.1 | 0.4 | L+ | H+ | 4 | S | | | | |
| | | | (62-100) | 0.5 | 0 | [illegible] | 25 | 42 | 8.1 | 0.5 | M | H+ | 6 | S | | | | |
| 4 | 1,3 | 56 | (0-15) | 0.5 | 0 | 25 | 21 | 100 | 8.0 | 0.6 | L+ | H+ | 4 | S | +5 | +4 | 0 | 12/VIII |
| 4 | 2,3 | 76 | (0-13) | 0.5 | 0 | 27 | 35 | 10 | 8.2 | 0.5 | L+ | H+ | 4 | S | +5 | +5 | 0 | 1/IX(patches) |
| 4 | 2,4 | 68 | (0-15) | 0.5 | 0 | 30 | 40 | 30 | 8.0 | 0.5 | L+ | H+ | [illegible] | S | +30[4] | +5 | 0 | 1/IX |
| 4 | 3,4 | 33 | (0-15) | 0 | 0 | 22 | 20 | 15 | 8.1 | 0.5 | L+ | H+ | 4 | S | +15[4] | +6 | 0 | 1/IX(patches) |
| | | | | 0.5 | 0 | 27 | 30 | 72 | 8.3 | 0.6 | L+ | H+ | 4 | S | | | | |
| 4 | 5,3 | 134 | (0-15) | 0.5 | 0.5 | 52 | 40 | 60 | 8.4 | 0.5 | L | H+ | 4 | | +10 | 97 | 166 | 16/VI(patches) |
| | | | (15-50) | 0.5 | 0 | 60 | 25 | 42 | 8.5 | 0.4 | L | H+ | 4 | 37 | | | | |
| | | | (50-58) | 0.5 | 0 | 30 | 25 | 34 | 8.6 | 0.3 | L+ | H+ | 4 | 31 | | | | |
| | | | (58-69) | 0.5 | 0 | 30 | 25 | 10 | 8.5 | 0.3 | L+ | H+ | 4 | 32 | | | | |
| | | | (69-91) | 0.5 | 0 | 22 | 20 | 11 | 8.6 | 0.3 | L+ | H+ | 4 | 34 | | | | |
| | | | (91-100) | 0.5 | 0 | 35 | 15 | 37 | 8.3 | 0.6 | L+ | H+ | 4 | 37 | | | | |

*S = saturated

[1,2] High (H), medium (M), low (L) or none (NIL). The degree within each category is indicated by a + or - sign. Alberta Environment (undated).

[3] Very coarse (1), coarse (2), medium (3), fine (4), very fine (5), organic (peaty) (6). Alberta Environment (undated).

[4] 1976 data.

differences in soil texture and organic matter content but these represent particular local circumstances and show no correlation with differences in vegetation types. There are high free lime contents in all of the soils. The pH values are all high and show no meaningful trends between vegetation types. The analyses of variance (Table III) showed that the variations in soil K, Na and S concentrations were not correlated with vegetation type.

Some factors show variation with vegetation patterns. Ice records showed a tendency toward early melt-out in the two species-rich classes and longer persistence or permafrost conditions under species-poor vegetation sites. Also, Anova results showed strongly significant variations in site elevation and water table level data (Table III). The Neuman-Keuls test (Table IV) showed that the variation in ground water level was not significant between type 1 and 2 sites or type 3 and 4 sites, the variation was between those two groups (i.e., between type A and type B sites). The creek elevation data give conflicting results (Table IV) showing that a type I error was made in the test (Zar 1974). Considering the strongly significant correlation (r = 0.91) between ground water level and site elevation (Table V), it seems reasonable to assume that the error lies in result $\mu_2 = \mu_3 = \mu_4$, and that these data, too, show significant variation only between type A and type B sites (i.e., $\mu_1 = \mu_2 \neq \mu_3 = \mu_4$).

Table III. Analysis of Variance of Selected Environmental Parameters

| Parameter | df | MS | F | F ratio of .95 Fractile | F ratio of .99 Fractile |
|---|---|---|---|---|---|
| Na content of top 15 cm of soil | 14 | 275 | 1.65 | 3.34 | 5.56 |
| S content of top 15 cm of soil | 14 | 524 | 0.64 | | |
| K content of top 15 cm of soil | 14 | 105 | 0.14 | | |
| Elevation of site above Rock Creek | 14 | .82 | 6.30* | | |
| Depth of groundwater table-15/VII | 14 | 16,477 | 11.25* | | |

*Significant at 99 percent confidence level

Table IV. Newman-Keuls Multiple Range Test of Groundwater Level and Site Evaluation Data

| | Comparison | $\bar{X}_1-\bar{X}_2$ | SE | $H_o:\mu_A=\mu_B$ q | p | $H_A:\mu_A\neq\mu_B$ q.0.05,14,p | Conclusion |
|---|---|---|---|---|---|---|---|
| GROUNDWATER LEVEL | Vegetation Type: | | | | | | |
| | 1 vs. 3 | 122.8 | 19.2 | 6.40 | 4 | 4.11 | $H_o$ rejected |
| | 1 4 | 108 | 17.5 | 6.17 | 3 | 3.70 | $H_o$ rejected |
| | 1 2 | 35.5 | 19.2 | 1.85 | 2 | 3.03 | $H_o$ accepted |
| | 2 3 | 87.2 | 19.2 | 4.55 | 3 | 3.70 | $H_o$ rejected |
| | 2 4 | 72.5 | 17.5 | 4.14 | 2 | 3.03 | $H_o$ rejected |
| | 4 3 | 14.75 | 17.5 | .84 | 2 | 3.03 | $H_o$ accepted |

$\therefore \mu_1=\mu_2\neq\mu_3=\mu_4$

| | Comparison | $\bar{X}_1-\bar{X}_2$ | SE | q | p | q.0.05,14,p | Conclusion |
|---|---|---|---|---|---|---|---|
| SITE ELEVATION | 1 vs. 3 | 0.90 | 0.18 | 4.99 | 4 | 4.11 | $H_o$ rejected |
| | 1 4 | 0.95 | 0.16 | 5.44 | 3 | 3.70 | $H_o$ rejected |
| | 1 2 | 0.42 | 0.18 | 2.33 | 2 | 3.03 | $H_o$ accepted |
| | 2 3 | 0.48 | 0.18 | 2.66 | 3 | 3.70 | $H_o$ accepted |
| | 2 4 | 0.475 | 0.16 | 2.88 | 2 | 3.03 | $H_o$ accepted |
| | 4 3 | 0.005 | 0.16 | 0.304 | 2 | 3.03 | $H_o$ accepted |

$\therefore \mu_1=\mu_2$

$\mu_2=\mu_3=\mu_4$

Table V. Calculation of Correlation Coefficient for Groundwater Level and Site Elevation Data

| | | |
|---|---|---|
| Ground Water Depth: | $\Sigma x^2 = 69931.6$<br>$\overline{X} = 65.9$ | $H_o: p = o$<br>$H_A: p \neq o$ |
| Elevation | $\Sigma y^2 = 44137.6$<br>$\overline{Y} = 93.4$<br>$\Sigma xy = 50748$ | |
| $r = .913$ | $r_{0.01,2,16} = .590$ | $\therefore$ reject $H_o$ |
| $r^2 = .834$ | | |

The soil moisture data show that in mid-season most type 3 and 4 sites were saturated while type 1 and type 2 sites were not. The differing type A soil moisture content figures are biologically meaningful only when examined in terms of plant available moisture. While the broad soil texture classes used make close comparison impossible, inspection of moisture availability curves (e.g., Black 1968, Russell 1973) reveals that the moisture contents of the unsaturated soils represent conditions close to field capacity. Pressure plate extraction of twenty of the Rock Creek Valley soils showed one-third bar (approximate field capacity) soil moisture contents as being in the 20 to 30 percent range, corroborating this interpretation. Patterns of soil moisture variation between type 1 and type 2 sites were not distinguishable.

The patterns of variation in vegetation types and the main environmental factors are summarized in Figure 13, a schematic profile of transect 3.

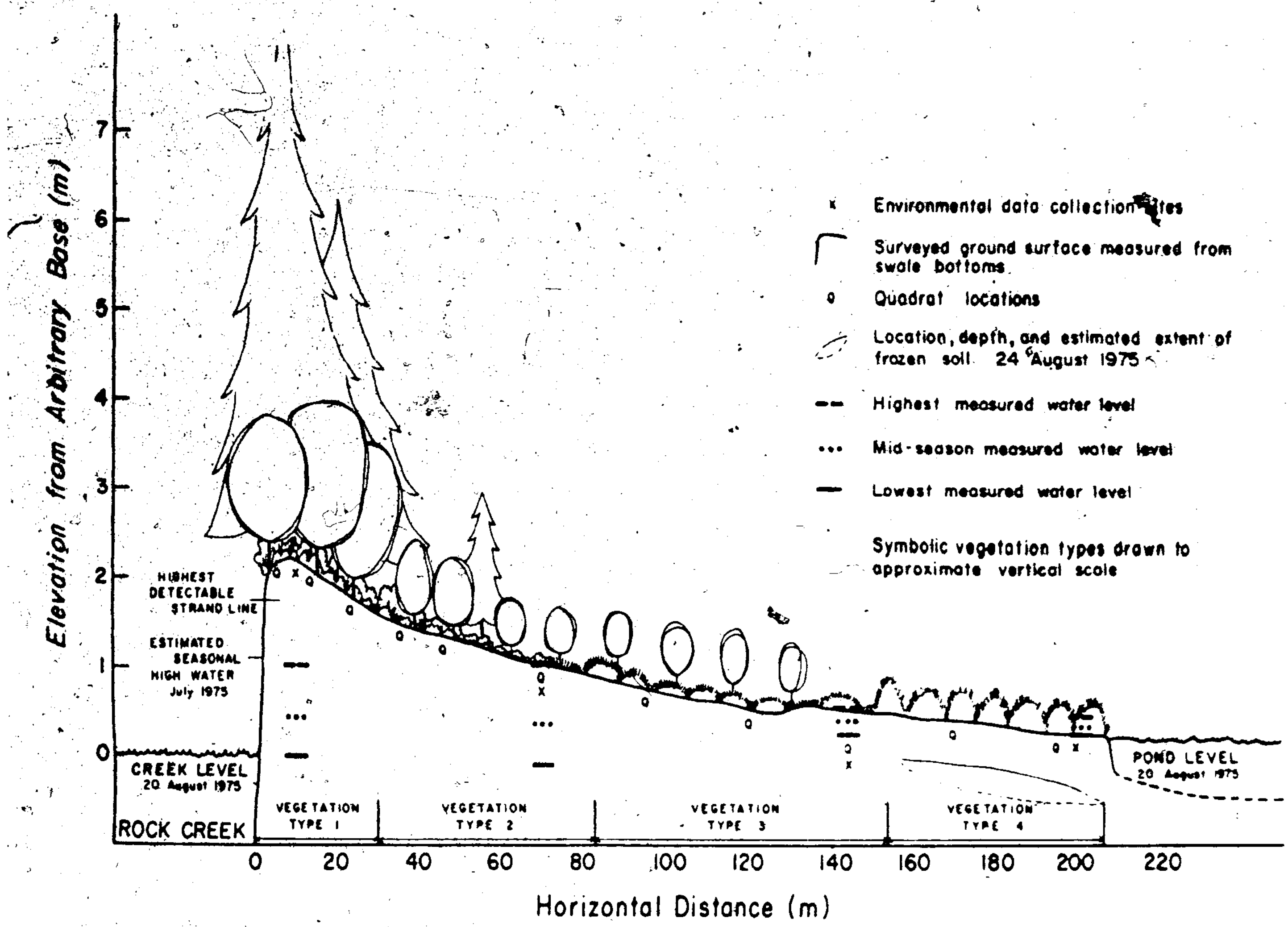



Figure 13. Surveyed Cross-Sectional Profile of a Typical Transect from Rock Creek to Open Water (Transect 3)

# CHAPTER 5: DISCUSSION AND CONCLUSION

# 5. DISCUSSION AND CONCLUSION

## 5.1 Vegetation Classification

Theoretically, the sample plot size was too small to adequately (90%) sample the most complex communities. Despite this, it does not seem likely that a significantly different classification would have been obtained with a larger plot size. As mentioned, the nested quadrat data show that the minimal plot size needed for vegetation type 2 was 8 $m^2$. All type 2 sites as well as the simple type 3 and 4 areas were therefore adequately sampled by the 9 $m^2$ quadrat. Thus the type 1 group, differentiated by increased species richness and the presence of certain species, should have been easily distinguishable by comparison with the others, even if not fully described in itself. It seems likely therefore, that the small quadrat size was not detrimental to the final results.

The information analysis classification scheme clearly identified basic differences with the valley's vegetation cover that were visually distinguishable on the ground and which showed a close relationship to initial, subjectively discerned, patterns. The two unit and four unit classes (Figures 11 and 12) are of similar pattern to the three physiognomically defined units that most casual observers would discern. They show fundamental differences from such a classification, however, and are not merely a slightly simpler and a slightly more complex classification respectively. Based upon the total complement of species present in each quadrat, the two unit classification represents two very different groups which form the most fundamental vegetation patterns of the valley and within which other differences are more subtle. Each of these two can be subdivided into two groups which are still different enough to be mappable. The distinction between the preliminary and IA classifications lies most significantly in the division of parts of the structurally very similar shrub thickets, which field inspection verifies as being obviously different, into each of the two main vegetation classes. Even at this simple level, a clear improvement in classification has been achieved over the physiognomic distinctions first used. It should also be remembered that, although they were not examined in this study, some of the classes "below" 1-4 also represent distinguishable, repeatedly occurring vegetation types (3(a)-3(b) and 4(a)-4(b) certainly do). Overall, therefore, the information analysis classification produced meaningful groupings which were objectively defined, and hence are highly comparable.

This seemingly satisfactory classification scheme yielded 9 units at its third level. But several of them did not seem as consistently identifiable in the field as the first four, and I had previously identified 15 vegetation types by inspection. The discrepancy seems likely to be due to a combination of two causes - inconsistencies in the initial analysis and the limitations inherent in a presence/absence classification.

Firstly, the initial identifications were based upon easily observed features of easily distinguishable species. The obvious spruce, willows and birch and those herbs flowering in mid-June provided a biased and not necessarily consistent basis for the preliminary entitiation. As well, lack of familiarity with the local flora undoubtedly reduced my sensitivity to overall patterns of variation which otherwise might have been noted and described differently.

It seems likely that the major part of the disparity between the number of communities recognized versus those identifiably classified is due to limiations in the classification scheme itself. Firstly, because any classification can only group together like entities, this sample of 114 units, two-thirds of which were in vegetation type B, may not possess adequate information for meaningful divisions at lower levels, even if they exist. Most importantly, though, is the fact that below the 4 unit division, the remaining classes were much more similar to each other (those below the 9 unit division were not recorded in Figure 10 but also show crowding of divisions at similar levels of "information") and species presence data were probably not sufficient to clearly distinguish more than a few of them.

Goodall's (1973) views support this interpretation. Thus the IA classification provided sound and distinct classes at the 4-unit level examined in the present study, although the further divisions are probably not as reliable.

## 5.2 Vegetation-Landform Relationships

### 5.2.1 Soil Nutrients

The working hypothesis of this study was that the vegetation patterns of the study site would be correlated to ecologically "effective" factors which varied at the landform scale; soil nutrients and soil moisture were selected as likely factors to test. Analysis of data from the soil samples shows that differences in available soil nutrients and in the soil attributes which often affect nutrient availability, pH and organic matter content, do not correlate with vegetation distribution patterns. This permits only one conclusion: the vegetation patterns within the study area cannot be attributed to differences in availability of the important plant nutrients.

These negative results seem reasonable when one considers the origin of the parent materials involved - alluvium transported from sedimentary rocks of the Rocky Mountains. The homogenizing action of transportation should help to establish, despite differences in landform configuration, a strongly similar chemical basis for the soils. Further, the immaturity of all the soils suggests little post-deposition modifications have occurred. The established drainage system and lack of organic matter buildup have precluded development of major differences in nutrient cycling systems and consequent development of new patterns of nutrient distribution. All these conditions contribute to the highly similar plant nutrient contents found in soils within the different vegetation patterns. That these conclusions differ from those of Dirschl and Coupland (1972) may be due to the fact that their study, despite the claim of the article, was done on a lacustrine plain and not on a delta or alluvial plain. Such environments possess many potentially different characteristics.

### 5.2.2 Landforms and Vegetation Patterns

The elevation of all type A and type B vegetation types are significantly different from each other. The four major vegetation types of the study site possess progressively different elevations along each transect on which they occur. These differences reflect the relief of the alluvial landforms of the valley: landforms are indeed correlated with the major patterns of plant distributions.

Relief by itself does not influence plant growth at all, but it is ecologically significant here (as in many other delta/floodplain areas) because relief is highly correlated with water levels. The existence of higher and well-drained levees, splays and other features, and lower, flat interchannel sites in an area with abundant water results in the creation of two distinct habitats.

The properties of higher, better drained sites versus lower, wetter ones are well known, as are the normal plant responses (Brady 1974, Daubenmire 1974, etc.). In the lower Rock Creek Valley, the moisture content data suggests that the stream levees provide a moist but drained site, presumably with relatively warm temperatures, a relatively long growing season, good aeration, and the other attributes of a "mesic" habitat. The relatively benign conditions of the higher ground support many species. The lower areas of the back-swamps are always wet and possess harsh conditions for plant establishment and growth - relatively low temperatures and presumably low oxygen. The waterlogged interchannel areas thus support a depauperate flora. The line of intersection between the horizontal surface corresponding to the highest recorded water table level (which also matched early season levels observed in April, 1976), and the sloping land surface matches the type Z/A division line almost exactly. These two very different vegetation types are a consequence of two very different environments. They are abruptly divided since the presence of high water levels acts as an environmental control. Local microtopography provides the environmental variation (Harper and Sagar 1953) that permits a narrow ecotonal transition between the two vegetation types.

There was no significant difference in those environmental factors, considered above, from type 1 and type 2 sites, but inspection of the field data suggests reasons for the differing plant distribution patterns. Type 1 sites, despite differences in absolute elevation, are all on relatively high (greater than 1 m) sites beside Rock Creek. Since the creek does not normally come near to exceeding its banks, the base level itself will not induce saturated soil conditions in these creekside sites and the proximity of the creek channel permits rapid water table response, and hence more drainage, when the water level falls in early summer and following rainstorms. At those times of the year, however, water levels are high everywhere else. Type 2 sites, which possess a variety of drainage regimes, including some which are very well drained in mid-season, are then inundated or have water tables close to the ground surface (Appendix 6). This is related more to their relative positions in the landscape rather than to their absolute elevations: they are mostly downslope of type 1 sites (e.g., Figure 13). Four of the exceptions are on transects 11, 12 and 15, and 4 - beside groundwater fed streams and a water filled abandoned channel, respectively - which have relatively steady water levels which lower relatively slowly during the season.

These features of type 2 sites must, in the first case, add moisture from uphill drainage, and, in both cases, prolong (relatively) early season and post rainy weather wetness. The greater distance to Rock Creek, or the slower water level responses of the other nearby water bodies must increase the time required for the water table to lower and thus contribute to a moister site. Thus it would seem that the important difference between sites which support type 1 and type 2 vegetation is in the length and reliability of drained soil conditions - a conclusion in conformity with Dirschl and Coupland's (1972) "summary of pertinent literature."

The high water record of 16 August, 1976 (Appendix 6) from site 1 of transect 4 shows it to be well drained, unlike other type 2 sites. April observations noted standing water in depressions there, however, as with other type 2 sites, and it seems likely that similar moisture related controls over vegetation pattern operate there as elsewhere. The spring versus mid-season differences is probably due to the midwinter freezing ~~of~~ overland flow from springs near the edge of the study area (Figure 8) which was seen to create a large icing 30 to 40 cm thick in that part of the valley. This raised the level of the "ground surface" in the interchannel areas near transect 4, which perched the runoff and meltwater levels much higher than was possible in midseason when such ice is not present. The pattern of slow drainage, discussed above, can then become influential.

The only type 2 site on the edge of Rock Creek, on transect 14, was on a slip-off slope. This site was considerably lower than the transect 1 site across the creek which supported type 1 vegetation. Like the other type 2 areas, on low banks downstream, its landform position seems to indicate a lengthy period of high ground water levels and, again, water-level control over vegetation type.

The specific environmental control over the distribution of the Salix species is not clearly distinguishable, despite the often sharp type 3 and 4 division which their presence and absence create. Daubenmire (1968) described this common vegetational pattern and others like it. He suggested that such zonations are due to different species' tolerances to factors often limiting in standing water habitats - nutrients (seemingly not a factor here), temperature and aeration of the rooting medium. The patterns are probably rendered particularly distinct, he says, by the existence of the distribution of the superior competitor to sites near the limit of its environmental tolerance, followed sharply by the different vegetation growing without that species present.

### 5.2.3 Soil Frost

Although distinguishing exact cause and effect is impossible without experiment, it seems likely that the presence of ice late into the season in the species-poor sites is a consequence rather than an initiator of the different vegetation patterns. The sedge meadow and willow/sedge areas with long enduring frost (or permafrost in some cases) all possess the same properties that seem likely to contribute to the frost presence. The dead sedges form a dense mat averaging from about 15 to 50 cm above the ground surface in different areas, which tends to completely cover the swales between the tussocks. This is likely to have two significant effects, each typical of vegetative cover but here more extreme, that work to maintain low soil temperatures: the shading of the soil and the provision of an insulating dead air space above the cold ground (Geiger 1961).

While the presence of frozen ground probably slows local water level responses to changes in base level, the surface drainage is continuous with the open water (Figure 13) and the frost should not be a cause of the high water tables. If high water is independent of, and not maintained by, soil frost, then it is most likely that heavy sedge growth has been fostered by wet conditions of low sites. It also seems likely, therefore, that the long lasting soil frost is a consequence of conditions inherent to that vegetation cover, rather than being one of the causes of such plant growth.

5.2.4 Vegetation Patterns Showing Different Environmental Relationships

in three parts of the study site, important vegetation patterns of the same type as those described seem to have different environmental relationships than those already discussed. Along Whitefish Creek a forest cover upstream gives way to a stream bank community identical to the back-swamp vegetation. Only near to the confluence with Rock Creek do the stream banks again possess type 2 vegetation. The stream is groundwater fed, carries no visible sediment during the field season, and possesses no levees. The bank sides are nearly vertical, being cut into the valley fill. The stream surface establishes the local base level. In upstream areas and near Rock Creek, the creek has cut deeply (2 to 2.5 m) into the substratum, and its surface is normally about 1 m or more below the surrounding ground surface. As elsewhere in the valley, soil drainage - in this case resulting from the depression of the groundwater table rather than site elevation due to landform structure - seems the likely cause of the more complex vegetation along Whitefish Creek. (The zone of trees is likely better developed on the north side of the creek because of the waterlogging influence of overland flow, from groundwater springs, down the interchannel basin on the south side.)

Type B vegetation may exist upstream from the lake since it acts as the local base level. The creek is consequently incised little near to the lake, due to the low gradient in that part of the valley. The stream surface has been maintained at or near the edge of the creek banks, which are not well drained and thus possess typical wet site vegetation.

Magic Creek, a groundwater-fed stream with distinctly smaller flow than Whitefish, is partially paralleled by type 2 vegetation and partly by species-poor types. These patterns seem to reflect three influences - current stream regime, relict landform features, and overland flow from spring discharge on the north slope. That Magic Creek is underfit for the leveed channel outlined by the trees beside it is easily visible on Plate 6. The channel remains (occupied by Magic Creek through most of its length) but the initiating stream has not flowed for many years, judging from the similar vegetation patterns today and visible on 1952 aerial photographs. Only a narrow central strip of the former levees supports more complex vegetation. The relatively higher local base level now being maintained has killed many trees, especially in the northwest corner of the study area. This pattern seems similar to the levee subsidence and vegetational degeneration along abandoned channels described by Vann (1959) and Thom (1967). The north-south creekside asymmetry of the vegetation patterns seems to reflect the higher water levels generated by the flow of springs from the north hillside, as compared to the somewhat better (formerly perhaps much better) drained areas on the south side of the creek.

Another apparently anamalous situation lies in the water level, site elevation and frost presence pattern of the third site on transect 5 (Table I). This type 4 sedge meadow has very low water tables in late summer, loses its frost fairly early in the season, and is much higher above the Rock Creek base level than the other type 4 sites. It is the only transect between the abandoned channel of Rock Creek and Rock Creek itself. The typical cross-sectional topography is of similar relief here to that elsewhere (e.g., Figure 13), but is of higher elevation, probably reflecting the high levees (or deeper downcutting) of the two large channels nearby. While the summer water levels drop quite low, the sedges maintain themselves (with somewhat less vigorous growth than elsewhere but with no signs of invasion by other species) in equilibrium with their environment. However, conditions in the early season are similar here and in other sedge sites - all then possess standing water. After the high rainfall of August 1976 this site was flooded to similar levels, suggesting that the same saturated conditions control moist site vegetation patterns here as elsewhere in the valley.

## 5.3 Conclusions

In this relatively simple alluvial habitat, where no regular floods produce continual environmental variation and major complexities of vegetational dynamics, the broad vegetation-landform correlations seem directly relatable to identifiable ecological causes. But simple correlations of landforms and their constituent soil attributes alone could not explain even landscape scale phenomena, although only edaphic factors were ultimately identified as controlling plant distributions. Active consideration of the basic environmental processes and of past events was necessary in achieving even the first level of understanding of the valley floor vegetation presented here. Despite the original intentions of this study, therefore, the "static" conditions of the valley could not, reasonably, be separated from the dynamic ones for separate investigation. That initial emphasis was valuable because of its provision of basic information, which permitted some conclusions, but it was more useful as a basis for further observation and interpretation of the valley environment. Ecosystems are entities that operate over time. Both their subunits and the processes inherent to them must be considered in a balanced analysis.

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WATER SURVEY OF CANADA, 1976.

# APPENDICES

# APPENDIX 1

## DESCRIPTIONS OF REPRESENTATIVE SOIL PROFILES

1. Location: Transect 3, Site 1
   Date Described: 1 August, 1975

*Rego Gleysol*

| Horizon | Depth (cm) | Description |
|---|---|---|
| L | 3.5-0 | Semi-decomposed organic matter; abundant micro and very fine, plentiful fine, and few medium and coarse roots; abrupt, wavy boundary 1-2 cm thick. |
| $C_1$ | 0-10 | Dark grayish brown (10 YR 4/2 d) very fine sandy loam; common fine faint light brown mottles; weak, structureless, amorphous, very friable; abundant micro and few medium and coarse roots; abrupt wavy boundary 1-2, 5 cm thick. |
| $C_2$ | 10-42 | Brown to dark brown (10 YR 4/3 d) silt loam to very find sandy loam; common fine faint light brown mottles, weak, structureless, single grain loose - very friable, abundant micro, very fine and fine, plentiful medium and few coarse roots, gradual wavy boundary 6-11 cm thick. |
| $C_3$ | 42-100 | Dark grayish brown (10 YR 4/2 d), very fine sandy loam; many fine faint light brown mottles; weak, structureless, amorphous, very friable; abundant micro, very fine and fine, few medium and very few coarse roots; composed of thin, wavy, near horizontal laminations. |

2. Location: Transect 3, Site 2
   Date Described: 1 August 1975

*Rego Gleysol*

| Horizon | Depth (cm) | Description |
|---|---|---|
| L | 1. -0 | Semi-decomposed organic matter, abundant micro, very fine, plentiful fine, and few medium roots, abrupt wavy boundary 1-2 cm thick. |
| $C_1$ | 0-38 | Grayish brown (10 YR 3/3), silt loam to very fine sandy loam, many fine distinct orange brown, many fine faint light brown, and few medium distinct orange-brown mottles, weak structureless, amorphous, abundant micro and very fine, plentiful fine and few medium roots, clear smooth boundary 4-7 cm thick. |
| $O_B$ | 23-25 | Semi-decomposed organic matter, abundant micro and very fine roots, abrupt smooth boundary 0-1 cm thick. |
| $C_2$ | 38-100 | Brown to dark brown (10 YR 4/3 d), very fine sandy loam to silt loam, weak, structureless, amorphous, plentiful, micro, very fine and fine roots, organic matter found within horizon. |
| $O_B$ | 49-50.5 | Semi-decomposed organic matter, abundant micro and very fine roots, abrupt wavy boundary 0-1 cm thick. |
| $O_B$ | 72-75 | Semi-decomposed organic matter, abundant micro and very fine roots, abrupt wavy boundary 0-1 cm thick. |

# APPENDIX 2

ALBERTA RESEARCH COUNCIL
WATER ANALYSIS REPORT

Mer 6   Tp 52   Rge 2   Sec 8   Lsd 1

| | | | |
|---|---|---|---|
| Lab no. | 75 751 | | D M Y |
| Index no. | 5698 | Date sampled | 22 7 75 |
| Well depth(ft) | | Date submitted | |
| Water level(ft) | | Date analysed(major) | 18 8 75 |
| Top open interval(ft) | | Date analysed(minor) | |
| Bottom open interval(ft) | | Sampled by | R.BARNES |
| Altitude(ft) | | Sample Source | SPR |
| Bedrock elevation(ft) | | TDS(mg/l) | 196.0 |
| Owners name | RESCOUNCIL | Hardness(as CaCO3) | 192.2 |
| Field Cond(micromhos/cm) | 320 | Alkalinity(as CaCO3) | 165.6 |
| Field pH | 7.6 | Cond(micromhos/cm@25C) | 360.0 |
| | | Lab pH | 7.8 |

MAJOR CONSTITUENTS

| | mg/l | meq/l | % of total anion or cation |
|---|---|---|---|
| Calcium(Ca) | 52.0 | 2.59 | 64.2 |
| Magnesium(Mg) | 15.2 | 1.25 | 30.9 |
| Sodium(Na) | 3.8 | 0.17 | 4.1 |
| Potassium(K) | 1.3 | 0.03 | 0.8 |
| Carbonate(CO3) | 0.0 | 0.00 | 0.0 |
| Bicarbonate(HCO3) | 207.0 | 3.39 | 85.8 |
| Sulphate(SO4) | 25.5 | 0.53 | 13.4 |
| Chloride(Cl) | 1.0 | 0.03 | 0.7 |
| Nitrate(NO3) | 0.2 | 0.00 | 0.1 |
| Hydroxide(OH) | | | |
| Silica(SiO2) | 3.8 | | |
| Calcium(Acid) | 47.0 | | |
| Magnesium(Acid) | 14.3 | | |

| | |
|---|---|
| Total anions(epm) | 3.955 |
| Total cations(epm) | 4.043 |
| Ion balance error(%) | 1 |
| TDS balance error(%) | 4 |

MINOR CONSTITUENTS

Iron 0.10 ppm

OTHER MEASUREMENTS

Field Temp(C) 3.00   Fluoride(F) 0.10 ppm

# APPENDIX 3

## VASCULAR PLANTS FOUND IN STUDY AREA - 1975

Equisetaceae

1. *Equisetum arvense* L.
2. *Equisetum fluviatile* L.
3. *Equisetum scirpoides* Michx.
4. *Equisetum variegatum* Schleich.

Pinaceae

5. *Juniperus communis* L.
6. *Picea glauca* (Moench) Voss X *englemannii* Parry ex Englem.

Juncaginaceae

7. *Triglochin palustris* L.

Gramineae

8. *Agropyron dasystachyum* (Hook.) Scribn.
9. *Agrostis scabra* Willd.
10. *Bromus pumpellianus* Scribn.
11. *Calamagrostis neglecta* (Ehrh.) Gaertn.
12. *Deschampsia caespitosa* (L.) Beauv.
13. *Festuca brachyphylla.* Schultes
14. *Festuca saximontana* Rydb.
15. *Hierochloe odorata* (L.) Beauv.

16. Phleum alpinum L.

17. Poa alpina L.

18. Poa arctica R. Br.

19. Poa interior Rydb.

20. Poa leptocoma Trin.

21. Trisetum spicatum (L.) Richt.

Cyperaceae

22. Carex aquatilis Wahlenb.

23. Carex aurea Nutt.

24. Carex capillaris L.

25. Carex gynocrates Wormsk.

26. Carex vesicaria L.

27. Eriophorum brachyantherum Trautv.

Juncaceae

28. Juncus balticus Willd.

29. Juncus castaneus Sm.

Liliaceae

30. Tofieldia pusilla (Michx.) Pers.

Orchidaceae

31. Cypripedium passerinum Richards.

32. Habenaria hyperborea (L.) R.Br.

33. Spiranthes romanzoffiana Cham. & Schl.

Salicaceae

34. *Populus balsamifera* L.

35. *Populus tremuloides* Michx.

36. *Salix arbusculoides* Anderss.

37. *Salix candida* Fluegge.

38. *Salix glauca* L.

39. *Salic interior* Rowlee.

40. *Salix mackenzieana* (Hook.) Barratt

Betulacea

41. *Betula pumila* L. var. *glandulifera* Regel.

Polygonaceae

42. *Polygonum viviparum* L.

43. *Rumex occidentalis* S. Wats. var. *fenestratus* (Greene) Le Page.

Caryophyllaceae

44. *Arenaria rubella* (Wahlenb.) J.E. Sm.

45. *Cerastium beeringianum* Cham. & Schlect.

46. *Stellaria longipes* Goldie

Ranunculaceae

47. *Anemone multifida* Poir.

48. *Anemone parviflora* Michx.

49. *Ranunculus gmelinii* Dc.

50. *Ranunculus natans* C.A. Mey. var. *intertextus* (Greene) L. Benson.

Crucifereae

51. *Arabis lyrata* L. var. *kamchatica* Fisch.
52. *Braya humilis* (C.A. Mey.) Robins.
53. *Cardamine pensylvanica* Muhl.
54. *Descurainia pinnata* (Walt.) Britt.
55. *Draba praealta* Greene
56. *Rorripa islandica* (Oeder) Borbas.

Saxifragaceae

57. *Chrysosplenium tetrandum* (Lund.) Fries.
58. *Parnassia montanensis* Fern. and Rydb.
59. *Ribes oxyacanthoides* L.

Rosaceae

60. *Amelanchier alnifolia* Nutt.
61. *Dryas drummondii* Richards.
62. *Fragaria virginiana* Duchesne.
63. *Geum macrophyllum* Willd.
64. *Potentilla fruticosa* L.
65. *Potentilla gracilis* Dougl.
66. *Rosa acicularis* Lindl.
67. *Rubus acaulis* Michx.
68. *Astragalus alpinus* L.
69. *Astragalus eucosmus* Robins.
70. *Astragalus frigidus* (L.) A. Gray var. *americanus* (Hook.) S. Wats.
71. *Hedysarum alpinum* L.

72. Lathyrus ochroleucux Hook.

73. Oxytropis sericea Nutt. var. spicata (Hook.) Barneby.

75. Oxytropis splendens Dougl.

76. Vicia americana Muhl.

Elaeagnaceae

77. Elaeagnus commutata Berhn.

78. Shepherdia canadensis (L.) Nutt.

Onagraceae

79. Epilobium angustifolium L.

80. Epilobium glandulosum Lehm.

81. Epilobium latifolium L.

82. Epilobium leptophyllum Raf.

Pyrolaceae

83. Moneses uniflora (L.) A. Gray

84. Pyrola asarifolia Michx. var. purpurea (Bunge) Fern.

85. Pyrola secunda L.

Ericaceae

86. Arctostaphylos rubra (Rehder & Wils.) Fern.

87. Arctostaphylos uva-ursi (L.) Spreng.

Primulaceae

88. Primula egaliksensis Wormskj.

Gentianaceae

89. Gentianella amarella (L.) Borner ssp. acuta (Michx.) J.M. Gillett

Polemoniaceae

90. Polemonium caeruleum L. ssp. occidentale (Greene) Davidson

Boraginaceae

91. Mertensia paniculata (Ait.) G. Don

Scrophulariaceae

92. Castelleja miniata Dougl.

93. Castilleja occidentalis Torr.

94. Euphasia disjuncta Fern. & Wieg.

95. Pedicularis groenlandica Retz.

96. Rhinanthus crista-galli L.

97. Veronica americana (Raf.) Schw.

Rubiaceae

98. Galium boreale L.

Caprifoliaceae

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

Valerianaceae

100. *Valeriana septentrionalis* Rydb.

Campanulaceae

101. *Campanula rotundifolia* L.

Compositeae

102. *Achillea millefolium* L.
103. *Agoseris glauca* (Pursh.) Raf.
104. *Antennaria pulcherrima* (Hook.) Greene
105. *Antennaria rosea* Greene.
106. *Arnica fulgens* Pursh.
107. *Aster foliaceus* Lindl.
108. *Aster occidentalis* (Nutt.) T. & G.
109. *Aster sibericus* L.
110. *Erigeron lonchophyllus* Hook.
111. *Petasites vitifolius* Greene
112. *Senecio pauperculus* Michx.
113. *Solidago multiradiata* Ait.
114. *Taraxacum ceratophorum* (Ledeb.) DC.
115. *Taraxacum officinale* Weber.

## APPENDIX 4

## PRELIMINARY CLASSIFICATION OF VEGETATION TYPES

| Vegetation Type | |
|---|---|
| 1. | Tussocky broad bladed sedge meadow. |
| 2. | Tussocky narrow bladed sedge meadow. |
| 3. | Sedge meadow with occasional low willow present. |
| 4. | Tall willow/sedge/grass savanna. |
| 5. | Low tussock grass/sedge/herb. |
| 6. | Low spruce/low willow/herb. |
| 7. | Low willow/spruce. |
| 8. | Spruce/willow, mixed flora including many legumes. |
| 9. | Willow/low spruce/low tussock sedge/elephant head. |
| 10. | Willow/swamp birch/occasional spruce. |
| 11. | Low spruce/low willow/tussocky sedge. |
| 12. | Sedge/bryophyte. |
| 13. | Low spruce/low willow/swamp birch. |
| 14. | Tall spruce/low willow/low birch. |
| 15. | Low willow/high tussock sedge. |

# APPENDIX 5

## SPECIES RECORDED IN VEGETATION QUADRATS

(Number codes follow Appendix 3)

| Vegetation Type | Transect, and Quadrat | Species Recorded |
|---|---|---|
| 1(a) | 1,01 | 1,3,4,6,8,20,28,38,39,40,66, 71,78,79,84,85,93,102,104 |
| 1(a) | 3,01 | 1,3,4,6,22,32,38,40,41,62, 69,71,85,93.102 |
| 1(a) | 3,02 | 1,3,4,6,22,32,38,39,40,41, 62,69,72,78,84,91,93,95,99, 102,105,110,112,114 |
| 1(a) | 3,03 | 1,3,4,6,22,23,38,39,40,41, 62,83,84,85,95,102,105,110, 112,114,115 |
| 1(a) | 5,01 | 1,4,6,8,17,22,34,38,39,40,42, 62,71,73,78,49,84,87,89,102, 112 |
| 1(a) | 5,02 | 1,3,4,6,21,22,38,39,40,62, 71,102,104,105,112 |
| 1(a) | 5,03 | 1,4,6,22,23,35,38,39,40,62, 89,93,102,105,112,114 |
| 1(a) | 5,04 | 1,6,17,21,22,28,38,39,40,42, 47,62,69,99,102,104,105,109, 110 |
| 1(a) | 8,01 | 1,3,4,6,8,21,23,38,39,40,62, 71,79,84,85,93,95,102,104,115 |
| 1(b) | 1,02 | 1,3,4,6,8,23,28,33,34,39,40, 41,58,62,76,78,79,84,93,95, 102,104,110,112 |
| 1(b) | 1,03 | 1,3,4,8,11,15,20,21,22,23, 28,32,33,34,39,40,58,62,79, 84,85,93,95,102,104 |
| 1(b) | 1,04 | 1,3,4,6,22,23,24,32,34,38, 39,40,41,42,58,62,78,79,84, 85,93,95,102,104,105 |

| Vegetation Type | Transact, and Quadrat | Species Recorded |
|---|---|---|
| 1(b) | 2,01 | 1,3,4,6,8,11,12,20,21,22,34, 38,39,40,41,42,62,64,67,70, 71,78,79,84,85,93,95,102,104, 110,112 |
| 1(b) | 2,02 | 1,3,4,6,20,21,22,23,32,33,34, 38,39,40,41,42,58,62,67,70, 84,85,89,93,95,100,102,104, 105,107,110 |
| 1(b) | 2,03 | 1,3,6,22,23,32,33,38,39,40, 58,62,67,78,84,85,93,95,102, 104,107,110,112 |
| 1(b) | 9,01 | 1,6,12,22,23,28,32,33,38,39, 40,58,62,64,78,84,93,95,102, 104,105,110,112 |
| 1(b) | 9,02 | 1,4,6,8,22,23,28,32,34,38,39, 40,58,63,64,76,78,79,84,93, 95,102,104,110,112 |
| 1(b) | 13,01 | 1,3,4,6,22,32,38,39,40,58, 62,67,76,78,79,84,85,95,102, 110 |
| 1(b) | 13,02 | 1,3,4,6,22,23,28,32,38,39, 40,41,58,62,64,67,84,85,95, 96,102,104,105,112 |
| 2(a) | 2,04 | 6,20,22,32,38,39,40,58,62,63, 67,84,93,110,112 |
| 2(a) | 2,05 | 22,32,38,39,40,58,62,67,82, 84,112 |
| 2(a) | 3,04 | 6,12,22,32,38,40,69,102,105, 107,110,112,114 |
| 2(a) | 3,05 | 6,20,22,38,39,40,62,110,112 |
| 2(a) | 3,06 | 6,22,38,39,40,46,112,114 |
| 2(a) | 4,04 | 12,22,23,38,40,63,82,110,112 |
| 2(a) | 9,03 | 22,23,28,32,38,39,40,62,63, 82,84,110,112 |

| Vegetation Type | Transect, and Quadrat | Species Recorded |
|---|---|---|
| 2(a) | 12,01 | 4,22,38,39,40,58,63,82,110, 112 |
| 2(b) | 4,02 | 1,3,6,12,17,21,22,23,28,33 38,40,42,84,93,95,112 |
| 2(b) | 4,03 | 1,6,12,22,[illegible],28,[illegible],112 |
| 2(b) | 11,01 | 1,3,6,11,22,[illegible],67, 79,85,91,[illegible] |
| 2(b) | 11,02 | 11,22,26,38,39,40,41,62,67, 79,84 |
| 2(b) | 14,01 | 1,3,12,22,38,39,40,62,79, 84,102,104,111 |
| 2(b) | 15,01 | 3,12,22,23,27,28,38,39,40,41, 42,58,95,110,112 |
| 2(c) | 4,01 | 1,4,6,22,23,32,38,40,42,62, 69,70,76,84,93,95,104,110,112 |
| 2(c) | 5,05 | 8,11,20,22,26,38,40,62,63,82, 89,93,95,105,110,112 |
| 2(c) | 8,02 | 1,4,6,8,11,12,20,22,23,28,38, 39,40,62,76,79,84,93,95,110, 112,115 |
| 2(c) | 8,03 | 1,3,4,6,8,20,22,23,32,34,36, 38,39,40,58,62,63,82,84,95, 110,112,114,115 |
| 2(c) | 13,03 | 6,8,15,22,23,28,38,39,40,41, 42,62,64,67,70,82,95,105, 110,112,115 |
| 3(a) | 1,05 | 1,22,39,40 |
| 3(a) | 2,06 | 6,11,22,38,39,40,67,82,110 |
| 3(a) | 3,07 | 22,28,37,38,39,40,41,82,112 |
| 3(a) | 3,08 | 22,37,38,39,40,82,110 |
| 3(a) | 3,09 | 22,37,38,39 |

| Vegetation Type | Transect, and Quadrat | Species Recorded |
|---|---|---|
| 3(a) | 4,05 | 12,22,37,38,40,82,112 |
| 3(a) | 4,06 | 12,22,37,38,40,82 |
| 3(a) | 4,07 | 12,22,37,38,40,82 |
| 3(a) | 7,05 | 22,38 |
| 3(a) | 8,04 | 1,11,22,38,39,40,43,82,110 |
| 3(a) | 9,04 | 1,12,22,32,38,39,46,82,115 |
| 3(a) | 14,04 | 11,22,38,39,40,82.112 |
| 3(a) | 14,07 | 11,22,26,38,39,41,82,112 |
| 3(a) | 15,04 | 11,22,39,40,41 |
| 3(a) | 15,05 | 22,38,40 |
| 3(a) | 15,06 | 11,22,38,40 |
| 3(b) | 6,01 | 22,26,38,40,41,46,82 |
| 3(b) | 6,02 | 4,6,22,25,28,38,40,41,67, 84,95 |
| 3(b) | 6,03 | 22,25,38,40,41,67,95 |
| 3(b) | 7,01 | 11,22,27,38,40,41,95 |
| 3(b) | 7,02 | 4,22,38,40,41,67 |
| 3(b) | 7,03 | 11,22,38,40,41 |
| 3(b) | 7,04 | 11,22,38,40,41,82 |
| 3(b) | 10,02 | 6,22,26,38,39,40,41,82 |
| 3(b) | 15,02 | 3,6,22,38,40,41,42,69 |
| 3(b) | 15,03 | 3,6,22,38,40,41 |
| 3(b) | 15,07 | 11,22,38,40,41 |
| 3(b) | 15,08 | 11,22,38,40,41 |
| 3(b) | 15,09 | 11,22,38,40,41 |

| Vegetation Type | Transect, and Quadrat | Species Recorded |
|---|---|---|
| 3(b) | 15,10 | 22,26,38,41 |
| 4(a) | 1 06 | 11,20,22,26,39,63,82 |
| 4(a) | 8,05 | 1,11,20,22,26,38,43,62,63, 82 |
| 4(a) | 8,06 | 11,20,22,38,39,43,63,82 |
| 4(a) | 8.07 | 11,20,22,37,38,39,43,63,82 |
| 4(a) | 8,08 | 11,22,26,43,46,47,82 |
| 4(a) | 9,05 | 1,11,20,22,26,38,39,46,63,82 |
| 4(a) | 9,06 | 11,20,22,26,38,39,43,46,82 |
| 4(a) | 9,07 | 11,22,26,38,43,46,63,82 |
| 4(a) | 9,08 | 11,22,26,39,43,46,63,82 |
| 4(a) | 9,09 | 11,22,26,39,43,46,82 |
| 4(a) | 14,02 | 11,12,22,26,38,43,46,63,82, 112 |
| 4(a) | 14,03 | 11,12,22,39,43,46,82,110 |
| 4(a) | 14,10 | 11,22,26,43,46,82 |
| 4(b) | 1,07 | 22,26,82 |
| 4(b) | 1,08 | 22,26,82 |
| 4(b) | 1,09 | 22,26 |
| 4(b) | 2,07 | 11,22,26,38,82 |
| 4(b) | 2,08 | 22,26 |
| 4(b) | 2,09 | 22,43,82 |
| 4(b) | 2,10 | 22,26 |
| 4(b) | 3,10 | 22,26,46,82 |
| 4(b) | 3,11 | 22,26,46 |

| Vegetation Type | Transect, and Quadrat | Species Recorded |
|---|---|---|
| 4(b) | 5,06 | 11,22,26,46,53 |
| 4(b) | 5,07 | 22,26,49,53 |
| 4(b) | 6,04 | 22,38,46,82 |
| 4(b) | 6,05 | 22,46,82 |
| 4(b) | 6,06 | 22,46,82 |
| 4(b) | 8,09 | 22,26,39,43,46 |
| 4(b) | 8,10 | 22,26 |
| 4(b) | 10,01 | 22,26,82 |
| 4(b) | 10,03 | 22,26,38,39,67,82,85 |
| 4(b) | 10,04 | 22,26 |
| 4(b) | 11,03 | 11,22,26,38,82 |
| 4(b) | 11,04 | 22,26 |
| 4(b) | 11,05 | 22,26 |
| 4(b) | 12,02 | 11,22,26,38,39,82 |
| 4(b) | 12,03 | 22,26 |
| 4(b) | 12,04 | 22,26 |
| 4(b) | 13,04 | 22,26,38,67,82 |
| 4(b) | 13,05 | 11,22,26,82 |
| 4(b) | 13,06 | 22,26 |
| 4(b) | 14,05 | 22,82 |
| 4(b) | 14,06 | 22,26,82 |
| 4(b) | 14,08 | 11,22,26,38,39,63,82 |
| 4(b) | 14,09 | 22,26,43,46,82 |
| 4(b) | 14,11 | 22,26,43,46 |

# APPENDIX 6

## GROUNDWATER TABLE LEVELS

| Location | Vegetation Type | Depth of Water Level Below Ground Surface* in cm. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 16-18 June | 29-30 June | 15-17 July | 30-31 July | 12 Aug. | 24 Aug. | 1 Sept. | 23 Sept. | 16† Aug. |
| Transect 1 | | | | | | | | | | |
| Site 1 | 1(b) | | 32 | 72 | 96 | 106 | 92 | 86 | 100 | 27 |
| Site 2 | 4(a) | | 4 | 12 | 40 | 52 | 37 | 22 | 52 | at surf. |
| Site 3 | 4(b) | | +16 | +4 | at surf. | at surf. | +4 | at surf. | at surf. | +5 |
| Transect 2 | | | | | | | | | | |
| Site 1 | 1(b) | | | 114 | 139 | 131 | 136 | 94 | 147 | 67 |
| Site 2 | 3(a) | | | 41 | 64 | 70 | 45 | 29 | 47 | at surf. |
| Site 3 | 4(b) | +10 | +7 | at surf. | at surf. | at surf. | at surf. | at surf. | at surf. | +5 |
| Transect 3 | | | | | | | | | | |
| Site 1 | 1(a) | | | 176 | 202 | 216 | 206 | 202 | 218 | 115 |
| Site 2 | 2(a) | 8 | 4 | 66 | 97 | 115 | 96 | 92 | 108 | +3 |
| Site 3 | 3(a) | 6 | 7 | 11 | 21 | 32 | 13 | 8 | 28 | +4 |
| Site 4 | 4(b) | 6 | 12 | +6 | at surf. | at surf. | +6 | at surf. | at surf. | +16 |
| Transect 4 | | | | | | | | | | |
| Site 1 | 2(c) | | | 132 | 149 | 155 | 148 | 138 | 166 | 77 |
| Site 2 | 2(a) | 12 | 2 | 74 | 94 | 107 | 79 | 74 | 94 | +4 |
| Site 3 | 2(a) | 28 | 5 | +3 | 13 | 6 | 4 | 4 | 15 | +6 |
| Site 4 | 3(a) | 8 | 4 | at surf. | at surf. | at surf. | at surf. | | at surf. | +10 |
| Transect 5 | | | | | | | | | | |
| Site 1 | 1(a) | | | 17[illegible] | 197 | 212 | 202 | 199 | 214 | 140 |
| Site 2 | 2(c) | | | 121 | 173 | 203 | 168 | 160 | | +10 |
| Site 3 | 4(b) | | | 97 | 138 | 166 | 135 | 125 | 151 | +10 |

*Measurements taken with respect to ground surface in a swale bottom

†1976, highest recorded water levels

# APPENDIX 7

## DEPTH TO FROZEN SOIL

| Location | Vegetation Type | Depth of Soil Frost Below Ground Surface[1] in cm (averages of five measurements): 16-18 June | 29-30 June | 11 July | 24 July | 12 Aug. | 24 Aug. | 1 Sept. |
|---|---|---|---|---|---|---|---|---|
| **Transect 1** | | | | | | | | |
| Site 1 | 1 | *no ice* | *no ice* | *no ice* | *no ice* | *no ice* | *no ice* | *no ice* |
| Site 2 | 4 | 18 | 29 | 43 | *no ice* | *no ice* | *no ice* | *no ice* |
| Site 3 | 4 | 7 | | 23 | 35 | 39 | 41 | 43 |
| **Transect 2** | | | | | | | | |
| Site 1 | 1 | *no ice* | *no ice* | *no ice* | *no ice* | *no ice* | *no ice* | *no ice* |
| Site 2 | | *no ice* | *no ice* | *no ice* | *no ice* | *no ice* | *no ice* | *no ice* |
| Site 3 | 4 | 5 | 15 | 33 | 38 | 46 | 47 | 45 |
| **Transect 3** | | | | | | | | |
| Site 1 | 1 | *no ice* | *no ice* | *no ice* | *no ice* | *no ice* | *no ice* | *no ice* |
| Site 2 | 2 | 41 | 44 | 100+ | *no ice* | *no ice* | *no ice* | *no ice* |
| Site 3 | 3 | 14 | 19 | 31 | 44 | 51 | *no ice* | 49 |
| Site 4 | 4 | 13 | 29 | 32 | 50 | 54 | 64 | 56 |
| **Transect 4** | | | | | | | | |
| Site 1 | 2 | 36 | 55 | *no ice* | *no ice* | *no ice* | *no ice* | *no ice* |
| Site 2 | 2 | 36 | 55 | *no ice* | *no ice* | *no ice* | *no ice* | *no ice* |
| Site 3 | 3 | 25 | 36 | 50 | 72 | *no ice* | *no ice* | *no ice* |
| Site 4 | 3 | 5 | 18 | 32 | 45 | 61 | 62 | 55 |
| **Transect 5**[2] | | | | | | | | |
| Site 1 | 1 | 57 *(patches)* | *no ice* | *no ice* | *no ice* | *no ice* | | |
| Site 2 | 2 | 42 *(patches)* | *no ice* | *no ice* | *no ice* | *no ice* | | |
| Site 3 | 4 | 34 *(patches)* | *no ice* | *no ice* | *no ice* | *no ice* | | |

[1]Measurements taken with respect to ground surface in swale bottoms

[2]Transect 5 data recorded in 1976