VEGETATION MAPPING IN NORTHERN MANITOBA
WITH LANDSAT:
PRELIMINARY ASSESSMENT OF BARREN-GROUND
CARIBOU WINTERING RANGE

By

Larry Nelson Gordon Horn

A Practicum Submitted
In Partial Fulfillment of the
Requirements for the Degree,
Master of Natural Resources Management

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ABSTRACT

Vegetation type maps covering approximately 76,000 km^2 of northern Manitoba were made using Landsat multispectral scanner data to provide a preliminary assessment of barren-ground caribou (*Rangifer tarandus groenlandicus*) wintering range. Landsat digital data for six summer Landsat scenes were analysed with principal component enhancement. Extensive ground sampling was conducted during three summer field seasons to determine species composition and spatial distribution of major vegetation associations. Mapping accuracy was assessed by ground truth and low flying aircraft. A preliminary winter range use study was conducted in February, 1981.

Vegetation associations were represented on six National Topographic Series (NTS) maps at a scale of 1:250,000. The subarctic forest region, characterized by seven major vegetation associations, covered approximately 75 percent of the study area. The tundra region, characterized by five major vegetation associations, covered the remaining 25 percent. Recent forest fires, 1972 to 1980, have burned approximately 9 percent of the subarctic forest region. Three categories of burn were identified.

A preliminary assessment of the suitability of each vegetation association to support barren-ground caribou, revealed approximately 25 percent of the study area to be prime winter habitat, 35 percent to be satisfactory, 15 percent to be marginal, and 10 percent to be unsatisfactory. Water bodies cover 15 percent of the study area.

Factors influencing mapping accuracy were complex, and included variation among vegetation classes in both errors of inclusion and omission. Sources of mapping error were explored and biological significance of classification and mapping errors were discussed.

ACKNOWLEDGEMENTS

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ACRONYMS

ARIES	Applied Resource Image Exploitation System
CCRS	Canada Center for Remote Sensing
dbh	diameter measured at breast height
DICS	Data Image Correction System
EBIR	Electron Beam Image Recorder
ERTS	Earth Resources Technology Satellite
MRSC	Manitoba Remote Sensing Center
NAPL	National Air Photo Library
NRC	National Research Council
NTS	National Topographic Series
PASS	Prince Albert Satellite Station
PC	Principal Component
PCA	Principal Component Analysis
SCSS	Shoe Cove Satellite Station
UTM	Universal Transverse Mercator
VSI	Värriö Snow Index
ZTS	Zoom Transfer Scope

1.0 INTRODUCTION

1.1 Problem Statement

The rapid decline of the Kaminuriak caribou since the 1940's suggests an urgent need for development of a coordinated management strategy. Habitat mapping would enable greater understanding of the relationship between caribou and their environment. Because the total range required to satisfy caribou's winter biological requirements encompasses an area of thousands of square kilometers, conventional means of mapping vegetation type with high altitude aerial photography would be time consuming and costly. Another option is to use Landsat satellite data which provide relatively inexpensive information on a near real-time basis.

1.2 Background

The subarctic forest of northern Manitoba has long been recognized as wintering range for barren-ground caribou (*Rangifer tarandus groenlandicus*). Recent population estimates indicate that there has been a drastic decline in caribou numbers (Banfield 1954, Parker 1972, Thompson et al. 1978). Accompanying this decline has been a reduction in the use of traditional wintering range by caribou in northern Manitoba. Because of the importance of caribou as an economic, social, and biological resource to northern native people, the Manitoba Government initiated a major program in 1976 to study the caribou situation.

Dialogue between caribou managers and resource users in Manitoba, Northwest Territories, and Saskatchewan exposed differing views pertaining to the caribou problem. Though there was general agreement that there are fewer animals now than in the past, differing theories were advanced to account for the decline of caribou. One view expressed by resource users was habitat destruction by fires. There remained however, a dichotomy of opinion among caribou researchers regarding the impact of fire on caribou range. In an effort to provide definitive answers on the impact of fire, the Manitoba Government initiated a barren-ground caribou winter range mapping program in 1978. Caribou managers with the Wildlife Branch, Manitoba Department of Natural Resources felt that a technique which was capable of monitoring large tracts of caribou range on a regular basis would provide a framework for coordinated habitat management and research programs.

1.3 Objectives

The primary objective of this study was to determine the extent and types of vegetation associations found on barren-ground caribou winter range in northern

Manitoba. Specific objectives were:

1. To develop a vegetation classification based on parameters which are important to caribou and which can be detected by current satellite technology.

2. To produce vegetation cover maps for six NTS map sheets at a scale of 1:250,000 and provide a preliminary suitability assessment of vegetation associations for the support of barren-ground caribou.

3. To assess the feasibility of using Landsat data in development of an operational technique for monitoring caribou winter habitat.

1.4 Limitations

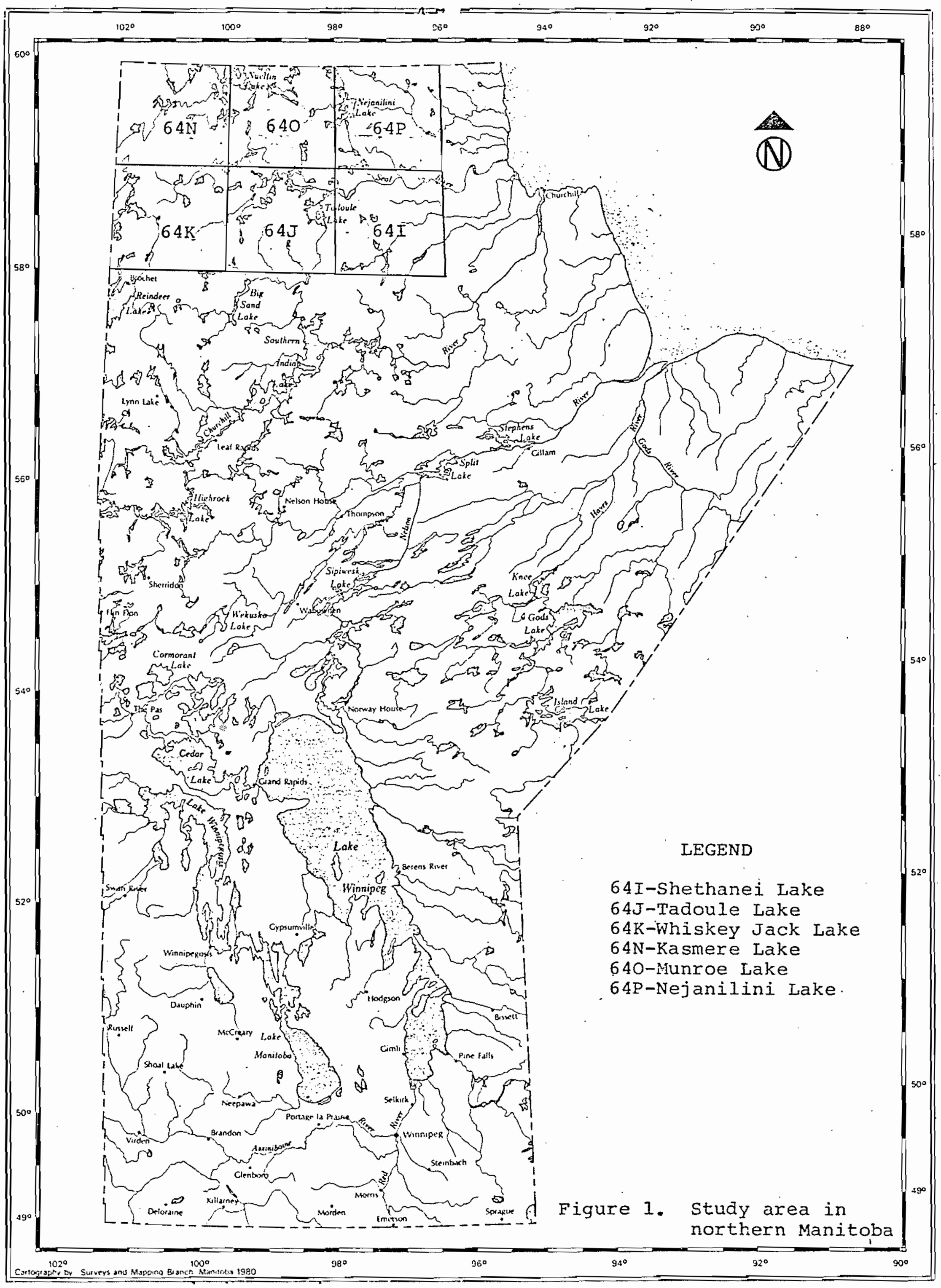
1. The remoteness and climate of the study area result in an extremely short field season. This limited time available for collection of ground truthing data.

2. All aerial surveys were conducted with fixed-wing aircraft therefore accessibility to some vegetation associations for ground sampling purposes was limited.

3. Suitability assessment of each vegetation association for the support of barren-ground caribou was based on limited data and is therefore only a preliminary assessment. Habitat suitability assessment has been identified as an area requiring further research.

1.5 Study Area

The study area is located in northern Manitoba (figure 1) between the 58th and 60th parallels and the 96th and 102nd meridians. The area encompasses six National Topographic Series (NTS) map sheets of 1:250,000 Series: 64I; 64J; 64K; 64N; 64O; and 64P.



LEGEND

64I-Shethanei Lake
64J-Tadoule Lake
64K-Whiskey Jack Lake
64N-Kasmere Lake
64O-Munroe Lake
64P-Nejanilini Lake

Figure 1. Study area in northern Manitoba

1.5.1 Physiography and Drainage

Tarnocai (1975) has described the physiography in this region as gently undulating with overall flatness interrupted by eskers and drumlinized drift plains. Much of the land surface is poorly drained. Major rivers include the Seal, Cochrane, Knife, Caribou, and Wolverine which exhibit seasonal fluctuations in water level and variable flow rates. There are numerous shallow land-locked lakes and ponds with peat or boulder shorelines.

1.5.2 Flora

The study area encompasses the northwestern transition within the Boreal Forest Region as described by Rowe (1977). Along the treeline, a relatively abrubt transition zone lies between the subarctic forest and tundra. Subarctic forest vegetation is dominated by black spruce(*Picea mariana*), which occupy a variety of habitats from dry esker ridges to wet bogs. Widely spaced trees and sparse undergrowth provide ideal conditions for lichen growth. Baldwin (1953) and Ritche (1960) provide a botanical account of the major vegetation associations found in the area. Tundra vegetation is dominated by lichens, sedges, and heath. Black spruce is less common on the tundra, and many show signs of wind-pruning. Trees are often found growing only in depressions and along lake shores.

Common and scientific names of vegetation species identified by the researcher in this study are listed in Appendix I. A collection of vascular and lichen flora gathered by the researcher, remains with the Wildlife Branch, Thompson. Additional information on the vascular flora (Scoggan 1957), lichen flora (Hale 1969), and moss flora (Conrad 1977) is available.

1.5.3 Fauna

Banfield (1977) and Godfrey (1979) provide information on habits and distribution of mammals and birds,respectively, found in the study area. Mammals and birds observed by the researcher during aerial and ground surveys of the study area are listed in Appendix II.

1.5.4 Climate

Climatic data for the study area are limited because the only permanent weather station at Lac Brochet was just recently made operational in December 1980. Mean monthly temperatures for 1978-80 recorded for Brochet (57^{o} 53' N x 101^{o} 41' W) were compiled from Manitoba Regional Services data, and are reported in Appendix III.

Generally, climate of the study area is characterized by cool wet springs and relatively dry moderate summers. Baldwin (1953) reported spring frosts at Brochet in mid June and autumn frosts in early September.

1.5.5 Land Use

Hunting, fishing, and trapping continues to play an important role in the lifestyle of many native people in northern Manitoba. Chipewyan Indians who historically lived a nomadic lifestyle in this region have, in recent years, established permanent residence in Tadoule Lake and Lac Brochet. The community of Brochet, a Cree and Metis community, has existed for over a hundred years. Fish and wildlife use is centered around these communities, however, seasonal movement by game results in hunting activity being dispersed throughout the area.

There are few sport fishing lodges in the study area. Major camps are situated at Bain Lake, Stoney Lake, Munroe Lake, and Duck Lake.

The Seal and Cochrane rivers provide scenic canoe routes and offer challenging rapids, even for the most experienced canoeist.

Several mining exploration activities have been conducted in the study area on a seasonal basis. The most notable of these camps was operated by United Sisco Mining Co., just south of Kasmere Lake.

Significant deposits of uranium have been located in the northwest portion of the study area on NTS-64N (Figure 1).

2.0 LITERATURE REVIEW

2.1 Introduction to Landsat

Three Landsat satellites, formerly called ERTS, are in a near-polar, sun-synchronous orbit about 900 km above the earth's surface (Harper 1976). Repetitive coverage is provided by one satellite on an 18-day cycle. A multispectral scanner (MSS) subsystem on-board each satellite detects electromagnetic energy reflected from the earth's surface in four wavelength bands: Band 4, 0.5 to 0.6 um; Band 5, 0.6 to 0.7 um; Band 6, 0.7 to 0.8 um; and Band 7, 0.8 to 1.1 um. The scanner sweeps terrain across a swath 185 km wide, in six simultaneous strips 79m in width. Intensity of electromagnetic energy is measured and recorded at 57m intervals along each strip. Each interval, corresponding to an area of 79m by 57m on the earth's surface, is called a pixel; an acronym for picture element. MSS ouput, recorded in digital form, is relayed to one of two satellite receiving stations in Canada: Prince Albert Satellite Station (PASS), Saskatchewan; or Shoe Cove Satellite Station (SCSS), Newfoundland.

Special preprocessing of Landsat data is required to compensate for anomalies introduced by the MSS system. The first category of adjustment, radiometric calibration, makes possible equalization of gain changes which may occur in the six detectors of a spectral band during transmission or quantization of brightness levels (Strome et al. 1975). Anomalies introduced by variations in satellite perspective are corrected for by geometric calibration. Geometric corrections are much more extensive than radiometric calibration. Strome et al. (1975) elaborates on preprocessing Landsat data. Even after radiometric and geometric corrections have been applied, there are several other factors which affect image quality and ability to distinguish ground features.

Dave (1980) found that atmospheric blurring is a function of atmospheric haze, solar zenith angle, position of surface feature with respect to local nadir direction, and wavelenth of the radiation. Turner (1973) states that atmospheric scattering of radiation increases spectral variation, resulting in reduced contrast between adjacent ground feature. Atmospheric effects are more pronounced at some wavelengths than at others. For example, the effect of haze is much greater for the shorter wavelength band, 0.55 um to 0.58 um, than for the band at longer wavelengths, 0.80 um to 1.0 um. Otterman and Fraser (1979) state that the spectral response of a pixel may be affected by reflectance from pixels from as far away as 7 km. Magnitude of this effect would be determined by such factors as relative reflectance of scene and background, average height of scattering layer, scattering phase function of atmospheric constituants, and atmospheric attenuation characteristics. Smith et al. (1980) analysed terrain geometric effects and optical scattering properties of dense *Pinus* forest and found that effective illumination angles between the surface and sun at the time of image acquisition ranged between 30 and 80 degrees. Beaubien (1979) examined factors affecting reflectance of forest stands and found that apart from forest species, class distributions were affected by stand age and density, and exposure of slopes. Beaubien found that the younger and/or denser a stand, the greater its reflectance. This relationship was particularly noted in the infrared band. Colwell (1974) discusses in greater detail parameters affecting reflectance of vegetation cover.

Landsat products are available in either photographic or digital format. The choice of product is important because the quantity and quality of data, as well as the means required to extract desired information, differs significantly. Harper (1976) states that information obtainable from a photographic product is limited by physical shortcomings of the film and/or printing paper. For example, printing paper is capable of providing 14 discernible shades of grey whereas satellite data, transmitted in the form of binary digits, distinguish 64 shades of grey. Already optical resolution has been degraded more than four times in the shift from digital to photographic format. The spatial loss of information on photographic products is even greater. Spatial loss results from limited ability to recreate detail provided by 7½ million picture elements per Landsat scene on 70mm film. Computer assisted analysis of digital data can provide more information than that obtainable from photographic products.

Two general methods of digital analysis have been developed for Landsat mapping, classification and image enhancement. Alfoldii (1978) provides an introduction to digital images and digital analysis techniques. Johnston and Howarth (1980) describe classification, generally, as a method by which spectral data are statistically sorted and displayed as different symbols. Each symbol portrays a specific, discrete spectral category to which a land or vegetation class is assigned. Goldberg and Shlien (1976) describe two approaches to automated classification, supervised and unsupervised. With supervised classification, the user specifies certain groups of picture elements as training samples which are representative of the class of interest. A computer then estimates the statistical parameters of the training samples and classifies the remaining pixels into the corresponding classes. The second approach, unsupervised classification, is based upon the use of a clustering algorithm to identify seperable clusters in the data. The user must then correlate these clusters with the ground cover classes of interest. Thompson et al. (1980) used an unsupervised classification routine employing clustering by migrating means, for caribou habitat mapping in the southern district of Keewatin. La Perriere et al. (1980) used a supervised classification with a modified clustering technique for moose-habitat analysis in Alaska. Hall et al. (1979) were able to distinguish three categories of burn severity on tundra in Alaska with an unsupervised classification.

A second method of analysis, known as image enhancement, is a procedure which transforms digital data into a more expressive, interpretable form. With image enhancement, subtle radiometric or spectral details are accentuated prior to visual interpretation. Johnston and Howarth (1980) describe four digital enhancement techniques for vegetation mapping in the subarctic environment and found that linear contrast stretch was most effective for delineating bog and fen patterns, whereas band ratioing, video-filtering, and principal component enhancements were of marginal value. Beaubien (1980) achieved successful results with principal component enhancement for delineation of subarctic vegetation on the north shore of Quebec by choosing appropriate training areas to form components of an image. The specific ground cover types were then enhanced with three principal color components (Kourtz and Scott 1978).

McQuillan (1975) outlines capabilities and benefits of remote sensing systems in Canadian northern resource development. Included in a list of applications are: topographic mapping; land and resource inventories; engineering construction; land-use, terrain, soils and vegetation mapping; management of forest resources; land-use planning; environmental monitoring; and environmental impact assessment. He also provides several cost comparisons between Landsat and aircraft methods.

2.2 Barren-ground Caribou Winter Habitat Requirements

Each species has a unique set of habitat requirements which must be met if that animal is to survive and reproduce. Literature was examined to ascertain parameters of winter habitat known to be important to barren-ground caribou. A comprehensive understanding of caribou habitat requirements and a knowledge of where those requirements are met, would be valuable to wildlife managers. Some habitat parameters such as snow conditions and their effect on caribou biology are difficult to quantify. Habitat elements which fulfill essential biological requirements of food, cover, and mobility were examined.

Studies of craters, cratered sites, and analysis of rumen contents have demonstrated that lichens are primary forage of caribou on the taiga winter range (Scotter 1967, Kelsall 1968, Miller 1976, Skogland 1980). Kelsall (1968) found that winter diet of barren-ground caribou consisted of up to 50 percent perennial plants, but generally lichens dominate. Edwards and Ritcey (1960) comment on the importance of arboreal lichens to *Rangifer arcticus* within their winter habitat when snow is deep and there is little else available. Skoog (1968) found that caribou thrive without lichens and normally supplement their lichen diet with other plant foods. Diet of caribou has been shown by researchers to also include plant species listed in table 1. The diverse range of plants from lichens to sedges and shrubs, supports Bergerud's (1972) conclusion that caribou are feeding generalists. Because of the preponderance of studies which indicate that lichens are the most frequently utilized forage in the winter diet of caribou, presence of lichens was considered to be an essential component of prime winter range.

Miller's (1976) seasonal comparison of 545 rumen samples showed marked changes in proportions of forage classes as caribou moved through different habitat types. In the taiga, lichens dominated the diet although dominance decreased significantly ($P < 0.001$) from 80 percent in November, to 50 percent in April. In November, grasslike plants were the second most abundant forage item however by April the proportion had significantly ($P < 0.01$) decreased. Miller (1976) states that seasonal availability appears to dictate forage use by caribou after early winter.

Availability of forage depends on depth and hardness of snow cover, as well as proximity of travel routes to feeding areas and treeless escape and loafing cover. Pruitt (1959) states that snow cover exerts a profound influence on behaviour, migration, and

Table 1. Forage of caribou as determined from direct observation of feeding, feeding trials, or rumen analysis.

Caribou Forage	Author				
	Scotter (1967)	Person et al. (1980)	Skogland (1980)	Miller (1976)	Edwards and Ritcey (1960)
Stereocaulon spp.	X	X	X	X	
Cladonia mitis			X		
Cladonia rangiferina		X	X		
Cladonia alpestris	X	X	X	X	X
Cetraria spp.	X	X	X	X	X
Alectoria spp.	X			X	X
Lycopodium spp.				X	X
Eriphorum spp.		X			
Equisetum spp.	X		X	X	X
Epilobium spp.			X		
Carex spp.	X		X	X	X
Empetrum spp.	X			X	
V. Vitis-idaea	X	X	X	X	
V. Uliginosum	X			X	
Vaccinium myrtilloides	X		X	X	X
Oxycoccus sp.				X	
Loiseleuria	X	X		X	
Ledum groenlandicum	X			X	
Ledum decumbens	X	X			
Kalmia sp.				X	
Chamaedaphne sp.	X			X	
Andromeda sp.	X			X	
Arctostaphylos spp.	X		X	X	
Salix spp.	X	X	X	X	X
Betula nana		X			
Betula glandulosa	X			X	

survival of caribou. Pruitt (1959) suggests that ideal snow conditions for caribou winter range appear to be: 1) hardness not over 60 gm/sq. cm for forest snow and not over 700 gm/sq. cm for lake snow; 2) density not over 0.20 for forest snow and not over 0.32 for lake snow; and 3) depth not over 50 or 60cm. Another important feature of snow cover is its maturation process. Snow morphology undergoes a series of changes in thickness, hardness, density, grain size, and structure (Klein *et al*. 1950). The sequence can be completely upset by strong wind, wind combined with high temperature,or when liquid precipitation occurs. Pruitt (1979) derived a mathematical model which relates reindeer activity to snow cover features. Pruitt's Värriö Snow Index (VSI) enables a quantitative assessment of snow cover. Pruitt contends that hard snow layers have different hindrance effects depending on whether the hard layer is at the center, top, or near the base. For example a very thin, hard layer on the snow surface has a greater hindrance effect in terms of mobility than the same layer at the base. A hard layer at the base would hinder caribou's ability to crater for food.

It was assumed that features of the vegetation association affect the snow maturation process such that snow conditions vary among vegetation associations throughout the year under different climatic conditions. For example, areas of greater crown closure would result in favourable snow conditions during years of deep snow or when high winds create hard snow crusts in open areas.

Theories about the effects of fire on vegetation in the subarctic forest have important implications for caribou habitat management (Scotter 1964). Ecological effects of fire in the northern environment have been documented by Rowe et al. 1974, Kershaw and Rouse 1976, Johnson and Rowe 1977, Kelsall et al. 1977, and Rouse and Mills 1977. The argument for fire suppression on caribou range is stated by Johnson and Rowe (1975) in the following,

> "caribou are climax animals dependent on the climax boreal forest for survival in the winter season, their preferred winter food consists primarily of fruticose ground lichens and pendulous arboreal lichens that characterize climax coniferous types, fire destroys the lichens which, once burned away, are only renewed by a slow process of succession extending over many decades; fire therefore, exerts one of the controls over population size of the barren-ground caribou."

It is likely that all researchers would agree that the short term effect of fires on caribou habitat is negative as it removes food, however, a dichotomy of opinion regarding the long term effect of fire would remain.

Banfield (1954) states that destruction by fire of a large part of winter range would result in starvation and consequent reduction in barren-ground caribou population. Kelsall (1968) concluded that the limiting effects of forest fires had been negligible on caribou population but only because the numbers were low and had already declined. Lutz (1956) believed that increased size and frequency of fires following settlement and gold-rush days in interior Alaska were primarily responsible for reduced caribou numbers. Pruitt (1959) noted caribou avoided burned areas in northern Saskatchewan. Scotter (1971) concluded fire damaged winter range of barren-ground caribou has increased with growth of settlement and exploitation, and there is a reduced potential carrying capacity. Scotter also states reduced potential carrying capacity does not appear to be the factor limiting caribou populations but may have reduced it to the point where men, wolves, and other factors could keep numbers low.

Skoog (1968) concluded that reduced numbers of caribou were not the result of burning forests and that fire has had little influence in the fluctuation of caribou numbers. Bergerud (1974) rejects the belief that winter food scarcity has limited this species and it is his opinion that over-hunting and local increases in wolf predation are responsible for the caribou decline. Miller's (1976) studies on the Kaminuriak caribou also lead to the conclusion that winter food does not limit caribou numbers. Miller also suggests that fire maintains vegetative heterogeneity and stimulates lichen production.

While researchers agree that fire is a natural phenomenon on the range of barren-ground caribou, the extent to which it effects caribou numbers remains open to discussion. Further research is required to determine prevalence, recurrence, and ecological effects of fires, as it relates barren-ground caribou.

3.0 METHODS

3.1 Landsat Data Acquisition

Two methods of locating Landsat data for this study were used -- a manual search of microfiche cards at MRSC and a computer scan of imagery stored at CCRS. Requests for a computer search were made through User Assistance at CCRS, Ottawa. Minimum scene requirements specified for this study were, relevant path and row reference number; time frame, July 1972 to August 1980; minimum band quality, fair; and maximum cloud cover, 15 percent. All Landsat data for this project were purchased from Prince Albert Satellite Station (PASS), Saskatchewan. Photographic data used in this study are listed in Appendix IV. For further details on ordering Landsat data see Appendix V.

Additional aerial photography of the study area was made available through Surveys and Mapping Branch, Manitoba Department of Natural Resources. Black and white aerial photography from 1957 was available for the entire study area at scale 1:60,000. Approximately 12,000 km^2 of NTS-64K was photographed in color during June and July 1967 at scale 1:15,840.

3.2 Processing Landsat Data

Landsat computer compatible tapes (CCTs) had standard radiometric and geometric corrections applied (Strome et al. 1975). A digital enhancement technique was used to maximize information obtainable from Landsat data. A Karhumen-Loeve (principal component) transform was used to create statistics files for a subarea (approximately 100,000 pixels) on each Landsat scene (Kourtz and Scott 1978). Selection of training areas within each subarea was outlined by Dixon (1981). Training areas were required to form components of the image. The second step of the image enhancement process was to map components from three K-L transforms into color space (Taylor 1974). DIPIX Systems Ltd., Ottawa, was contracted to perform principal component color enhancement using the ARIES(Applied Resources Image Exploitation System) package. Enhancements were performed for six CCTs (Table 2). A maximum of eight color classes per NTS map sheet were requested. Color enhanced images were registered to the UTM grid system. Image output was obtained on 70mm film and nine 10-inch square color prints were produced for each map sheet. CCTs are stored at MRSC and color enhanced images remain with the Wildlife Branch, Thompson.

3.3 Field Programs

Field programs were administered by the Manitoba Department of Natural Rēsources, Wildlife Branch,

Table 2. Landsat CCTs selected for principal component analysis.

Map Sheet	Frame No.	Image Date	Sun Elevation (degrees)	Cloud Cover (percent)	Band Quality 4 5 6 7
NTS-64I	20564-16490	76/08/08	44	0	G G G G
NTS-64P	10425-17123	73/09/21	29	0	G G E E
NTS-64O	21700-17025	79/09/18	28	5	G G G G
NTS-64J	21682-17023	79/08/31	35	5	G G G G
NTS-64K	11075-17023	75/07/03	50	5	G G F F
NTS-64N	21666-17130	79/08/15	39	0	G G G G

Northeastern Regional Office, located at Thompson, Lynn Lake, and Churchill. Vegetation data were gathered during three summer field seasons, from 1978 to 1980. A preliminary caribou range use study was conducted in February, 1981. A summary of field programs is found in Appendix VI.

3.3.1 Aerial Surveys

Aerial surveys were used for assessing mapping accuracy. An aerial sampling point was termed a "fly-by" and represented an area on the ground of approximately 2.5 km^2 (250 ha or 540 pixels). Fly-bys were plotted on maps in such a manner that at least one side was adjacent to a recognizable ground feature such as a lake or river, which served as a reference point for observers. Each fly-by was examined for approximately three minutes from a height of 600 to 800 feet (180-240m) AGL while the aircraft was kept in a tight bank by the pilot. One observer would record data on a standard data form (Appendix VII for example), and the second observer would photograph each fly-by with a hand-held 35mm camera. Dominant relief class, tree species, ground cover association, and crown closure were assessed for the entire fly-by area. At burned sites, evidence of regeneration was recorded. All aerial survey data and 35mm photogrphs remain with the Wildlife Branch, Thompson.

Chi-square tests were conducted to determine if the outcome of fly-by observations were dependent on either observer experience or vegetation associations. An experienced observer was defined as one who had become familiar with vegetation associations of the study area by each of the following means: 1) air photo interpretation; 2) prior aerial reconnaissance of the study area; and 3) previous visits to ground sites. Vegetation associations were grouped into two categories, subarctic forest and tundra. Two observers on the same side of the aircraft, one in front seat and one in back, would independently record observations of the same fly-by on standard data sheets. Similarities and differences in observations between observers were noted and the following null hypotheses were tested:

Test #1 H_O: Similarities and differences noted in fly-by observations on tundra vegetation were not dependent on observer experience.

Test #2 H_O: Similarities and differences noted in fly-by observations on subarctic forest vegetation were not dependent on observer experience.

Test #3 H_O: Similarities and differences noted in fly-by observations between two experienced observers were not dependent on vegetation conditions.

Tests were conducted to determine effect of sample size area on the ability to classify crown closure for a fly-by cell plotted on color aerial photographs (1:15,840). Five sample size areas were classified: 1) 300 m^2; 2) 2,800 m^2; 3) 7,800 m^2; 4) 20,100 m^2; and

5) 31,400 m^2. Air photo classification was conducted by three interpreters. On each trial the interpreters were permitted to see only the sample area to be classified. Crown closure within the sample size area was determined and compared with crown closure assigned to the entire cell. Sample classifications which did not match crown closure assigned to the cell were noted.

3.3.2 Ground Surveys

Ground surveys were conducted to gather detailed information for each vegetation type. Data gathered from ground surveys remain with the Wildlife Branch, Thomspon. A vegetation type or association was defined as an area of above ground vegetation and its associated environment which possessed similar species composition throughout, with a relatively uniform spatial distribution of the dominant tree and understory species, and a relatively uniform height in canopy and understory strata.

Accessibility to ground survey sites was subject to limitations of using fixed-wing aircraft. Lakes had to be a minimum of 1 km in length, had to be relatively free of rocks, and had to have sufficient depth to accommodate a float-plane. Wind conditions and shoreline profile had to be considered prior to each landing. Low water levels further restricted accessibility in 1979. On the tundra where winds were always prevalent and many lakes were shallow and boulder-lined, accessibility was a problem.

Ground data were gathered from within several 5-m radius circular plots at each site and recorded on data sheets (Appendix VIII for example). Vegetation cover was vertically separated into four horizontal strata consisting of a ground, field, shrub, and forest stratum. Ground stratum included lichens and mosses. Field stratum was comprised of all ericaceous shrubs, herbaceous plants, and sedges less than 75cm in height. Separation of shrub and field strata at 75cm was intended to separate the subnivian vegetation (field stratum) from supranivian vegetation (shrub stratum). Forest canopy was defined as the coverage of branches and foliage formed by tree crowns.

Total plot coverage of each stratum was determined by estimating the area occupied by all plant species of a stratum and expressed as a percentage of the whole area ($78.5m^2$). Percentage cover of dominant species was recorded for each stratum in the same manner. A dominant species was defined as a plant which had the greatest area coverage in a particular stratum. Frequency and average height of trees were recorded by dbh class. Tree disks were taken 15cm above ground and aged using a 10x binocular microscope. Arboreal lichen abundance was estimated to be either dense, moderate, trace, or nil. All other plant species found in a 5-m radius plot were recorded in (Appendix IX). Relative abundance of each species within a vegetation type is based on cover and frequency with which a plant in each strata may be expected to occur throughout the study area. Cover-abundance categories are summarized in Table 3.

In burned areas particular attention was given to the amount and type of regeneration. Regeneration was described as sprouting, invasion by mosses, and/or seedling establishment. Seedlings were cut down and aged. Barriers to burning, islands of remaining forest, and intensity of burn in relation to relief and vegetation type were noted. Intensity of burn was described as how much vegetation in each strata was consumed. For example, an intense burn was one where trees were burned from the base to the top. A burn was considered light where only ground cover and tree bases were burned.

Range biomass data were collected in August 1980. A 25-cm square plot was randomly located within a 5-m radius plot in five different vegetation types. Due to the time consuming sampling process and adverse weather conditions only one plot per transect was

Table 3. Cover-abundance categories used to describe vegetation.

Cover-Abundance	Estimated Area of Cover	Frequency
Very Abundant	> 50%	> 75%
Abundant	25-50%	50-75%
Sparse	10-25%	25-50%
Rare	< 10%	< 25%

sampled. All lichens, sedges, and leaves from shrubs were removed from the plot and placed in seperate paper bags. Living and dead portions of lichen podetia were gathered but not seperated. Only above-ground parts of sedges were collected. On one occasion arboreal lichens were collected from a black spruce in an upland open black spruce cover type. Arboreal lichens were removed from the trunk and branches, up to a height of 3 meters. All samples were oven dried at 80°C for four hours in ovens at the Botany Department, University of Manitoba and then weighed.

3.3.3 Winter Range Survey

Aerial surveys were flown Februrary 2-6, 1981 using a fixed-wing aircraft to determine distribution of barren-ground caribou. Locations of wintering bands were plotted on 1:250,000 vegetation maps. Bedding and feeding sites were described. Track orientation, form, and proximity to islands and shorelines were noted. Response to burn areas was observed and recorded. One stop was made in an area where there was evidence of cratering. Craters are formed by caribou pawing through snow in order to obtain ground forage. Vegetation type, distance of craters from lake shore, and crater density were noted. Exposed substrate and available forage in each crater were also noted.

A set of NRC Standard Snow Instruments (Klein *et al*.

1950) were used to gather data on snow conditions. At each snow station the following information was gathered: 1) location, 2) habitat, 3) pukak (fragile, columnar basal layer of api) and air temperature, 4) vertical snow hardness, 5) total api (snow on the ground, forest) depth, 6) thickness and horizontal hardness of each snow layer, and 7) ground vegetation. Snow data were analysed using Pruitt's (1979) Värriö Snow Index (VSI).

3.4 Vegetation and Burn Mapping

Preliminary interpretation was used for selecting field sampling sites and as a means for recognizing similarities and differences among vegetation types. Relief, species composition, and density of forest cover were used to describe vegetation types. Vegetation type boundaries were delineated on color enhanced sub-images using color and spatial patterns as the criteria for differentiating vegetation types. Smallest area mapped was about 150 ha or approximately 320 pixels. Vegetation type boundaries were transferred from 1:250,000 color enhanced satellite sub-images to 1:250,000 mylar base maps with the Bausch and Lomb Zoom Transfer Scope (ZTS). Care was taken to ensure that type boundaries matched between adjacent map sheets.

Forest fire boundaries were delineated on black and white satellite imagery using grey tones as criteria for differentiating recent burns from adjacent vegetation types. Fire boundaries were transferred from 1:1,000,000 satellite photographs to a 1:250,000 mylar base map with the ZTS. Adjustments made with the ZTS to compensate for image distortion due to geometric anomalies in Landsat data. Burn masks remain with the Wildlife Branch, Thompson.

An area dot grid (one dot per square kilometer) was used to determine proportion of each cover type per map sheet. Approximately 12,000 dot/vegetation association counts were made per map sheet. Area (km^2) of each cover type was estimated by multiplying the area of the map sheet by the proportion of the cover type. Water was included as a cover type for area determination.

3.5 Barren-ground Caribou Range Suitability Assessment

Limited field data enabled only a qualitative assessment of each vegetation association's suitability to support barren-ground caribou. Criteria to assess preliminary habitat suitability include: 1) food presence and availability, 2) ease of mobility, and 3) presence of escape and loafing cover. Habitat was described as either prime, satisfactory, marginal or unsatisfactory.

3.6 Map Accuracy Assessment

An aerial sampling technique was used to assess accuracy of vegetation mapping for each NTS map sheet. Vegetation association was compared between cover type observed from fly-bys and cover type delineated on each map. Fly-by map comparisons were standardized to a 10,000 unit area, using the proportion, vegetation association area against subarctic forest area, as a weighting factor. Discrepancy between field observations and mapping unit was considered to be an error from one of two kinds. Tables with standardized results are found in Appendix X.

Standardized area of vegetation association per 10,000 square units (S), was calculated by

$$S_i = P_i \times 10{,}000$$

where i represents a specified vegetation association.

P is the proportion determined from the area dot-grid count.

The relationship between fly-by observations (i) and map units (m) was standardized by

$$S_{im} = S_i \frac{O_{im}}{A_i}$$

where S_{im} represents standardized area in the ith vegetation association classified as the mth mapping unit,

O_{im} is the number of fly-by observations in the ith vegetation association delineated on the map as the mth unit,

A_i is the total number of fly-by observations in the ith vegetation associaton, and

S_i is the standardized area of each vegetation association per 10,000 square units.

Two kinds of errors were noted, classification and mapping. Classification errors (E_{ci}) were made when fly-by observations from the ith vegetation association were incorrectly classified as the mth unit. Total classification errors for the ith vegetation assocation (E_{ci}) were determined by

$$E_{ci} = S_i - C_{im}$$

where C_{im} represented the number from the ith vegetation association correctly classified as the mth unit. The probability of making a classification error for the ith vegetation association (P_{ci}) was determined by

$$P_{ci} = \frac{E_{ci}}{S_i}$$

Mapping errors (E_{om}) were made when a vegetation association from the mth map unit was incorrectly mapped as the ith vegetation association. Total mapping errors for the mth mapping unit (E_{om}) were determined by

$$E_{om} = R_m - C_{im}$$

where R_m is the row total for the mth mapping unit.

The probability of making a mapping error for the mth mapping unit (P_{om}) was determined by

$$P_{om} = \frac{E_{om}}{R_m} ,$$

4.0 RESULTS AND DISCUSSION

Subarctic forest and tundra vegetation were mapped at scale 1:250,000 with Landsat digital data. A discussion of Landsat data selection techniques employed and a detailed description of each vegetation association are presented. Accompanying each vegetation description is a preliminary assessment of that vegetation type's suitability as barren-ground caribou habitat. Mapping accuracy is discussed and a summary of mapping costs are presented. Potential applications of results for barren-ground caribou management are outlined. Finally, feasibility of an operational program for monitoring caribou habitat is examined. Recommendations are made in the concluding chapter.

4.1 Landsat Data Selection and Processing

Examination of Ertsfiche (microfiche cards) was sufficient for ordering Landsat photographic products. On each fiche card, information was provided enabling determination of ground feature contrast and an estimate of cloud cover for each Landsat scene. Assessment of spectral contrast was limited, however, to the infrared band (0.7 to 0.8 um). Data anomalies resulting from radiometric and geometric errors could not be determined by examination of Ertsfiche alone. Because of negative effects on enhancement techniques introduced by radiometric and/or geometric errors, an assessment of band quality was required prior to digital enhancement. A computer print-out specifying band quality was necessary for selection of Landsat digital data.

In this study, data of similar band quality were chosen for computer analysis (Table 2). Differences between scenes due to different atmospheric conditions were kept to a minimum by selecting imagery which was as cloud-free as possible. Differences between Landsat scenes due to different vegetation phenology were reduced by choosing summer imagery from July to September. Efforts were also made to obtain imagery with sun elevation not less than 30°. A limited number of scenes were available for NTS-64O and 64P due to either unacceptable cloud cover or poor band quality, therefore imagery with sun elevation less than 30° had to be chosen.

Sun elevation is an important aspect to consider especially in areas of high relief where a shadow effect may be introduced (Beaubien 1979). In this study area and particularly for NTS-64O and 64P, terrain was relatively flat, therefore shadow effect was not a major problem. Of greater significance was the relationship between sun elevation and illumination of ground features.

Beaubien (1979) states that sun elevation at time of satellite overpass is important for determining reflectance value of forest stands, and subsequently distribution of vegetation classes obtained from digital enhancement techniques. High sun angles result in greater surface reflectance whereas low sun angles result in reduced surface reflectance. With low illumination, the effective range over which MSS data gathered reduced, therefore, it is difficult to detect subtle differences in spectral response between similar vegetation associations.

Photographic products of principal component color enhancement were printed at a scale 1:250,000. A maximum of eight color classes were generated for each map sheet. Johnson and Howarth (1980) recommend that care be taken when assigning a unique ground cover class to a spectral category represented as a color theme on a classified image. Color themes may be misleading if they are assumed to represent unique ground classes. The same care must be exercised when interpreting colors on enhanced images. For example, lime green on the color enhancement of NTS-64J most often represented an upland spruce lichen vegetation association. Examination of the corresponding black and white film positive for NTS-64J revealed lime green also represented cloud cover. Problems of interpretation were encountered on map sheets with more than eight vegetation classes present, as only eight color classes were generated with the enhancement technique. This meant that two vegetation associations were represented as the same color. This problem was particularly evident for the transition between sub-arctic forest and tundra on NTS-64O and 64P where as many as 15 vegetation classes were present. Air photo interpretation was therefore necessary for accurate classification in the transition area. As many as 15 color classes could have been generated with the enhancement technique at an additional cost of $350 per map sheet.

Five of six Landsat color enhancements were registered to UTM map coordinates. This costly process would not have been required had DICS data been available. NTS-64K was not registered to UTM coordinates but this did not hamper image interpretation. It did mean however, more time had to be spent transferring typed vegetation boundaries to the 1;250,000 mylar base map.

Additional air photo interpretation was required to complete mapping for three NTS map sheets where satellite coverage was incomplete. Percent area missed was as follows: NTS-64P, 3 percent; NTS-64N, 7 percent; and NTS-64O, 9 percent. These areas were missed because Landsat scenes chosen did not completely cover map sheets of interest. It was not known at that time that off-track Landsat scenes could have been purchased.

Minor difficulties were encountered in matching the boundaries of vegetation associations along the border between two adjacent map sheets. This problem resulted from the use of multidate imagery. For example, color enhanced image dated July 1975 for NTS-64K indicated a large burn had extended onto the adjacent map sheet, NTS-64J. Examination of September 1975 black and white film positives for NTS-64K and 64J verified existence of a burn on both map sheets. However, the enhanced image dated August 1979 for NTS-64J gave no indication of a burn. Subsequent ground truthing and examination of supplementary Landsat data revealed that the turquoise color portrayed two very different vegetation associations, mature upland open black spruce and revegetated burn less than 15 years. Once alerted to this situation, it then became necessary to produce a burn mask for every map sheet using supplementary data from Landsat and aerial photographic sources. Where discrepancies of vegetation association boundaries between two adjacent sheets was more subtle, air photo interpretation was necessary.

4.2 Vegetation Description

A vegetation classification based on parameters known to be important to caribou was required. Habitat features relating to caribou's general biological requirements of food, mobility, and cover were emphasized. Description of vegetation associations was based on quadrat data collected during ground surveys. Vegetation associations were classified by characters of relief, species composition and spatial distribution. A preliminary, qualitative assessment of each vegetation association's suitability for the support of barren-ground caribou accompanies each vegetative description.

The nature of vegetation in the study area includes aspects of both the community concept and the continuum concept of vegetation. According to the community concept, vegetation is composed of well-defined, discrete, integrated units which can be combined to form abstract classes or types reflective of natural entities in the real world (McIntosh 1967). Transition zones between adjacent communities are excluded from this concept on the grounds that they form only a negligible proportion of the total area in any large tract of vegetation. According to the continuum concept, vegetation changes continuously and is not differentiated, except arbitrarily, into sociological entities (McIntosh 1967). Aerial and ground surveys conducted during this study revealed several distinct vegetation patterns accompanied by numerous transition zones between adjacent, well defined vegetation types. The researcher thus acknowledges Pielou's (1969) remark that few ecologists hold either theory in pure form.

Table 4 shows percent mean cover of each vegetation strata within every vegetation association. Caution is recommended when interpreting these results because only limited field data were available for several vegetation associations. The category upland open birch is not included in this table as ground data were unavailable.

Areas having a high percent mean lichen cover in the ground stratum were considered to be important for caribou. Vegetation associations of upland open black spruce, upland spruce lichen, and upland heath complex provide prime habitat in terms of food presence. Areas with a high percent mean moss cover in the ground stratum would not be considered as suitable habitat for caribou. A notable exception

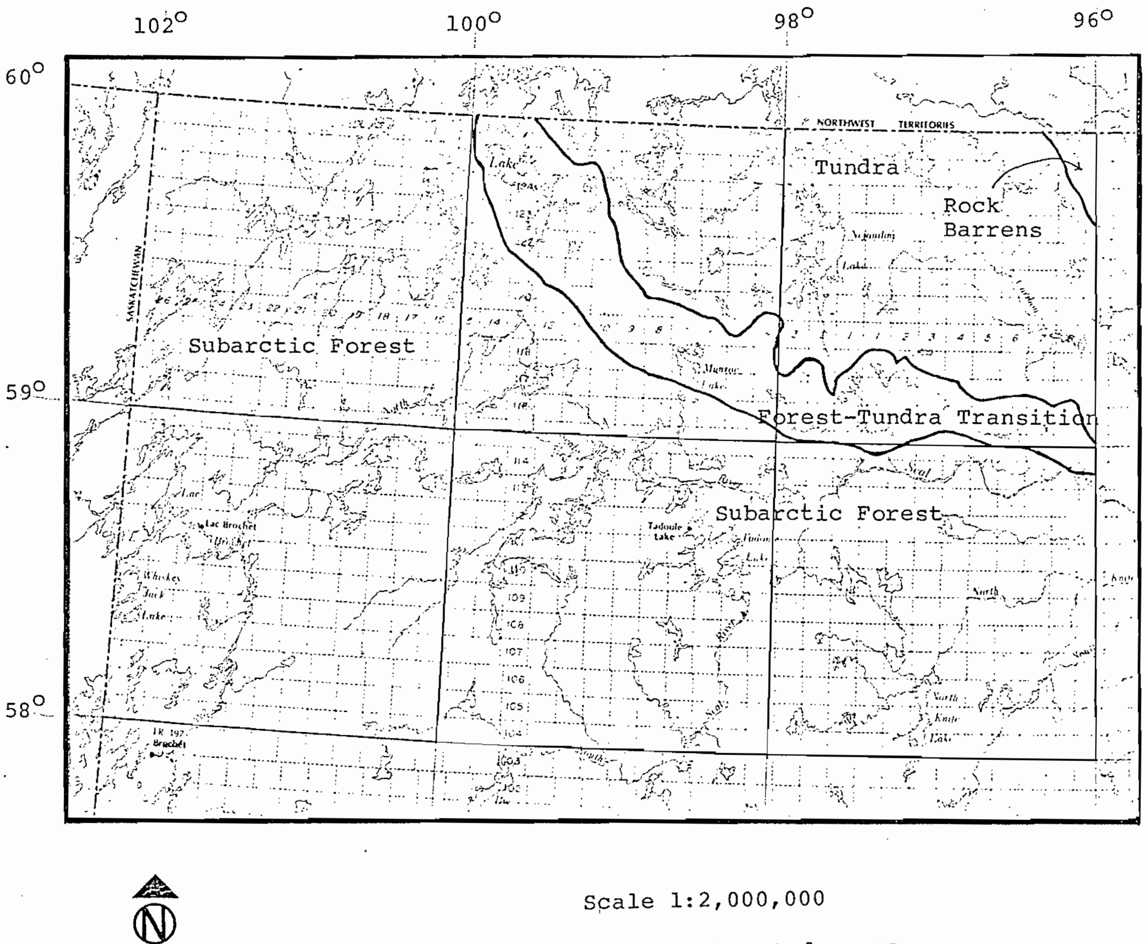
Table 4. Percent mean cover in vegetation strata within a 5-m radius sample plot.

VEGETATION TYPE	n	Tree Stratum	Shrub Stratum		Field Stratum	Ground Stratum	
			SAPLING	SHRUB		LICHEN	MOSS
Upland Closed Black Spruce	32	57	8	15	33	43	37
Upland Open Black Spruce	89	30	7	16	37	60	9
Upland Spruce Lichen	25	10	6	6	31	68	3
Lowland Closed Black Spruce	15	60	9	15	60	16	78
Lowland Open Black Spruce	68	25	10	10	56	18	59
Fens	8	3	4	32	67	Nil	83
Upland Lichen Heath	15	3	Nil	9	52	66	2
Upland Heath Complex	6	3	2	17	49	32	19
Rock Barrens	3	2	3	Nil	27	12	Nil
Lowland Sedge Cottongrass	5	2	1	4	79	9	Nil
Lowland Heath Complex	5	7	3	2	62	37	30
Revegetated Burn	6	Nil	Nil	Nil	50	Nil	17
Revegetated Burn & Forest	5	Nil	Nil	6	28	4	22

however, would be fens and lowland sedge cottongrass where sedges and grasses make up a large portion of the percent mean cover for field stratum. For all other vegetation associations, ericaceous shrubs are the largest component of the field stratum. Because of the seasonal importance to caribou, vegetation associations which provide abundant sedge and grass forage would be considered satisfactory habitat in terms of food presence.

Two other important aspects of caribou biology could be related to percent mean forest cover. For example, both upland and lowland closed black spruce would not provide suitable loafing or escape cover because of the relatively dense forest. On the other hand, more open forest types would provide suitable escape cover. Lakes and fens provide the best loafing cover. Tree cover in an open subarctic forest would be sufficient for the reduction of snow hardening effects induced by high winds. Hard snow conditions would be encountered on open tundra and on burn areas in the subarctic forest. While hard snow conditions provide a good medium over which caribou can travel, their ability to forage is hindered.

Two major vegetation regions characterize the study area. Subarctic forest covers approximately



Scale 1:2,000,000

Figure 2. Major vegetation regions of the study area.

65 percent of the area and tundra vegetation accounts for 20 percent. Approximately 15 percent of the area is covered by water. A narrow transition band exists between the two vegetation regions (Figure 2). Detailed vegetation maps of scale 1:250,000 are located at the back of this report.

4.2.1 Subarctic Forest

The subarctic forest is characterized by seven major vegetation associations and three classes of burn regeneration. Vegetation associations of this region were grouped into two main categories on the basis of relief. Upland vegetation types were distinguished from one another by crown closure and percent mean lichen and moss cover of the ground stratum. Lowland vegetation was also classified on the basis of crown closure and ground cover. Generally, as percent mean forest cover decreased, percent mean lichen cover increased.

Upland Closed Black Spruce

Upland closed black spruce occurred on moderately drained summits and upper slopes. *Picea mariana* was the dominant tree species, however, pure stands of *Pinus banksiana* were common on NTS-64K and the south west corner of NTS-64N and 64J. Stands of *P. banksiana* could not be differentiated from *P. mariana*

Table 5. Basal area (m^2/ha) of tree stems per vegetation type.

VEGETATION TYPE	Diameter Breast Height (DBH) Class in Centimeters 2.5	5.0	7.5	10.0	12.5	15.0	Total of Averages
Upland Closed Black Spruce	0.7	2.6	5.5	5.1	2.6	1.4	17.9
Upland Open Black Spruce	0.5	2.0	3.8	3.7	1.2	0.9	12.1
Upland Spruce Lichen	0.3	0.8	1.0	1.4	1.1	0.7	5.3
Lowland Closed Black Spruce	0.5	2.6	4.1	3.8	2.4	1.6	15.0
Lowland Open Black Spruce	0.6	2.0	3.2	3.2	1.4	0.4	10.8

with Landsat color enhancements. Percent mean cover of forest canopy was 57 percent. Basal area was 17.9 m^2/ha (Table 5). Stand age was variable and ages of 7.5cm dbh ranged from 35 to 135 years. Arboreal lichens were abundant in overmature ($\geqslant$100 years) black spruce stands and sparse in upland immature ($<$35 years) jack pine. Area covered by shrub stratum was variable with percent mean cover 15 and standard deviation 18. *Alnus crispa* attained 2.5m in height on the south facing slopes where stand density was near 50 percent. Field stratum was abundant and largely comprised of ericaceous shrubs. *Ledum groenlandicum* and *Vaccinium uliginosum* were common caesptiose shrubs and *Vaccinium vitis-idaea* the common decumbent shrub. Ground stratum was very abundant. Lichens, *Cladonia alpestris* and *Cladonia mitis* were more prevalent than feather mosses *Pleurosium* spp. on south slopes where forest canopy opened. Limited field data from one location (58°38'N x 98°37'W) showed oven-dried, mean weight per 25cm^2 plot to be: 40.7g for lichens; 13.2g for mosses; 2.4g for sedges; 1.1g for shrub leaves. Shrubs and twigs were not sampled.

Upland closed black spruce was assessed as satisfactory in terms of its suitability for the support of barren-ground caribou. Arboreal and terrestrial lichens were not very abundant, but could serve as forage for caribou during winter. Escape and loafing cover were lacking because of the dense forest.

Upland Open Black Spruce

Upland open black spruce occurred on well drained summits and upper slopes. *Picea mariana* was dominant and *Pinus banksiana* was common on NTS-64K; and 64N. *Betula papyrifera* was frequently found to occur as solitary trees on open summits. Mean density of forest canopy was 30 percent and ranged from 15 percent on summits to 45 percent on north slopes depending on moisture regimes and exposure. Basal area was $12.1m^2/ha$ (Table 5). Stand age was variable and ranged from 30 to 200 years in samples taken of the 7.5cm dbh class. Arboreal lichens were abundant in over-mature black spruce ($>$ 100 years) and jack pine ($>$ 75 years). Oven-dry weight of arboreal lichens collected from a 140 year old *P. mariana* with height 5m, in dbh class 11cm, was 42.2g. There appears to be a great deal of arboreal lichens however, samples from other areas were not collected thus a comparison was not possible. In any event arboreal lichens are utilized by caribou, and as Edwards et al. (1960) remark, "the importance of arboreal lichens to caribou depends on whether other foods are plentiful or scarce at the time." Shrub stratum was variable with percent mean cover 16 and standard deviation 18. *Alnus crispa* and *Betula glandulosa* were more prolific on slopes then summits. Field stratum was abundant and generally comprised of ericaceous shrubs. *Vaccinium vitis-idaea* and *Empetrum nigrum* were most prolific in open areas between tree crowns, whereas, *Vaccinium uliginosum* was often located near tree bases and in shade. Ground stratum was very abundant and lichens predominate. *Stereocaulon* spp. was locally abundant. Limited ground data from two sites (59°33'N x 98°22'W and 59°04'W and 96°34'W) showed oven-dried, mean weight per 25cm^2 plot to be: 56.3g for lichens; 5.9g for mosses; 0.9g for shrub leaves.

Upland open black spruce was considered as prime winter habitat for barren-ground caribou. Very abundant ground cover of foliose lichens and abundant field stratum of ericaceous shrubs provide forage for caribou during winter. Forage under the soft api is accessible except under conditions of excessively deep snow. Aerial surveys revealed that feeding activity most often occurred in the upland open black spruce. Snow conditions may be modified by wind in areas where percent mean forest cover is around

20 percent, but generally snow is soft and mobility would not be hindered. Three snow stations established in this vegetation association showed log VSI ranged from 2.06 to 2.96 (Appendix XI). Observation of several bedding sites in this vegetation association were made during aerial surveys in February, 1981. The open forest also ensures escape cover, providing snow is not too deep or hard. Ideal habitat conditions exist when upland open spruce forests are found along lake shores. Lakes provide ideal escape and loafing cover. Pruitt (1959) observed that caribou often bed down 75 to 100 meters from shore and then travel into the forest to feed during the day. Numerous bedding sites, some with as many as 30 depressions in the snow, were observed on lakes in February. Bedding sites were estimated to be usually within 50 meters from shoreline.

Approximately 15,776 km^2 of upland open black spruce is found throughout the study area (Table 6). Over 30 percent of this cover type is found on NTS-64N.

Upland Spruce Lichen

Upland spruce lichen occurred on well drained eskers as well as summits and upper slopes. *Picea mariana* was dominant and *Betula papyrifera* was found

Table 6. Area (km^2) of each vegetation type.

COVER CATEGORY	Shethanei NTS-64I	Tadoule NTS-64J	Whiskey-Jack NTS-64K	Kasmere NTS-64N	Munro NTS-64O	Nejanilini NTS-64P	Study Area Total
Upland Closed Black Spruce	1,429	1,681	1,285	1,505	502	378	6,780
Upland Open Black Spruce	1,558	2,586	3,854	4,766	2,508	504	15,776
Upland Spruce Lichen	1,169	259	514	878	376	126	3,322
Upland Open Birch	-----	10	-----	-----	-----	---	10
Lowland Closed Black Spruce	2,857	2,716	128	1,254	2,007	504	9,466
Lowland Open Black Spruce	3,247	1,552	2,827	1,003	125	630	9,384
Fens	26	259	385	125	---	---	795
Upland Lichen Heath	26	-----	-----	-----	2,634	4,535	7,195
Upland Heath Complex	26	-----	-----	-----	125	882	1,033
Rock Barrens	--	-----	-----	-----	128	126	254
Lowland Heath Complex	649	-----	-----	-----	---	630	1,279
Lowland Sedge/Cottongrass	130	-----	-----	-----	627	2,016	2,773
Recent Burn	26	647	385	251	627	126	2,062
Revegetated Burn	26	517	129	376	376	125	1,549
Revegetated Burn & Forest	390	905	1,285	627	251	---	3,458
Water	1,429	1,810	2,056	1,756	2,257	2,016	11,324
Map Sheet Total	12,988	12,942	12,848	12,541	12,543	12,598	76,460

in small isolated clumps. Stands of mature (>75 years) jack pine were most abundant on sandy eskers of NTS-64K; 64J; and 64N. Percent mean forest cover was 10 percent. Basal area was 5.3 m^2/ha with 66 percent of this accounted for by trees in the 7.5, 10.0, and 12.5-cm dbh classes. Arboreal lichens were sparse in mature black spruce and overmature jack pine stands. shrub stratum was rare. Field stratum was abundant and was generally comprised of decumbent ericaceous shrubs. *Empetrum nigrum* and *Vaccinium vitis-idaea* were common on steep sandy slopes. Ground stratum was very abundant and dominated by *Cladonia* spp. with *Stereocaulon* spp. only locally abundant. Large open patches of sand and till are found along eskers. Boulders and stones are frequently covered by crustose lichens.

Upland spruce lichen was considered as prime winter habitat because of the very abundant forage. Northeast orientation of eskers associated with this cover type may figure prominently during migratory periods. Windswept crests of eskers enable relatively easy mobility and provide escape cover when compared with deep snow in surrounding forests. Snow on south facing slopes melts early in spring, exposing lichens, sedges and some mushrooms.

Upland Open Birch

This vegetation association occurs very rarely throughout the study area and only limited field data were available. Upland open birch occurred on well drained sandy eskers and upper slopes. *Betula papyrifera* was the dominant tree. Shrub stratum was abundant and dominated by *Betula* spp. Field stratum was sparse. *Arctostaphylos uva-ursi* and *Vaccinium vitis-idaea* were common caespitose shrub. Ground stratum was very abundant and dominated by lichens, *Cladonia* spp. and *Stereocaulon* spp.

This area was considered as prime habitat for the same reasons as upland spruce lichen.

Lowland Closed Black Spruce

Lowland closed black spruce occurred on imperfectly to poorly drained gentle slopes. *Picea mariana* was the dominant tree. Trees were generally cylindrical in shape and not as well formed as those on upland sites. Mean density of forest canopy was 60 percent. Stand ages range from 65 to 195 years in samples taken from the 7.5cm dbh class. Arboreal lichens were abundant in overmature black spruce stands. Shrub stratum was sparse with *Betula* spp. and *Salix* spp. most prolific in areas of poor drainage. Field stratum was very abundant and dominated by *Ledum* *groenlandicum* and *Vaccinium uliginosum*. Ground stratum was very abundant and dominated by *Sphagnum* spp. and *Pleurosium* spp.

Lowland closed spruce was considered to be marginal barren-ground caribou winter habitat. Terrestrial lichen forage was very rare. Arboreal lichens are very abundant and may be consumed near the perifery of this vegetation association but dense forest cover provides little escape or loafing cover.

Lowland Open Black Spruce

Lowland open black spruce occurred on poorly drained to saturated peat lands. *Picea mariana* was the dominant tree although *Larix laricina* was locally abundant. Mean density of forest canopy was 25 percent. Basal area measured 10.8 m^2/ha. Stand ages were variable but the majority were overmature because wet lowlands have less susceptability to burning. Arboreal lichens were abundant in overmature black spruce stands. Shrub stratum was sparse and dominated by *Betula* spp. Field stratum was very abundant with *Ledum groenlandicum* most prolific. *Rubus chamaeomorous* flourished on lowland open black spruce sites. Ground stratum was very abundant and dominated by *Sphagnum* spp. Terrestrial lichens were frequently found growing on summits and slopes of well drained microhummics. Microhummics are caused by permafrost action.

Lowland open black spruce was assessed as satisfactory barren-ground caribou winter habitat. Only limited amounts of terrestrial lichen forage are available. Miller (1976) suggests the occurrence of tamarack (*Larix laricina*) needles in rumens indicates caribou feed partly in lowland areas throughout the winter. Abundant arboreal lichens may provide an important food source to caribou when snow conditions hinder the availability of terrestrial lichens.

Fens

Fens occurred on saturated peat lands, in water filled depressions, and collapse scars. *Picea mariana* and *Larix laricina* were the dominant trees which usually grew around the periphery of a fen or on raised peat mounds in fen complexes. Mean stand density was 3 percent. Shrub stratum was abundant with *Betula nana* common on ribbed fens and around the periphery of collapsed areas. *Salix* spp. was most common under saturated conditions. Field stratum was very abundant and dominated by *Chamaedaphne calyculata* and *Kalmia polifolia*. *Carex* spp. was abundant. Ground stratum was very abundant and dominated by *Sphagnum* sp.

Fens were considered as satisfactory winter barren-ground caribou habitat. Miller (1976) states that *Andromeda* sp. and *Kalmia* sp. were more common in rumens collected in November and January-February than those collected in April. This suggested that caribou fed more frequently in fens in early and mid winter. Aerial observations in February revealed moderate feeding activity around fens. Several bedding sites were also noted in fens.

4.2.2 Tundra

Tundra, which covers approximately 25 percent of the study area, was characterized by five major vegetation associations. One of the most striking features of the tundra was the stunted growth of trees which were often restricted to lake shores and depressions. Terrain was relatively flat however subtle differences in relief resulted in two significantly different vegetation categories, upland and lowland.

Three upland vegetation associations were distinguished from one another by characteristics of species composition, amount of unsorted till, and degree of solifluction. Generally, summits and upper slopes were characterized by lichen heath associations however, in the northeast corner of NTS-64P lichen heath gave way to rock barrens, characterized by an overwhelming amount of unsorted till and boulders. On mid to upper slopes where soil stability may be reduced by the process of solifluction, lichen growth gave way to exposed areas of sand or till and upland heath complexes were present.

Two lowland vegetation associations were distinguished from one another by species composition.

Upland Lichen Heath

The most prevalent vegetation association of the tundra, upland lichen heath, occurred on moderately drained summits and upper slopes. *Picea mariana* were stunted and grew only in isolated depressions. Solitary *Larix laricina* seldom exceeded 2m in height in open areas. Density of forest canopy was less than 5 percent. Shrub stratum was rare with *Betula nana* commonly associated with drainage patterns. Field stratum was very abundant and formed a tangled mat with the ground stratum. *Ledum decumbens*, *Vaccinium vitis-idaea*, *Vaccinium uliginosum* var. *alpinum* and *Empetrum nigrum* were most common and were generally found in equal abundance. *Cladonia mitis* and *Cetraria nivalis* were the most common lichens Arboreal lichens were rare, however one arboreal lichen genera, *Alectoria* was common on the ground. Limited data (59°23'N x 97°42'W and 59°17'N x 97°04'W) showed oven-dried, mean weight per $25cm^2$ plot to be: 64.2g for lichens; 5.1g for sedges; and 5.8g for shrub leaves. Upland lichen heath covers approximately 9 percent of the study area.

Very abundant terrestrial lichens would suggest prime winter habitat however, adverse snow conditions hinder forage accessibility therefore upland lichen heath was assessed as satisfactory winter habitat. Excessive exposure and wind-swept uplands result in very hard snow conditions. Mobility, escape and loafing cover were not considered as limitations of the upland lichen heath.

Upland Heath Complex

Upland heath complex occurred on moderately drained summits and upper slopes where soil stability was reduced by solifluction. This cover class is similar to upland lichen heath but boulders, till, and sand patches were frequently found. *Picea mariana* was found only to grow near sorted rings. Forest canopy was less than 5 percent. Shrub stratum was sparse and dominated by *Betula nana* which seldom exceeded 1m in height. Field stratum was abundant and dominated by *Ledum decumbens*, *Vaccinium vitis-idaea; Vaccinium uliginosum* var. *alpinum*, and *Empetrum nigrum*. Ground stratum was abundant and dominated by *Cladonia* spp. and *Cetraria* spp. Unstable soils hampered lichen growth. Limited field data from one site (59°12'N x 96°38'W) showed oven-dried, mean weight per $25cm^2$ plot to be: 20.4g for lichens and 0.8g for sedges. Upland heath complex was assessed as marginally suitable winter habitat for barren-ground caribou. Forage was less plentiful than on upland lichen heath sites and wind exposed slopes also result in very hard snow conditions.

Rock Barrens

Rock barrens occurred on well drained summits and upper slopes and were characterized by boulders, stones, exposed till, sparse vegetation, and absence of trees. Shrub stratum was rare with *Betula nana* common to sites where drainage was not excessive. Field stratum was sparse with heath vegetation growing on sand and gravel patches between boulders. Ground stratum, characterized by *Cladonia* spp. and *Cetraria* spp. was rare. This vegetation association was most common to the northeast corner of NTS-64P and covered less than 1 percent of the study area.

The rare occurrence of forage species accompanied by hard snow conditions makes this vegetation association unsuitable barren-ground caribou winter habitat.

Lowland Sedge Cottongrass

Lowland sedge cottongrass occurred on poorly drained to saturated peat lands. *Picea mariana* and *Larix laricina* were the dominant trees however, forest cover was less than 5 percent. Shrub stratum was rare but field stratum was very abundant. *Carex* spp. and *Eriophorum* spp.common to the field stratum,and dominated the landscape. Ground stratum was very abundant and dominated by *Sphagnum* spp. Unvegetated areas of peat were evidence of permafrost action. Lowland sedge cottongrass covers approximately 4 percent of the study area.

Because of the importance of sedges and grasses to caribou in late winter and early spring, lowland sedge cottongrass was assessed as satisfactory winter habitat. Miller (1976) notes that sedges and grasses provide an important source of protein. Also, accumulation of snow in lowlands could hinder mobility or food availablility.

Lowland Heath Complex

Lowland heath complex occurred on poorly drained flat peat lands. *Picea mariana* and *Larix laricina* were the dominant trees. Density of forest cover was less than 5 percent. Shrub stratum was rare but field stratum was very abundant. *Ledum decumbens*, *Kalmia polifolia*, and *Vaccinium uliginosum* were common. Ground stratum was very abundant and dominated by *Sphagnum* spp., *Cladonia* spp., and *Cetraria* spp. Peat polygon formations were evident and terrestrial lichens grew abundantly on raised peat plateaus. Limited ground data from one location (59°54'N x 96°56'W) showed oven-dried, mean weight per 25cm^2 plot to be: 22.1g for lichens; 4.4g for sedges; and 6.5g for shrub leaves. Lowland heath complex covers approximately 2 percent of the study area.

Lowland heath complex was assessed as marginally suitable winter habitat. This area could also be used by caribou during spring because of the abundance of sedges.

4.2.3 Forest Fires

With only two settlements and sparse population found throughout the study area, the most likely cause of forest fires was lightning. During the cool, wet summer of 1978 only two small fires ($\leq$ 10 ha) were observed in the study area. In contrast, the in i ence of fire was very high during the hot dry summer of 1979 when several days of thunder storm activity were recorded during field season. Because this area is beyond the northern limit of Manitoba Forest Management Units and subsequently Forest Protection Services, once a fire is ignited it burns unchecked. Consequently fire damage often occurs over a very large area and fires are large in terms of total area burned. For example, one forest fire on NTS-64J burned an estimated 120,000 ha in 1973.

Landsat black and white photographs were used to create a burn mask for each map sheet. A random sampling of 1957 aerial photography for the study area also revealed the location of several burns.

With the aid of Landsat color enhancements supplemented by ground truth and aerial observations three categories of burn were identified.

Recent Burn

Recent burns were areas which burned between spring 1977 and fall 1980. Discrimination of relief within recent burn areas was not made on the maps. Burn intensity was however greater on dry upland sites than on wet lowland sites. Forest canopy was destroyed by fire and only standing scorched trees remained. Regenerative activity was not readily apparent. Shrub and field strata had been destroyed by fire and all that remained were charred above-ground stems. *Epilobium angustifolium* may be found on slopes. Ground stratum was destroyed and crustose lichens were burned off rocks.

Recent burns were considered unsuitable barren-ground caribou winter habitat because major forage species had been destroyed.

Estimated area burned on the study area during the 4-year period 1977-80 was 2.7 percent. Area burned on the subarctic forest during the same period was 3.92 percent. Subarctic forest annual rate of burn during the 4-year period 1977-80 was 0.98 percent. Recent burns were not observed on the tundra. Miller

(1976) calculated annual rate of burn on subarctic forest in northern Manitoba during the 12-year period 1955-67 to be 0.17 percent. Annual area burned in northern Manitoba during recent years has increased substantially. Scotter (1964) estimated 0.87 percent land area burned annually during the period 1940-55 in north central Saskatchewan.

Revegetated Burn

Areas classified as revegetated burns were estimated to have burned either just prior to 1972 or just prior to the acquisition of 1957 photography. This cover type included regeneration from both periods although of the two, the majority of areas indicated on maps were from the most recent period. It is likely that fire mapping for these periods was incomplete because only 1972 and 1957 imagery were used. Areas mapped however, represent at least minimum area burned.

Stand ages and amount of regeneration were extremely variable for this cover class. Limited field data showed immature (15-25 years) *Pinus banksiana* and *Picea mariana* were common to this class. *Pinus* regeneration was common on upland sites on NTS-64K and the southwest corner of NTS-64J and 64N. Twenty-five year old stands attained heights of 4m with percent mean forest cover of 35 percent. *Picea* regeneration was found throughout the subarctic forest. Fifteen year old stands may attain heights of 1.5m. On younger stands (10 years) *P. mariana* seedlings were 30cm high with abundant shrub stratum on upland sites. Field stratum was generally sparse although it was found to be locally abundant on several occassions, depending on site conditions and age. *Ledum groenlandicum* and *Vaccinium uliginosum* were common over the entire study area whereas *Vaccinium myrtilloides* was most common to NTS-64K. *Epilobium angustifolium* was found on all sites and *Carex* spp. was locally abundant. Ground stratum was sparse on younger stands where scorched earth comprised 50 to 75 percent of the ground cover. *Polytrichum* spp., *Dicranum* spp., and *Bryum* spp. were common. Generally, terrestrial lichens were rare, however, at one immature jack pine site (25 years) *Cladonia* spp. were abundant.

Revegetated burns were considered to be unsatisfactory winter habitat for barren-ground caribou because of forage scarcity. Older regeneration stands (> 25 years) would possibly be of marginal value providing terrestrial lichen regeneration as well established. Revegetated burns account for approximately 2.02 percent of the study area or 2.94 percent of the subarctic forest region. Subarctic forest annual rate of burn during the 7-year period 1965-1971 was estimated to be 0.42 percent.

Revegetated Burn with Residual Forest

The cover category, revegetated burn with residual forest, was an area over which a burn had taken place sometime between spring 1972 and fall 1976. Small patches of unburned forest, usually ± 100 ha, remained standing. Standing deadwood and scorched trees were found in burn areas. *Picea mariana* was the most common regenerative tree species although *Pinus banksiana* was more common to the south west. Black spruce seedlings were less than 30cm tall. Shrub stratum was rare with *Alnus crispa* and *Betula* spp. most often exhibiting resprouting. *Epilobium angustifolium* propagated by seed. Ground cover was sparse, usually invaded by *Polytrichum* spp. Lichens were rare, and usually found only in areas which had not been disturbed by fire.

Revegetated burns with residual forest were considered to be unsatisfactory habitat because of forage scarcity. This assessment is debatable as unburned forest will undoubtably be of some value to local concentrations of caribou. This cover type may in fact provide satsifactory habitat as open spaces created by burns could provide escape and loafing cover for local bands of caribou feeding in unburned "islands" of forest vegetation. Islands are formed when barriers to burning, such as lakes, wet lowlands, and eskers prevent fire advance. Shifts in wind direction and/or precipitation alters direction of fire advance and burn intensity. Further field observations are required to establish usage of unburned, forested islands within large burns by caribou.

Revegetated burn with residual forest, covered approximately 4.52 percent of the study area or 6.51 percent of the subarctic forest. Annual rate of burn in the subarctic forest during the 5-year period 1972-76 was 1.31 percent. Examination of fire trends over the 26-year period 1955-80 indicated an increase in annual rate of burn for subarctic forest (figure 3). Caution is recommended when comparing Miller's (1976) estimate of annual rate of burn with estimates obtained from this study. Miller's study area covered subarctic forest on NTS-64K whereas estimates for this study included subarctic forest from an area approximately 5 times the size. Annual rate of burn for NTS-64K during the 5-year period 1972-76 was 2.00 percent; and for the 4-year period 1977-80 the rate was 0.74 percent. These figures still indicate an overall increase in annual rate of burn since Miller's (1976) study.

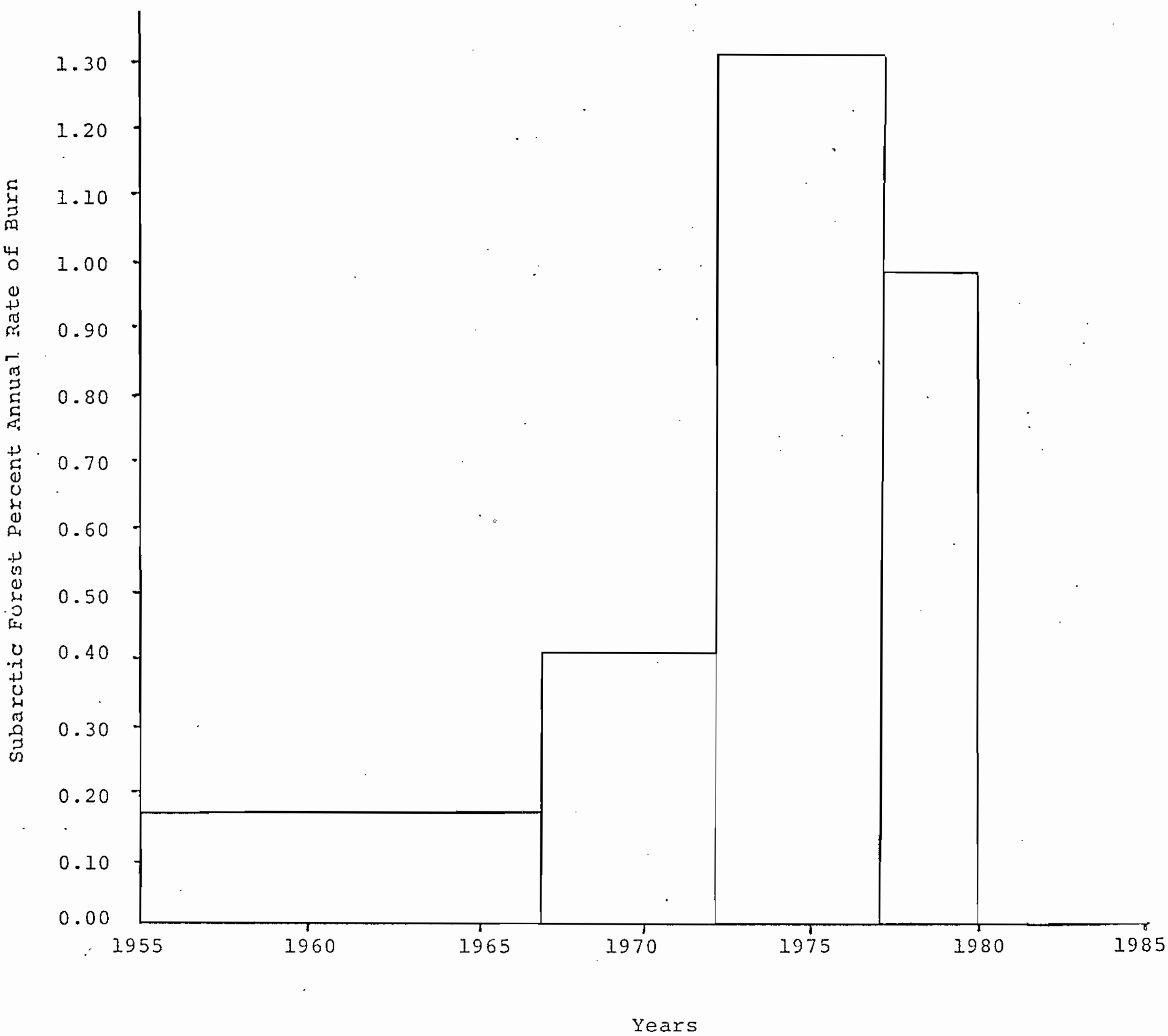


Figure 3. Subarctic forest percent annual rate of burn for the 26-year period 1955-80.

Note: 1955-67 percent annual rate of burn was 0.17 (Miller 1976).

4.3 Mapping Accuracy

The ability to identify correctly and locate ground features of interest, is a fundamental concern to Landsat users. Reliability of information which can be obtained from ARIES color enhancement of digital data, requires a statement of mapping accuracy. An aerial sampling technique was used for comparing field observations with map units. Probability of classification and mapping errors were summarized in table 7. Caution is recommended when evaluating these results as only limited field data were available for several vegetation classes. Factors influencing accuracy included project mapping objectives, Landsat system, observer bias in field observations, and image interpretation.

Fly-by data instead of ground data were used for map accuracy assessment for two reasons. First, there were more fly-by observations, therefore, a larger sample. Second, the relationship between area of ground plots ($78m^2$), area of minimum mapping unit (150 ha) and area of fly-by (250 ha) was considered important. An experiment was conducted to determine the effect of decreasing sample size area on classification accuracy. In an area of relatively homogenous vegetation cover it was found that as the size of the sampling unit decreased the error rate increased (Appendix XII). Class-

Table 7. Probability of classification errors (P_{ci}) and mapping errors (P_{mo}) for subarctic forest, tundra and burn cover types.

COVER TYPE	ERROR CATEGORY	SHETHANEI NTS-64I	TADOULE NTS-64J	WHISKEY JACK NTS-64K	KASMERE NTS-64N	MUNROE NTS-64O	NEJANILINI NTS-64P
Upland Closed	P_{om}	0.67	0.35	0.46	0.44	0.62	NE
Black Spruce	P_{ci}	NE[1]	0.17	0.32	0.22	0.50	NE
Upland Open	P_{om}	0.34	0.12	0.12	0.18	0.30	NE
Black Spruce	P_{ci}	0.50	0.25	0.11	0.20	0.32	0.67
Upland Spruce	P_{om}	NE	0.37	0.09	NE	NE	NS[2]
Lichen	P_{ci}	NE	0.20	0.38	0.59	0.75	NS
Upland Open	P_{om}	NS	NE	NS	NS	NS	NS
Birch	P_{ci}	NS	NE	NS	NS	NS	NS
Lowland Closed	P_{om}	0.49	0.19	0.86	0.46	0.19	NE
Black Spruce	P_{ci}	1.00	0.14	0.80	0.33	NE	0.50
Lowland Open	P_{om}	0.29	0.13	0.09	0.05	0.50	NE
Black Spruce	P_{ci}	0.42	0.21	0.06	0.24	0.11	0.33
Fens	P_{om}	NS	NE	0.24	0.28	NS	NS
	P_{ci}	NS	NE	0.17	NE	NS	NS
Recent Burn	P_{om}	NS	0.15	0.17	NE	0.08	NE
	P_{ci}	1.00	0.14	0.19	NE	NE	NE
Revegetated Burn	P_{om}	1.00	0.16	NE	0.04	0.10	NS
	P_{ci}	1.00	0.26	0.29	NE	0.37	NE
Upland Lichen	P_{om}	NS				0.08	0.04
Heath	P_{ci}	NS				0.27	NE
Upland Heath	P_{om}	NS				0.31	NS
Complex	P_{ci}	NS				NE	NS
Rock Barrens	P_{om}	NS				NE	NS
	P_{ci}	NS				NE	NS
Lowland Sedge	P_{om}	NS				0.29	0.27
Cottongrass	P_{ci}	NS				0.00	0.20
Lowland Heath	P_{om}	0.71				NS	0.69
Complex	P_{ci}	NE				NS	0.67

1. NE - No errors observed from sample
2. NS - No sample available

ification errors were not errors per se but rather where errors in the sense that they did not portray the forest crown closure generally found throughout the entire cell. Based on the results of this test the decision was made to use fly-by data for accuracy assessment. Ground data enabled a detailed analysis of the species composition and spatial distribution of vegetation association whereas the overview obtained from fly-by observations was more appropriate for assessing accuracy of interpretation from Landsat color enhancements.

An appreciable number of classification and mapping errors were attributed to mapping objectives. Objectives required discrimination of habitat parameters which could be related to caribou Biology. Vegetation associations with similar attributes were difficult to classify from aerial observations and difficult to interpret from Landsat color enhancements.

The ability of experienced and inexperienced observers to classify vegetation associations was examined. Chi-square analysis of fly-by observations on both tundra ($X^2_{.05,1}$ = 3.84, computed X^2 = 11.40) and subarctic forest ($X^2_{.05,1}$ = 3.84, computed X^2 = 22.03) was performed(Appendix XIII). It was found that two experienced observers could classify vegetation associations consistantly on the basis of aerial observations for either tundra or subarctic forest regions. Chi-square analysis led to acceptance of the null hypotheses that similarities and differences noted between two experienced observers are not dependent on general vegetation conditions ($X^2_{.05,1} = 3.84$, computed $X^2 = 2.71$) (Appendix XIII).

Classification errors made in the field contribute to reduced map accuracy however, biological implications of some classification errors are minimal. For example, an upland closed black spruce with 55 percent crown closure does not differ appreciably from an area classified as an upland open black spruce with 45 percent crown closure. The difference would show up as a mapping error. It is likely that at least one third of the classification and mapping errors (perhaps 35-55 percent) were due to the fact that distinction between similar vegetation associations was difficult.

Discrimination of pure jack pine stands and revegetated burns was not possible with Landsat color enhancements. Inability to discriminate jack pine stands was not considered to be a serious limitation to using principal component enhancement for caribou habitat mapping. Throughout the study area, aerial surveys revealed relatively few, pure jack pine stands. Ground truthing showed that ground cover and shrub species did not differ appreciably between open jack pine and black spruce stands. Inability to discriminate revegetated burns was a greater problem.

Revegetated burns were often confused with other vegetation associations. Distinction between vegetation associations located on map sheets NTS-64O and 64P was difficult because two different vegetation associations were represented by the same color. For example, upland lichen heath and upland open black spruce were both light green on the Landsat color enhancements. Air photo interpretation was necessary along the transition. Had 9-15 color classes been generated with the enhancement technique, revegetated burns, tundra vegetation classes, and subarctic forest classes could have been represented by their own color class. One further point regarding image interpretation and map production should be made.

Landsat color enhancements were detailed (pixel by pixel), photographic products. Delineation of small units (<150 ha) within larger units would have resulted in a map of such detail so as to be confusing. Boundaries between vegetation associations were therefore only approximations.

Technical limitations of the Landsat system likely made minor contributions to errors. The Landsat system was only capable of providing 80m resolution images. Considering scale of mapping and size of minimum mapping units, the biological significance of these errors were minimal and would possibly result in minor variations of boundary positions. As Landsat images of similar band quality were chosen, anomalies affecting digital data quality would be relativly the same for each scene. Strome et al. (1975) state that some residual errors remain after radiometric and geometric calibration.

4.4 Mapping Costs

The total estimated cost of mapping six NTS map sheets with Landsat data at a scale of 1:250,000 is $62,910 or about $0.82 per km^2. Costs per map sheet (table 8) reflect the demonstration and training aspects of the project, and would be considerably lower in an operational mode. Mapping cost comparisons between Landsat imagery and conventional mapping techniques employing aerial photography are difficult because one must consider factors of map scale and level of detail required for mapping. For example, as image scale decreases not only does information content increase but the cost

Table 8. Estimated costs by major tasks of vegetation mapping for one NTS map sheet (1:250,000).

MAJOR TASK	ESTIMATED COST	% OF SUBTOTAL
Operating Costs		
Equipment	$ 100	1
Landsat data	300	3
Field crew food & accomodation	800	9
Map printing & production	1,300	14
Fuel caching (11 bbls)	1,500	17
Principal component enhancement	2,365	26
Fixed-wing aircraft (25 hrs.)	2,750	30
Subtotal	9,115	
Overhead (15%)	1,370	
TOTAL	$10,485	

MAJOR TASK	STAFF MAN-DAYS	% OF TOTAL
Personnel Costs		
Preliminary interpretation	5	11
Field program planning & logistics	5	11
Field data gathering	15	34
Data analysis	5	11
Map production	10	22
Report writing	5	11
TOTAL	45	

of image acquisition for a fixed area increases. There are several aerial photographic products to choose from (ie. true color, color infrared, and black and white), each available over a wide range of scales. Landsat imagery is currently large scale and image acquisition costs are relatively inexpensive. McQuillan (1975) points out that an ecological land survey carried out in the James Bay area cost about $12.50 per square kilometer. Obviously much more information is obtained in a detailed inventory, but if a broad inventory is properly desinged, it should be capable of absorbing more detailed information at a later date. The information obtained from Lansat data depends on interpreter experience and/or the choice of classification or enhancement technique.

The most costly factor in this mapping project was incurred during field survey. Field surveys accounted for approximately 56 percent of the costs and 45 percent of the staff man-day requirements. These costs may be increased or decreased depending on the detail and intensity of field survey but one cannot escape high logistic costs associated with working in the north (ie. aircraft time and fuel caching operations).

Landsat data acquisition and processing was the second most costly factor (29 percent) in this project. A substantial saving of $850 per map sheet could have been achieved had DICS data been used instead of CCTs. At the time of project planning however, three month lead-time required for acquisition of DICS data would have essentially meant principal component enhancement would not have been available until after the 1980 field season. The entire project would have been delayed for over one year. Turn around times for obtaining Landsat products are an important consideration for project planning and scheduling. Turn around times considered for this project were: acquisition of CCT's, one week; acquisition of DICS, eight weeks; acquisition of Landsat photographic products, one week; principal component enhancement, two week.

While aerial photography offers some advantages over current satellite systems, in particular larger scale imagery with greater detail and sterographic coverage providing relief information, the most cost effective means of obtaining the desired information for this study was achieved through effective combination of satellite data, existing aerial photography, and aerial and ground surveys.

4.5 Application of Results for Management

The principal value of vegetation maps is that they provide a knowledge of present conditions and a data bank of information for future planning and research. Each vegetation cover map provides a synoptic reference base to which detailed information may be related. The maps may also be used to enhance the value of existing information. For example, caribou survey data gathered over the past ten years could be related to vegetation associations. In this manner, ecological relationships may be more easily grasped when results from several related studies are presented in synoptic form.

Aspects of caribou biology which have perplexed numerous researchers over the years include annual variations in caribou migration and range use patterns. Pruitt (1959) has stated that several physical parameters of snow influence movements of caribou and their distribution throughout much of their annual cycle. The inability to adequately sample and map snow cover features over large areas has been a major problem to date. Snow cover data from repetitive satellite imagery in conjunction with detailed ground information on snow and ice conditions would possibly aid in understanding migration patterns. For example, multidate analysis of satellite imagery could be used to monitor rate and pattern of snow accumulation or snow melt in early winter or late spring, respectively. Aerial surveys conducted during the migratory period could then be used to study caribou movement in relation to snow cover. Vegetation maps would be an ideal data base for this type of study as they provide for a logical separation of units that can be related not only to the biological requirements of caribou but also to habitat features which affect snow morphology.

The quality, extent, and distribution of habitat for wildlife species such as caribou and moose change with each fire season. Fires may have either a beneficial or detrimental effect depending on location, size, and intensity. For example, a large intense fire in the transition zone between subarctic forest and tundra may render an area unsuitable winter habitat for over 50 years whereas, a moderate fire in the southern most subarctic forest may result in a rejuvenation of lichen growth within 25 years. As a natural agent of regeneration and regulator of age class, forest fires' long-term effects may offset their initial damage. It would be valuable to map and monitor the history of burned areas to test theories of fire ecology and its effects on wildlife. The present study was a step towards answering the question, "How much damage do forest fires really do?"

The cost of producing up-to-date fuel type maps is prohibitive by conventional air photo methods. Fuel mapping involves mapping different forest fuels such as spruce, fens, and old burns. Vegetation maps may be used as fuel maps. Knowledge of the presence and extent of high fire risk areas would be valuable in routing fire detection aircraft patrols. For example, NTS-64N would be considered as an area highly susceptible to burning. Over 50 percent of the area is upland vegetation (ie highly susceptable to burning) and there are fewer barriers to burning on this map sheet than on any other. Accurate fuel maps would provide information on fuel types in the fire path when a fire is detected. This would provide fire fighting crews with knowledge of what resources should be deployed to a given fire. Action priorities could be established and the possibility of over-commitment to fires reduced.

By relating detailed ground studies to aircraft and satellite imagery,it is possible to use maps as a means of communicating in a pictorial manner. For example, many native people and caribou researchers attribute the caribou population decline to a high incidence of forest fires. Vegetation maps could be used to show extent of burns in the study area in relation to amount of unburned vegetation. The ratio of burned subarctic forest to unburned subarctic forest is presently 1:7. Individuals can often relate to spatial and temporal aspects of maps much easier than charts or other forms of presentation. Using these vegetation maps together with other information provides a valuable communication tool.

The value of vegetation maps is also evident in terms of environmental monitoring aspects. For example, when phenomena change with time it is necessary to have statistics on these phenomena over a number of years before one can predict effects of development projects. Observation of naturally induced changes may point out changes which man may cause. It would not be unreasonable to speculate that within the next two decades major development projects may be expected to occur within this vast region. Mining exploration is already underway, pipeline routes have been examined, and the region has a large hydro electric potential as yet untapped. Baseline data would be valuable prior to undertaking any major project. Knowledge of wildlife habitat would help in selection of routes. For example, for moose and caribou, it is desirable to avoid major wintering areas and important travel routes.

4.6 Feasibility of a Habitat Monitoring Program

The cost of compiling a habitat map varies with size and location of area to be covered, scale used, number of categories to be mapped, and degree of complexity inherent in the landscape. Landsat digital enhancement enabled rapid and fairly accurate delineation of major boundaries between cover types. Vegetation maps provide a base upon which habitat monitoring programs may be developed. As fire is the major factor influencing vegetation change in the study area, yearly production of burn masks would be valuable. The cost of acquiring black and white satellite images for an area of about 76,000 km^2 would be $66 annually. Images obtained in November where the first few snow-falls enhance the open areas created by fire would be sufficient for burn mask production. Fire boundary delineation and area determination for six NTS map sheets would require approximately two staff man-weeks.

Further understanding of the ecological effects of fires could be achieved with either digital enhancement or classification techniques. These processes are costly but not prohibitive if a single NTS map sheet were monitored every year with complete coverage of the area requiring say five years. With development projects such as pipelines or roads, monitoring would be possible prior to, during, and after completion of the project.

5.0 SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

5.1 Summary and Conclusions

The primary objective of this study was to determine the extent and types of vegetation associations found in northern Manitoba for the purpose of providing a preliminary assessment of barren-ground caribou winter range. Vegetation cover maps were produced for six NTS map sheets at a scale of 1:250,000. Each vegetation map provides not only a pictorial representation of present conditions but also a synoptic reference base to which detailed information may be related.

Seven classes of subarctic forest and five classes of tundra provided an adequate description of the vegetation for these regions. Vegetation classification was based on characterisitics of relief, species composition, and spatial distribution. The vegetation classification scheme provided for a logical seperation of units to which caribou's biological requirements of food, cover, and mobility could be related.

A preliminary assessment of the suitability of each vegetation association to support barren-ground caribou, revealed approximately 25 percent of the study area to be prime winter habitat, 35 percent to be satisfactory, 15 percent to be marginal, and 10 percent to be unsatisfactory. Given present range conditions, winter food scarcity for caribou was not considered as a factor limiting the present caribou population. The quality and distribution of habitat changes, with each fire season.

The primary cause of fire in this region is lightning. As exploration and recreation activities increase and population grows, the risk of fire will increase. Potential remains for devastation of thousands of square kilometers of caribou range each year because fires are allowed to burn unchecked. While the short-term effects of such devastation are ovbious, long-term effects remain unknown. Regenerative activity from fires which occurred during the 4-year period 1977-80 could not be detected with color enhanced 1980 satellite images alone. Landsat photographic data were also required. The extent to which caribou utilize regenerated areas was not definite. Although annual rate of burn of subarctic forest has increased since the mid 1950's, trends in recent years (1977-80) have indicated a slight decline from the 5-year period 1972-77. It is not likely that fires have had appreciable influence on the fluctuation of caribou numbers. The effect of fires will however alter local distribution of wintering caribou.

The feasibility of using Landsat data for vegetation mapping was demonstrated. Discrimination of major vegetation associations throughout the study was possible with Landsat color enhancements. Vegetation spectral signatures detected by sensors on-board Landsat provided the data base for color enhancement. Subtle differences in the spectral signature enabled discrimination among vegetation associations. Vegetation parameters which gave rise to subtle spectral differences included the combination of forest crown closure and ground cover species. Supplementary Landsat photos were required for location of revegetated burns. Drawbacks to locating optimum Landsat data were related to cloud cover and technical problems with the MSS system.

Factors influencing mapping accuracy included variation among vegetation classes in both errors of classification and mapping. Landsat photographic products provide an efficient means for monitoring change in vegetation pattern over time.

5.2 Recommendations

On the basis of this study, it is recommended that the following be given careful consideration:

1. A yearly habitat monitoring program should be undertaken to update vegetation maps. Large forest fires burning unchecked throughout the study area presently consume 0.98 percent of the subarctic forest annually. Landsat photographic products should be used annually to produce burn masks and monitor fire trends.

2. Research should be undertaken to determine the long term effects which forest fires have on the quantity and quality of habitat. Regenerative activity following fire should be examined to determine the rate of range recovery. The extent to which caribou untilize burned areas should be determined.

3. A fire control program which is consistant with resource utilization in the area should be developed. Presently, lightning is the primary cause of fire in this region however, as communities and resource development expand, the risk of man-induced fires will increase.

4. Surveys should be conducted during early, mid, and late winter to determine caribou habitat preferences. Biomass of forage species associated with each vegetation association should be determined in order to calculate the potential range carrying capacity.

5. The use of multidate Landsat imagery for studying trends in snow conditions over the entire range should be examined. Caribou migration should be examined in light of the pattern and rate of snow accumulation and melt in early winter and spring, respectively.

LITERATURE CITED

Alfoldii, T.T. 1978. Introduction to digital images and digital analysis techniques. Can. Dept. Energy Mines Resour. CCRS Tech. Note 78-1. 10pp.

Baldwin, W.K.W. 1953. Botanical investigations in the Reindeer-Nueltin lakes area, Manitoba. Nat. Mus. Can. Bull. 128: 110-142.

Banfield, A.W.F. 1954. Preliminary investigation of the barren-ground caribou, Can. Wildl. Serv. Wildl. Manage. Bull., Ser.1, No. 10A. 79pp.

Banfield, A.W.F. 1977. The Mammals of Canada. Natl. Mus. Nat. Sci. University of Toronto Press, Toronto. 438pp.

Beaubien, J. 1979. Forest type mapping from Landsat digital data. Photogrammetric Eng. (8): 1135-1143.

Beaubien, J. 1980. Forest typing from digitized Landsat images in Quebec. pp.53-58 in Remote Sensing Symposium, Can. Dept. Environ., Can. For. Serv., Great Lakes For. Res. Cent., Sault Ste. Marie, Ontario. 189pp.

Bergerud, A.T. 1972. Food habits of Newfoundland caribou. J. Wildl. Manage. 36: 913-923.

Bergerud, A.T. 1974. Decline of caribou in North America following settlement. J. Wildl. Manage. 38 (4): 757-770.

Colwell, J.E. 1974. Vegetation canopy reflectance. Remote Sensing of the Environ. 3: 175-183.

Conrad, H.S. 1977. How to know the mosses and liverworts. Wm. C. Brown. Co. Publ. Dubuque, Iowa. 266pp.

Dave, J.V. 1980. Effect of atmospheric conditions on remote sensing of a surface nonhomogeneity. Photogrammetric Eng. 46 (9): 1173-1180.

Dixon, R.J. 1981. Vegetation mapping the barren-ground caribou winter range in northern Manitoba using Landsat. TR-81-1.

Edwards, R.Y. and R.W. Ritcey. 1960. Foods of caribou in Wells Gray Park, British Columbia. Can. Field Nat. 74: 3-7.

Edwards, R.Y., J. Soos, and R.W. Ritcey. 1960. Quantitative observations on epidendric lichens used as food by caribou. Ecology, 41 (3): 425-431.

Godfrey, E.W. 1979. The Birds of Canada. Natl. Mus. Nat. Sci., Natl. Mus. Can. Ottawa, Ontario 428pp.

Goldberg, M. and S. Shlein. 1976. Computer implementation of a four-dimensional clustering algorithm. Can. Dep. Energy Mines Resour. CCRS Res. Rep. 76-2 31pp.

Hale, M.E. 1969. How to Know the Lichens. Wm. C. Brown Co. Publ., Dubuque, Iowa. 226pp.

Hall, D.K., J.P. Ormsby, L. Johnson, and J. Brown. 1979. Landsat digital analysis of the initial recovery of the Kokolik River tundra fire area, Alaska. NASA Tech. Memo. 80602. Goddard Space Flight Center, Greenbelt, Maryland. 15pp.

Harper D. 1976. Eye in the Sky. Can. Sci. Ser. Multiscience Publ. Montreal, Quebec. 164pp.

Johnson, E.A. and J.S. Rowe. 1975. Fire in the subarctic wintering ground of the Beverly caribou herd. Am. Midl. Nat. 94 (1): 1-14.

Johnson, E.A. and J.S. Rowe. 1977. Fire and vegetation change in western subarctic. Can. Dept. Indian and North. Aff. ALUR 1975-76-61. 58pp.

Johnston, I.L. and P.J. Howarth. 1980. Digital enhancements for vegetation mapping in a subarctic environment. Pages 405-410 in Proceedings of 6th Canadian Symposium on Remote Sensing, Halifax, Nova Scotia.

Kelsall, J.P. 1968. The migratory barren-ground caribou of Canada. Can. Wildl. Serv. Monogr. Ser. No. 3. 340pp.

Kelsall, J.P., E.S. Telfer, and T.D. Wright. 1977. The effects of fire on the ecology of the boreal forest with particular reference to the Canadian North: a review and selected bibliography. Can. Wildl. Ser. Occas. Pap. No. 32. 57pp.

Kershaw, K.A. and W.R. Rouse 1976. The impact of fire on forest and tundra ecosystems. Can. Dept. Indian and North. Aff. Final Rep. 54pp.

Klein, G.J., D.C. Pearce, and L.W. Gold. 1950. Method of measuring the significant characteristics of a snow cover. Natl. Res. Counc. Can. Techn. Memo. 18, 56 pp., mimeogr.

Kourtz, P.H. and A.J. Scott. 1978. An improved image enhancement technique and its application to forest fire management. Pages 72-78 in Proceedings of 5th Canadian Symposium on Remote Sensing, Victoria, British Columbia.

La Perriere, A.J., P.C. Lent, W.C. Grassaway, and F.A. Nodler. 1980. Use of Landsat data for moose-habitat analysis in Alaska. J. Wild. Manage. 44 (4): 881-887.

Lutz, H.J. 1956. Ecological effects of forest fires in the interior of Alaska. US. Dep. Agr. Tech. Bull. No. 1113. 121pp.

Miller, D.R. 1976. Biology of the Kaminuriak Population of barren-ground caribou. Part 3: Taiga winter range relationships and diet. Can. Wildl. Serv. Rep. Ser. 36. 41pp.

McIntosh, R.P. 1967. The continuum concept of vegetation. Bot. Rev. 33: 130-187.

McQuillan, A.K. 1975. Benefits of remote sensing in Canadian northern resource development. Can. Dept. Energy Mines Resour. CCRS Res. Rep. 75-6AX. 76pp.

Otterman, J. and R.S. Fraser. 1979. Adjacency effects on imaging by surface reflection and atmospheric scattering: cross radiance to Zenith. Appl. Optics 18: 2852-2860.

Parker, G.R. 1972. Biology of the Kaminuriak population of barren-ground caribou, Part I: Total number, mortality, recruitment, and seasonal distribution. Can. Wildl. Serv. Rep. No. 20. 93pp.

Person, S.J., R.E. Pegau, R.G. White, and J.R. Luick. 1980. In vitro nylon -bag digestiblities of Reindeer and Caribou forages. J. Wildl. Manage. 44 (3): 613-622.

Pielou, E.C. 1969. An introduction to mathematical ecology. John Wiley & Sons. New York, New York. 286pp.

Pruitt, W.O. Jr. 1959. Snow as a factor in the winter ecology of the barren-ground caribou (*Rangifer arcticus*). Arctic 12: 158-179.

Pruitt, W.O. Jr. 1979. A numerical "Snow Index" for reindeer (*Rangifer tarandus*) winter ecology (Mammalia, Cervidae). Ann. Zool. Fennici 16: 271-280.

Ritche, J.C. 1960. The vegetation of Northern Manitoba V. Establishing the major Zonation. Arctic 13 (2): 211-229.

Rouse, W.R. and P.F. Mills. 1977. Environmental Studies No. 2: A classification of fire effects on the microclimate of forest and tundra ecosystems. Can. Dept. Indian and North. Aff. Final Rep. 21pp.

Rowe, J.S. 1977. Forest regions of Canada. Can. Dept. Fish. and Environ. Can. For. Serv. Publ. No. 1300. 172pp.

Rowe, J.S., J.L. Bergsteinsson, G.A. Padbury, and R. Hermesh. 1974. Fire studies in the MacKenzie valley. Can. Dept. Indian and North. Aff. ALUR 73-74-61, 183pp.

Scoggan, H.J. 1957. Flora of Manitoba. Nat. Mus. Can. Bull. 140: 619pp.

Scotter, G.W. 1964. Effects of forest fires on the winter range of barren-ground caribou in northern Saskatchewan. Can. Wildl. Serv. Wildl. Manage. Bull. Ser. 1, No. 18. 111pp.

Scotter, G.W. 1967. The winter diet of barren-ground caribou in northern Canada. Can. Field Nat. 81: 33-39.

Scotter, G.W. 1971. Fire, vegetation, soil and barren-ground caribou relations in northern Canada. pp. 209-230 in Proceedings - Fire in the Northern Environment - A Symposium, Univ. of Alaska, Fairbanks, Alaska. 275pp.

Skogland, T. 1980. Comparative feeding strategies of Arctic and Alpine Rangifer. J. Animal Ecol. 49 (1): 81-98.

Skoog, R.O. 1968. Ecology of the caribou (*Rangifer tarandus granti*) in Alaska. Ph. D. Thesis, Univ. of California, Berkely, 699pp.

Smith, J.A., T.L. Lin, and K. J. Ranson. 1980. The Lambertain assumption and Landsat data. Photogrammetric Eng. 46 (9): 1183-1189.

Strome, W.M., S.S. Vishnubhatla, and F.E. Guertin. 1975. Format specifications for Canadian LANDSAT MSS system corrected computer compatible tape. CCRS. Can. Dept. Energy Mines Resour. Res. Rep. 75-3. 64pp.

Tarnocai, C. 1975. Exploratory terrain study of northern Manitoba and southern Keewatin, N.W.T. Can. Soil Survey, Winnipeg, Manitoba. 75pp.

Taylor, M.M. 1974. Principal components color display of ERTS imagery. Pages 295-307 in Proceedings 2nd Canadian Symposium on Remote Sensing. University of Guelph, Guelph, Ontario.

Thompson, D.C., G.H. Klassen, and C.A. Fischer. 1978. Ecological studies of caribou in the southern district of Keewatin, 1977. Report prepared for Polar Gas Project. Renewable Resources Consulting Services ltd. 116pp.

Thompson, D.C., G.H. Klassen, and J. Cihlar. 1980. Caribou habitat mapping in the southern district of Keewatin, N.W.T.: An application of Digital Landsat Data. J. Appl. Ecol. 17 (1): 125-138.

Turner, R.E. 1973. Atmospheric effects in remote sensing. Pages 549-583 in Shahrokhi F., (ed.) Remote sensing of earth resources. Univ. of Tennessee, Tullahome, Tenn.

Appendix I

Scientific and common names of plant species observed in the study area by the author. Taxonomic classification for vascular flora (Scoggan 1957), lichens (Hale 1969), and mosses (Conrad 1977) is available. Genus and species are listed by family.

Scientific name	Common name
Betula papyrifera	paper birch
Betula glandulosa	dwarf birch
Betula occidentalis	birch
Betula pumila	birch
Betula nana	birch
Alnus rugosa	speckled alder
Alnus crispa	green alder
Larix laricina	tamarack
Pinus banksiana	jack pine
Picea glauca	white spruce
Picea mariana	black spruce
Populus tremuloides	aspen
Populus balsamifera	balsam poplar
Salix spp.	willow
Ledum groenlandicum	labradour tea
Ledum decumbens	labradour tea
Kalmia polifolia	bog laurel
Chamaedaphne calyculata	leather leaf
Andromeda glaucophylla	bog rosemary
Andromeda polifolia	bog rosemary
Arctostaphylos uva-ursi	bearberry
A. rubra	heath
Loiseleuria procumbens	alpine azalea
Oxycoccus microcarpus	small cranberry
Vaccinium uliginosum	bilberry
V. uliginosum	alpine bilberry
V. vitis-idaea	rock cranberry
V. myrtilloides	blueberry
Empetrum nigrum	crowberry
Epilobium angustifolium	fireweed
Scirpus cespitosus	reed
S. microcarpus	reed
Eriophorum angustifolium	cottongrass
E. spissum	cottongrass
Carex spp.	sedge
Geocaulon lividum	northern comandra
Potentilla norvegica	potentilla
Rubus chamaemous	bog apple
Drosera rotundifolia	round-leaved sundew
Ribes glandulosum	skunk current
Ribes triste	red current
Saxifraga spp.	saxifrage
Isoetes spp.	quillwort

Scientific name	Common name
Equisetum sylvaticum	wood horstail
E. fluviatile	water horstail
E. arvense	field horstail
Lycopodium selago	club moss
L. complanatum	ground cedar
L. annotinum	stiff club moss
Cryptogramma crispa	rock brake
Dryopteris disjuncta	oak fern
Peltigera aphthosa	crustose
Cladonia alpestris	Foliose
C. amaurocraea	Foliose
C. cornuta	Foliose
C crispata	Foliose
C. deformis	Foliose
C. furcata	Foliose
C. gracilis	Foliose
C mitis	Foliose
C. pleurota	Foliose
C. rangiferina	Foliose
C. uncialis	Foliose
Stereocaulon paschale	Foliose
S. tomentosum	Foliose
Umilicaria hyperborea	Arboreal
Parmelia centrifuga	Crustose
P. physodes	Crustose
P. sinuosa	Crustose
Cetraria ciliaris	Arboreal
C. islandica	Foliose
C. rivalis	Foliose
Alectoria jubata	Arboreal
A. crinalis	Arboreal
A. fremontii	Arboreal
Usnea spp.	Arboreal

MOSSES

Scientific name
Spagnum spp.
Polytrichum commune
P. junipirinum
P. piliferum
Dicranum spp.
Bryum arenteum
Hylocomium splendens
Ptilidium
Marchantia
Pleurosium

Appendix II

Scientific and common names of mammals and birds observed by the researcher during aerial and ground surveys. Refer to Banfield (1977) for mammal taxonomy and Godfrey (1979) for birds.

Scientific name	Common name
Lepus americanus	snowshoe hare
Eutamias minimus	east chipmunk
Tamiasciurus hudsonicus	red squirrel
Glaucomys sabrinus	flying squirrel
Castor canadensis	beaver
Erithizon dorsatum	porcupine
Canus lupus	wolf
Vulpes vulpes	red fox
Ursus americanus	black bear
Ursus maritimus	polar bear
M. Pennanti	fisher
Lontra canadensis	river otter
R. tarandus	barren-ground caribou
Alces alces	moose

BIRDS

Scientific name	Common name
Gavia immer	common loon
Branta canadensis	Canada goose
Anas platyrhynchos	mallard
A. acuta	pintail
Mergus merganser	common merganser
Haliaeetus leucocephalus	bald eagle
Circus cyaneus	marsh hawk
Canachites canadensis	spruce grouse

Scientific name	Common name
Bonasa umbellus	ruffed grouse
Lagopus mutus	rock ptarmigan
C. vociferus	killdeer
Capella gallinago	common snipe
Larus argentatus	herring gull
Sterna hirundo	common tern
S. paradisaea	arctic tern
Bubo virginianus	great horned owl
Chordeiles minor	common nighthawk
Colaptes aurotus	yellow-shafted flicker
D. pubescens	downey woodpecker
Empidonax glaviventris	fly-catcher
Perisoreus canadensis	gray jay
Corvus corvax	common raven
C. brachyrhynchos	common crow
Parus hudsonicus	boreal chickadee
Turdus migratorius	robin
Hylocichla guttata	hermit thrush

Appendix III. Average monthly mean temperature (^{o}C) for Brochet calculated from 8:00 a.m. and 10:00 a.m. readings. Compiled from Manitoba Regional Services data.

YEAR	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
1978					+2.2	+10.2	+13.8	+13.2	+4.3	-1.8	-14.7	-24.6
1979	-34.3	-35.7	-15.9	-5.4	+3.5	+11.1	+19.4	+16.2	+5.7	-0.2	-16.2	-23.8
1980	-29.8	-27.2	-21.0	-5.1	+6.3	+26.4	+21.8	+15.5	+1.8	-1.7	-12.2	-29.8

Appendix IV

Landsat photographic products used in this study.

Path	Row	Date	Sun El (degrees)	Band	*Product Code
36	19	2/09/73	37	6	20
26	19	17/08/76	39	4,5,7	20
36	19	29/01/80	09	5	20
36	19	29/01/80	09	7	20
36	19	12/02/79	--	5	20
36	19	12/02/79	--	7	20
37	19	21/09/73	31	6	20
37	19	21/09/73	31	4,5,7	20
37	19	21/09/73	31	6	40
37	19	20/04/75	40	7	21
37	19	10/07/75	50	7	20
37	19	22/11/75	09	7	21
38	19	01/08/76	43	6	41
38	19	31/08/79	35	4,5,7	41
38	19	31/08/79	35	6	20
38	19	20/11/79	08	5	20
38	19	20/11/79	08	7	20
38	19	07/03/80	21	5	20
38	19	07/03/80	21	7	20
38	19	03/04/75	34	6	21
38	19	23/09/75	50	5	21
39	19	03/07/75	50	6	41
39	19	03/07/75	50	5	21
39	19	18/06/76	51	4,5,7	20
39	19	16/09/76	31	6	41
39	19	17/11/78	--	7	20
39	19	17/11/78	--	5	20
39	19	15/02/79	--	7	20
39	19	15/02/79	--	5	20
37	18	21/09/73	29	6	40
37	18	21/09/73	29	5	21
38	18	22/09/73	29	6	40
38	18	22/09/73	29	6	20
38	18	22/09/73	29	4,5,7	20
38	18	01/08/76	42	4,5,7	20
38	18	01/08/76	42	6	41
39	18	03/07/75	49	6	41
39	18	03/07/75	49	5	20
39	18	03/07/75	49	7	20
40	18	03/06/74	50	7	20
40	18	16/07/76	45	6	41
40	18	16/07/76	45	4,5,6	20
40	18	18/11/78	--	7	20
40	18	18/11/78	--	5	20
40	18	16/02/79	--	5	20
40	18	16/02/79	--	7	20

*PRODUCT CODE

20 - film positive, scale 1:1,000,000
21 - paper print, scale 1:1,000,000
40 - film positive, scale 1:250,000
41 - paper print, scale 1:250,000

Appendix V. CCRS Production centers and price list. Source: Correspondence with User Assistance, CCRS, Ottawa, July 16, 1980.

1. Prince Albert Satellite Station (PASS), Saskatchewan

The Prince Albert Satellite Station products include the following items:

- Colour Cibachrome prints (for Multispectral Scanner (MSS) data acquired at both Prince Albert and Shoe Cove starting March 1, 1978);

- Facsimile, Quick look Return Beam Vidicon (RBV) (for LANDSAT coverage west of and including Orbit 11 shown on the inset map);

- Full resolution black and white prints, positive transparencies, enlargements and 70mm film positives (for MSS data acquired at both Prince Albert and Shoe Cove);

- Computer Compatible Tapes (CCTs) (for MSS coverage west of and including Orbit 11 shown on the inset map and acquired starting March 1, 1978).

Customers are advised to order all LANDSAT products from the Prince Albert Satellite Station (exceptions to this rule are noted in paragraphs 2 and 3 below).

2. Shoe Cove Satellite Station (SCSS), Newfoundland

The following products are produced at SCSS and are shipped directly to customers:

- CCTs (for MSS coverage east of and including Orbit 10 shown on the inset map and acquired starting August 1, 1978);

- MSS Quick look Black and White prints, Facsimile transmission of NOAA, TIROS and LANDSAT MSS, and microfiche of LANDSAT MSS.

3. 2464 Sheffield Road, Ottawa, Ontario

The following products are produced in Ottawa and are shipped directly to customers from Ottawa:

- CCTs (for all Canadian MSS coverage acquired before March 1, 1978);

- UTM-registered LANDSAT data produced on the Digital Image Correction System (DICS) for all Canadian MSS coverage;

- Colour prints, transparencies and enlargements for all Canadian MSS coverage generated on the Colour Image Recorder;

- Full resolution RBV black and white prints.

Appendix V. CCRS Production centers and price list. Source: Correspondence with User Assistance, CCRS, Ottawa, July 16, 1980.

IMAGE SIZE	TYPE	SCALE	FORMAT	B&W	COLOR*
185mm	MSS	1:1,000,000	Paper	$ 9.00	$16.50
185mm	RBV	1:500,000	Paper	$ 9.00	
185mm	NOAA/TIROS	Any	Paper	$ 9.00	
185mm	NOAA/TIROS	Any	Film Pos.	$11.00	
371mm	NOAA/TIROS	Any	Paper	$22.00	
742mm	NOAA/TIROS	Any	Paper	$38.50	
371mm	MSS	1:500,000	Paper	$22.00	$44.00
371mm	RBV	1:125,000	Paper	$22.00	
742mm	MSS	1:250,000	Paper	$38.50	$88.00
742mm	RBV	1:125,000	Paper	$38.50	
70mm	MSS	1:3,369,000	Film Pos.	$35.00/4 band strip	
185mm	MSS	1:1,000,000	Film Pos.	$11.00	$20.00
185mm	RBV	1:500,000	Film Pos.	$11.00	
371mm	MSS	1:500,000	Film Pos.	$27.50	–
371mm	RBV	1:250,000	Film Pos.	$27.50	

COMPUTER COMPATIBLE TAPES

TYPE	TRACKS	BPI	FORMAT	PRICE
4 Band MSS	9	1,600	Tape Set	$220.00 (tape and Band 5 print included)
DICS	9	1,600	Tape	$110.00 (sub-scene plus colour Print)
NOAA	9	1,600	Tape Set	$220.00 (tape and Band 2 print included)

MICROFICHE			FAX**	
$220.00/month	$2,200.00/year	(ORBITS 7 to 90)	$ 27.00/image	
$ 41.67/month	$ 500.00/year	(ORBITS 1 to 9)	$ 100.00/day	(limit of 4 images/day)
$ 91.67/month	$1,100.00/year	(ORBITS 1 to 30)	$ 2,900.00/month	(up to 130 images)
			$33,000.00/year	(up to 1500 images)

Handling Charges: $5.00 per order at each production centre.

RUSH ORDERS:
1. For rush orders which cannot be handled under normal production conditions: Unit price X 2
2. To the carrier within 24 hours of reception of the order: Unit price X 3

DELIVERY

1. Postage extra to customers outside Canada.
2. Registered mail and special delivery charged directly to customer.
3. Courier services charged directly to customer.

PLEASE NOTE: PRICES ARE SUBJECT TO CHANGE ANNUALLY ON 1 APRIL.

*1. All colour prints are the same price, i.e.: CIR, SBI and EBIR (see Appendix "A")

**2. Orders in excess of 1,500 images are to be referred for pricing.

Appendix VI

SUMMARY OF SUMMER & WINTER FIELD PROGRAMS FOR VEGETATION

MAPPING & WINTER RANGE STUDY

FIELD SEASON	FIELD PERSONNEL	BASE CAMP LOCATION	AIRCRAFT (SURVEY HOURS)	PERCENT DOWN TIME	FIELD WORK COMPLETED: MAP SHEETS SURVEYED	NUMBER OF FLY-BYS	NUMBER OF TRANSECTS
SUMMER 1978	1 Biophysical Specialist 2 Summer Students 1 Pilot	Bain Lake (July 18- Aug. 26)	Cessna-185 Little Grand Rapids Air Service Ltd., (100 hrs.)	Bad Weather (46%)	(64O) Munroe	Reconnaissance	26
					(64P) Nejanilini	Reconnaissance	20
					(64N) Kasmere	Reconnaissance	10
SUMMER 1979	1 Crew Supervisor 1 Tadoule Lake Community Rep. 1 Summer Student 1 Pilot	Bain Lake (July- 15 Aug -28) CISCO Mining Camp (Aug-22-28)	Standard Beaver Manitoba Government Air Services (100 hrs.)	Bad Weather (25%) Forest Fire Smoke (10%)	(64J Tadoule	167	22
					(64K) Whiskey Jack	145	10
					(64N) Kasmere	103	6
					(64O) Munroe	86	4
					(64P) Nejanilini	83	2
SUMMER 1980	1 Crew Supervisor 1 Wildlife Technician 1 Remote Sensing Specialist 1 Tadoule Lake Community Rep. 1 Pilot	Lac Brochet (Jul. 21-24) Croll Lake (Aug. 18-24) Tadoule Lake (Sept. 2-5)	Standard Beaver Manitoba Government Air Services (60 hrs.)	Bad Weather (43%)	(64K) Whiskey Jack	66	7
					(64P) Nejanilini	35	4
					(64I) Shethani	24	0
					(64J) Tadoule	18	1
					(64O) Munroe	6	1
WINTER (Feb 2-6) 1981	1 Wildlife Technician 1 Conservation Officer 1 Research Analyst 1 Pilot	Overnight Stays in 3 Communities (Feb 2-5) Lac Brochet Brochet Tadoule Lake (2 nights)	Standard Beaver Manitoba Government Air Services (20 hrs)	No Down Time	(64K) Whiskey Jack	Winter Surveys	3 snow stations
					(64N) Kasmere	"	1 snow station
					(64O) Munroe	"	2 snow stations
					(64J) Tadoule	"	
					(64P) Nejanilini	"	

APPENDIX VII. Standard data form for fly-bys.

Date:		Relief Class				Forest Canopy				Forest Ground Cover						Tundra Ground Cover						Burned Over											
Map:			Estimated Area of Fly-by				Crown Closure															Tree Regeneration				Shrub Regeneration							
Site Number	Comments	Class	<25	25-50	>50	Species	<25	25-50	>50	Lichen	Lichen/ Shrub	Lichen/ moss	Moss/ shrub	Moss	Sand	Lichen Heath	Upland Heath Complex	Lowland Heath Complex	Sedge Cotton-grass	Rock Barrens	Species	Nil	<25	25-50	>50	Nil	<25	25-50	>50	Burn/Moss	Burn/ Lichen	Moss/ Lichen	Burn
		Up-Land																															
		Low-land																															

Appendix VIII. Ground data sheets for vegetation mapping.

DAY MONTH YEAR
MAP SHEET
SITE NUMBER
FLY-BY NUMBER
HABITAT
ARBOREAL LICHEN
SURVEYORS

VEGETATION STRATA	TOTAL COVER	DOMINANT SPECIES	DOMINANT COVER
FOREST CANOPY			
SAPLING			
SHRUB			
FIELD			
MOSS			
LICHEN			
SOIL/ROCKS			

TREE SAMPLE DATA
Sp.
Ht.
dbh
Age
Sp.
Ht.
dbh
Age

TREE SPECIES	1"	2"	3"	4"	5"	6"	7"	8"	9"	10"	11"	>11"
BETULA PAPYRIFERA	freq. ht.											
LARIX LARICINA												
PICEA GLAUCA												
PICEA MARIANA												
PINUS BANKSIANA												

COMMENTS:

APPENDIX X Species frequency in relation to number of plots recorded for each vegetation type

TADOULE LAKE

NTS-64J

Stratum	Vegetation Cover	Upland Clsoed Black Spruce	Upland Open Black Spruce	Upland Spruce Lichen	Lowland Closed Black Spruce	Lowland Open Black Spruce	Fens
Trees	Picea mariana	20	46	4	9	26	1
	Betula papyrifera	1	10	4	0	3	0
	Larix laricina	3	12	3	4	9	2
	Pinus banksiana	1	3	1	0	0	0
Shrub Stratum	Picea mariana (sapling)	15	40	2	7	26	1
	Betula papyrifera (sapling)	0	4	0	0	0	0
	Larix laricina (sapling)	1	6	1	3	9	2
	Pinus banksiana (sapling)	0	1	0	0	0	0
	Alnus rugosa	17	23	0	5	4	0
	Betula glandulosa	0	1	0	0	0	0
	B. occidentalis	0	0	0	0	0	0
	B. pumila	0	2	1	0	0	0
	B. nana	5	12	1	6	10	1
	Salix sp.	5	22	1	4	10	1
Field Stratum	Arctostaphylos rubra	0	1	0	1	1	0
	A. uva-ursi	1	0	2	0	0	0
	Andromeda polifolia	0	0	0	0	1	0
	Chamaedaphne calyculata	1	0	1	0	9	1
	Kalmia polifolia	1	5	1	2	8	1
	Ledum decumbens	1	2	0	4	9	0
	L. groenlandicum	18	46	3	9	25	1
	Loiseleuria procumbens	0	0	0	0	2	0
	Oxycoccus microcarpus	0	0	0	6	13	1
	Vaccinium myrtilloides	4	19	2	0	0	0
	V. uliginosum	9	39	3	6	16	0
	V. uliginosum var. alpinum	0	0	0	0	0	0
	V. vitis-idaea	18	46	5	9	24	0
	Empetrum nigrum	5	17	5	4	9	0
	Carex sp.	1	1	0	3	2	2
	Epilobium angustifolium	3	0	1	1	1	0
	Equisetum sp.	8	11	0	4	13	0
	Eriophorum angustifolium	0	0	1	0	0	0
	Geocaulon lividum	4	10	3	0	2	0
	Lycopodium sp.	1	4	0	0	0	0
	Rubus chamaeomorus	3	4	0	7	19	2
Ground Stratum – Mosses	Bryum sp.	2	6	1	0	7	0
	Dicranum sp.	5	16	3	3	10	1
	Pleurosium sp.	9	27	1	3	19	1
	Polytrichum sp.	10	16	1	2	23	1
	Sphagnum sp.	12	12	1	9	9	2
Ground Stratum – Lichens	Cetraria nivalis	6	23	4	0	4	0
	Cetraria islandica	0	0	0	0	0	0
	Cladonia sp.	20	47	0	7	20	0
	C. alpestris	0	0	4	2	0	0
	C. cornuta	0	0	0	0	0	0
	C. furcata	0	0	0	0	0	0
	C. mitis	0	0	3	2	0	0
	C. pleurota	0	0	0	1	0	0
	C. rangiferina	0	0	3	2	0	0
	Stereocaulon tomentosum	6	29	4	2	3	0
	Parmelia sp.	0	0	0	0	0	0
	Peltigera sp.	0	0	0	0	0	0
	Alectoria sp.	18	34	4	8	20	0
	Usnea sp.	14	27	4	7	20	0
	Number of plots recorded	21	47	5	9	26	2

APPENDIX IX Species frequency in relation to number of plots recorded for each vegetation type

WHISKEY JACK LAKE

NTS-64K

Stratum	Vegetation Cover	Upland Closed Black Spruce	Upland Open Black Spruce	Upland Spruce Lichen	Lowland Closed Black Spruce	Lowland Open Black Spruce	Fens
Trees	Picea mariana	8	19	1	1	7	0
	Betula papyrifera	1	2	1	0	0	0
	Larix laricina	0	6	0	1	5	1
	Pinus banksiana	4	7	1	0	1	0
Shrub Stratum	Picea mariana (sapling)	5	15	1	1	11	0
	Betula papyrifera (sapling)	0	1	0	0	0	0
	Larix laricina (sapling)	0	6	0	1	4	1
	Pinus banksiana (sapling)	2	5	0	0	0	0
	Alnus rugosa	6	1	0	1	0	0
	Betula glandulosa	0	1	0	0	0	0
	B. occidentalis	0	0	0	0	0	0
	B. pumila	0	0	0	0	0	0
	B. nana	0	3	0	1	3	1
	Salix sp.	6	10	0	1	1	1
Field Stratum	Arctostaphylos rubra	0	0	0	0	0	0
	A. uva-ursi	3	5	1	0	1	0
	Andromeda polifolia	0	0	0	0	2	1
	Chamaedaphne calyculata	0	0	0	0	4	1
	Kalmia polifolia	0	1	0	0	4	1
	Ledum decumbens	0	1	0	0	5	0
	L. groenlandicum	9	13	1	1	7	1
	Loiseleuria procumbens	0	1	0	0	0	0
	Oxycoccus microcarpus	1	1	0	1	9	1
	Vaccinium myrtilloides	3	13	1	0	1	0
	V. uliginosum	5	8	1	1	8	1
	V. uliginosum var. alpinum	0	0	0	0	0	0
	V. vitis-idaea	9	19	1	0	10	0
	Empetrum nigrum	1	12	1	0	7	0
	Carex sp.	0	0	0	0	2	0
	Epilobium angustifolium	3	2	0	0	0	0
	Equisetum sp.	4	3	0	1	3	1
	Eriophorum angustifolium	0	0	0	0	1	0
	Geocaulon lividum	3	3	1	0	1	0
	Lycopodium sp.	0	3	0	0	0	0
	Rubus chamaeomorus	3	1	0	1	12	1
Ground Stratum – Mosses	Bryum sp.	1	2	0	0	2	1
	Dicranum sp.	1	9	1	1	3	1
	Pleurosium sp.	6	4	0	1	2	1
	Polytrichum sp.	3	3	0	1	12	1
	Sphagnum sp.	1	1	0	1	3	1
Ground Stratum – Lichens	Cetraria nivalis	5	13	1	0	3	0
	Cetraria islandica	0	0	0	0	0	0
	Cladonia sp.	9	16	1	0	4	0
	C. alpestris	0	0	0	0	0	0
	C. cornuta	0	0	0	0	0	0
	C. furcata	0	0	0	0	0	0
	C. mitis	0	0	0	0	0	0
	C. pleurota	0	0	0	0	0	0
	C. rangiferina	0	0	0	0	0	0
	Stereocaulon tomentosum	5	12	1	0	1	0
	Parmelia sp.	0	0	0	0	0	0
	Peltigera sp.	0	0	0	0	0	0
	Alectoria sp.	9	13	1	1	9	0
	Usnea sp.	9	12	1	0	7	0
	Number of plots recorded	9	19	1	1	12	1

APPENDIX X

Species frequency in relation to number of plots recorded for each vegetation type

KASMERE LAKE

NTS-64N

Stratum	Vegetation Cover	Upland Closed Black Spruce	Upland Open Black Spruce	Upland Spruce Lichen	Lowland Closed Black Spruce	Lowland Open Black Spruce	Fens
Trees	Picea mariana	4	9	8	1	18	1
	Betula papyrifera	0	0	1	0	1	0
	Larix laricina	0	4	0	1	12	1
	Pinus banksiana	0	0	1	0	0	0
Shrub Stratum	Picea mariana (sapling)	4	8	7	1	18	0
	Betula papyrifera (sapling)	0	0	1	0	1	0
	Larix laricina (sapling)	0	2	0	1	11	1
	Pinus banksiana (sapling)	0	0	0	0	0	0
	Alnus rugosa	3	1	3	1	5	0
	Betula glandulosa	0	1	1	0	2	1
	B. occidentalis	0	0	0	0	0	0
	B. pumila	0	1	2	0	1	0
	B. nana	2	4	4	1	3	0
	Salix sp.	1	4	4	1	9	1
Field Stratum	Arctostaphylos rubra	0	0	0	0	3	0
	A. uva-ursi	0	0	0	0	0	0
	Andromeda polifolia	0	0	0	0	0	1
	Chamaedaphne calyculata	0	0	0	0	0	1
	Kalmia polifolia	0	1	0	1	5	1
	Ledum decumbens	0	3	1	0	8	1
	L. groenlandicum	4	8	6	1	18	1
	Loiseleuria procumbens	0	0	0	0	1	0
	Oxycoccus microcarpus	0	0	0	1	6	1
	Vaccinium myrtilloides	0	0	4	0	0	0
	V. uliginosum	3	8	5	1	15	1
	V. uliginosum var. alpinum	0	0	0	0	0	0
	V. vitis-idaea	4	9	8	1	18	0
	Empetrum nigrum	4	5	3	1	13	0
	Carex sp.	3	1	0	0	6	0
	Epilobium angustifolium	0	0	0	1	1	0
	Equisetum sp.	1	2	0	1	10	1
	Eriophorum angustifolium	0	0	0	0	0	0
	Geocaulon lividum	0	0	1	0	0	0
	Lycopodium sp.	0	1	1	0	2	0
	Rubus chamaeomorus	0	1	0	1	11	0
Ground Stratum – Mosses	Bryum sp.	1	3	0	0	6	0
	Dicranum sp.	3	3	2	0	5	1
	Pleurosium sp.	4	3	1	1	10	1
	Polytrichum sp.	1	3	0	1	2	0
	Sphagnum sp.	2	0	1	0	16	1
Ground Stratum – Lichens	Cetraria nivalis	4	7	8	0	2	0
	Cetraria islandica	0	2	0	0	0	0
	Cladonia sp.	0	0	0	0	0	0
	C. alpestris	4	8	7	1	5	0
	C. cornuta	0	2	2	1	3	0
	C. furcata	0	1	0	0	0	0
	C. mitis	0	4	3	1	2	0
	C. pleurota	0	3	2	0	2	0
	C. rangiferina	0	5	7	0	5	0
	Stereocaulon tomentosum	3	6	8	1	7	0
	Parmelia sp.	0	0	0	0	0	0
	Peltigera sp.	0	1	0	0	2	0
	Alectoria sp.	2	6	4	0	9	0
	Usnea sp.	2	4	6	0	11	0
	Number of plots recorded	4	9	8	1	19	1

APPENDIX X Species frequency in relation to number of plots recorded for each vegetation type

MUNROE LAKE

NTS-64O

Stratum	Vegetation Cover	Upland Closed Black Spruce	Upland Open Black Spruce	Upland Spruce Lichen	Lowland Closed Black Spruce	Lowland Open Black Spruce	Fens	Upland Lichen Heath	Upland Heath Complex	Lowland Heath Complex	Lowland Sedge Cottongrass
Trees	Picea mariana	1	14	8	1	8	0	5	2	1	1
	Betula papyrifera	1	3	3	0	2	0	0	0	0	0
	Larix laricina	0	2	0	0	4	1	0	0	0	0
	Pinus banksiana	0	0	0	0	0	0	0	0	0	0
Shrub Stratum	Picea mariana (sapling)	1	14	6	1	7	0	4	0	1	0
	Betula papyrifera (sapling)	0	1	2	0	1	0	0	0	0	0
	Larix laricina (sapling)	0	1	1	0	4	0	0	2	1	0
	Pinus banksiana (sapling)	0	0	0	0	0	0	0	0	0	0
	Alnus rugosa	1	5	2	0	5	0	0	0	0	0
	Betula glandulosa	0	0	1	0	0	0	0	0	0	0
	B. occidentalis	0	0	0	0	0	0	0	0	0	0
	B. pumila	0	4	1	0	0	0	5	0	0	0
	B. nana	0	2	2	0	5	1	7	4	1	0
	Salix sp.	1	1	2	0	6	0	1	1	1	0
Field Stratum	Arctostaphylos rubra	0	0	1	0	2	0	0	1	0	0
	A. uva-ursi	0	0	0	0	0	0	0	0	0	0
	Andromeda polifolia	0	0	0	0	0	0	1	3	0	1
	Chamaedaphne calyculata	0	1	0	0	0	1	0	0	0	0
	Kalmia polifolia	0	1	0	0	2	1	0	1	1	1
	Ledum decumbens	0	4	2	1	3	0	6	4	2	1
	L. groenlandicum	1	10	3	1	6	1	2	0	1	0
	Loiseleuria procumbens	0	2	2	0	0	0	5	2	0	0
	Oxycoccus microcarpus	0	1	0	1	3	0	0	0	0	0
	Vaccinium myrtilloides	0	2	0	0	0	0	0	0	0	0
	V. uliginosum	1	10	6	0	7	1	2	2	0	1
	V. uliginosum var. alpinum	0	0	1	0	0	0	7	2	1	1
	V. vitis-idaea	1	12	7	1	7	0	9	4	2	1
	Empetrum nigrum	1	6	6	0	3	0	7	4	1	1
	Carex sp.	0	1	1	0	4	1	1	2	0	1
	Epilobium angustifolium	0	0	0	0	1	0	0	0	0	0
	Equisetum sp.	0	0	0	0	4	0	0	0	0	0
	Eriophorum angustifolium	0	0	1	0	0	1	0	0	0	1
	Geocaulon lividum	0	2	1	0	0	0	0	0	0	0
	Lycopodium sp.	0	2	0	0	1	0	0	0	0	0
	Rubus chamaeomorus	0	0	0	1	4	0	0	3	2	1
Ground Stratum – Mosses	Bryum sp.	0	0	0	0	2	0	2	2	2	0
	Dicranum sp.	0	6	4	0	2	0	0	0	0	0
	Pleurosium sp.	1	3	0	1	5	1	0	0	1	0
	Polytrichum sp.	0	1	0	0	0	0	0	0	0	0
	Sphagnum sp.	1	4	0	1	6	1	0	2	1	1
Ground Stratum – Lichens	Cetraria nivalis	0	7	7	0	3	0	7	4	2	1
	Cetraria islandica	0	4	3	0	0	0	3	0	1	0
	Cladonia sp.	0	0	0	0	0	0	0	0	0	0
	C. alpestris	1	12	8	1	1	1	7	4	2	1
	C. cornuta	1	5	0	1	1	0	2	1	1	0
	C. furcata	0	6	7	0	0	0	5	1	0	0
	C. mitis	1	8	4	1	0	0	6	2	2	1
	C. pleurota	0	10	5	1	1	0	6	1	1	0
	C. rangiferina	1	8	6	1	1	0	8	3	1	1
	Stereocaulon tomentosum	0	11	6	0	2	0	6	1	0	0
	Parmelia sp.	1	2	0	0	0	0	0	0	0	0
	Peltigera sp.	0	1	0	0	0	0	0	0	0	0
	Alectoria sp.	1	8	3	0	4	0	8	1	2	0
	Usnea sp.	0	6	4	1	4	0	0	0	0	0
	Number of plots recorded	1	14	8	1	8	1	11	4	2	1

APPENDIX IX Species frequency in relation to number of plots recorded for each vegetation type

NEJANILINI LAKE

NTS-64P

Stratum	Species	Upland Open Black Spruce	Lowland Closed Black Spruce	Lowland Open Black Spruce	Upland Lichen Heath	Upland Heath Complex	Rock Barrens	Lowland Heath Complex	Lowland Sedge Cottongrass
Trees	Picea mariana	1	1	1	0	1	0	0	1
	Betula papyrifera	0	0	0	0	0	0	0	0
	Larix laricina	0	1	2	0	0	0	0	0
	Pinus banksiana	0	0	0	0	0	0	0	0
Shrub Stratum	Picea mariana (sapling)	0	1	2	0	1	1	0	0
	Betula papyrifera (sapling)	0	0	0	0	0	0	0	0
	Larix laricina (sapling)	0	1	2	0	1	0	0	0
	Pinus banksiana (sapling)	0	0	0	0	0	0	0	0
	Alnus rugosa	1	1	0	1	0	0	0	0
	Betula glandulosa	0	0	0	0	0	0	0	0
	B. occidentalis	0	0	0	0	0	0	0	0
	B. pumila	0	0	0	0	1	0	0	0
	B. nana	1	1	2	4	3	1	1	2
	Salix sp.	1	1	2	1	2	0	0	0
Field Stratum	Arctostaphylos rubra	0	0	0	2	2	1	0	0
	A. uva-ursi	0	0	0	0	0	0	0	0
	Andromeda polifolia	0	0	1	3	0	0	0	2
	Chamaedaphne calyculata	0	0	0	0	0	0	0	0
	Kalmia polifolia	0	0	1	1	1	0	1	2
	Ledum decumbens	0	0	2	5	2	1	1	2
	L. groenlandicum	1	1	1	0	1	0	0	0
	Loiseleuria procumbens	0	0	0	3	1	2	0	0
	Oxycoccus microcarpus	0	0	0	0	0	0	0	0
	Vaccinium myrtilloides	0	0	0	0	0	0	0	0
	V. uliginosum	1	1	2	0	0	0	0	1
	V. uliginosum var. alpinum	0	0	0	4	3	2	1	3
	V. vitis-idaea	1	1	2	4	3	1	1	1
	Empetrum nigrum	1	1	2	5	3	3	1	2
	Carex sp.	0	1	2	2	3	0	0	0
	Epilobium angustifolium	0	0	0	0	0	0	0	0
	Equisetum sp.	0	1	2	0	0	0	0	3
	Eriophorum angustifolium	0	0	0	0	0	0	0	0
	Geocaulon lividum	0	0	0	0	0	0	0	0
	Lycopodium sp.	0	0	0	0	0	0	0	0
	Rubus chamaeomorus	0	1	2	2	1	0	1	3
Ground Stratum – Mosses	Bryum sp.	0	0	0	0	1	2	1	0
	Dicranum sp.	0	0	1	1	3	0	0	0
	Pleurosium sp.	0	0	1	0	0	0	0	0
	Polytrichum sp.	1	0	1	1	0	1	0	2
	Sphagnum sp.	1	1	2	1	1	0	1	3
Ground Stratum – Lichens	Cetraria nivalis	1	0	0	5	2	2	1	0
	Cetraria islandica	0	0	2	1	0	0	0	0
	Cladonia sp.	1	1	2	0	0	0	0	0
	C. alpestris	0	0	0	4	2	0	1	0
	C. cornuta	0	0	0	1	1	1	0	0
	C. furcata	0	0	0	0	0	1	0	0
	C. mitis	0	0	0	3	2	1	1	0
	C. pleurota	0	0	0	4	3	0	0	0
	C. rangiferina	0	0	0	4	3	2	1	1
	Stereocaulon tomentosum	1	0	0	2	2	1	0	0
	Parmelia sp.	0	0	0	0	0	0	0	0
	Peltigera sp.	0	0	0	0	1	0	0	0
	Alectoria sp.	1	0	1	5	1	2	0	0
	Usnea sp.	0	1	1	0	0	0	0	0
	Number of plots recorded	1	1	2	5	3	2	1	3

Vegetation Cover

APPENDIX X. Standardized results for accuracy assessment.

Two kinds of errors were noted, in classification and mapping. Classification erros (E_{ci}) were made when fly-by observations from the ith vegetation association were incorrectly classified as the mth unit. Total classification errors for the ith vegetation association (E_{ci}) were determined by

$$E_{ci} = S_i - C_{im}$$

where C_{im} represented the number from the ith vegetation association correctly classified as the mth unit. The probability of making a classification error for the ith vegetation association (P_{ci}) was determined by

$$P_{ci} = \frac{E_{ci}}{S_i}$$

Mapping errors (E_{om}) were made when a vegetation association from the mth map unit was incorrectly mapped as the ith vegetation association. Total mapping errors for the mth mapping unit (E_{om}) were determined by

$$E_{om} = R_m - C_{im}$$

where R_m is the row total for the mth mapping unit. The probability of making a mapping error for the mth mapping unit (P_{om}) was determined by

$$P_{om} = \frac{E_{om}}{R_m}$$

Standardized results are present in the following tables.

Proportion of area covered by each vegetation type.

COVER CATEGORY	Shethanei NTS-64I	Tadoule NTS-64J	Whiskey Jack NTS-64K	Kasmere NTS-64N	Munroe NTS-64O	Nejanilini NTS-64P
Upland Closed Black Spruce	0.11	0.13	0.10	0.12	0.04	0.03
Upland Open Black Spruce	0.12	0.20	0.30	0.38	0.20	0.04
Upland Spruce Lichen	0.09	0.02	0.04	0.07	0.03	0.01
Upland Open Birch	----	0.01	----	----	----	----
Lowland Closed Black Spruce	0.22	0.21	0.01	0.10	0.16	0.04
Lowland Open Black Spruce	0.25	0.12	0.22	0.08	0.01	0.05
Fens	0.01	0.02	0.03	0.01	----	----
Upland Lichen Heath	0.01	----	----	----	0.21	0.36
Upland Heath Complex	0.01	----	----	----	0.01	0.07
Rock Barrens	----	----	----	----	0.01	0.01
Lowland Heath Complex	0.05	----	----	----	----	0.05
Lowland Sedge/Cottongrass	0.01	----	----	----	0.05	0.16
Recent Burn	0.01	0.05	0.03	0.02	0.05	0.01
Revegetated Burn	0.01	0.04	0.01	0.03	0.03	0.01
Revegetated Burn & Forest	0.03	0.07	0.10	0.05	0.02	----
Water	0.11	.14	0.16	0.14	0.18	0.16

Standardized results for NTS-64I map accuracy assessment.

Cover type observed from fly-bys.

Cover type delineated on the map.

	Upland Closed Black Spruce	Upland Open Black Spruce	Upland Spruce Lichen	Lowland Closed Black Spruce	Lowland Open Black Spruce	Recent Burn	Reveg. Burn	Lowland Heath Complex	Row Total	E_{om}	P_{om}		
Upland Closed Black Spruce	1236			2472					3708	2472	0.67		
Upland Open Black Spruce		674			234	112			1020	346	0.34		
Upland Spruce Lichen			1012						1012	00	0.00		
Lowland Closed Black Spruce					468		449		917	449	0.49		
Lowland Open Black Spruce		674			1639				2313	674	0.29		
Recent Burn									00	00	0.00		
Revegetated Burn					234				234	234	1.00		
Lowland Heath Complex					234			562	796	562	0.71		
Column Total	1236	1348	1012	2472	2809	112	449	562	10,000				
E_{ci}	00	674	00	2472	1170	112	449	00					
P_{ci}	0.00	0.50	0.00	1.00	0.42	0.00	0.00	0.00					

Standardized results for NTS-64J map accuracy assessment.

Cover type observed from fly-bys

Cover type delineated on the map.

	Upland Closed Black Spruce	Upland Open Black Spruce	Upland Open Birch	Upland Spruce Lichen	Lowland Closed Black Spruce	Low-land Open Black Spruce	Fens	Recent Burn	Reveg. Burn	Row Total	E_{om}	P_{om}	
Upland Closed Black Spruce	1235	383			172				110	1900	665	0.35	
Upland Open Black Spruce	86	1724		46		48			55	1959	235	0.12	
Upland Open Birch			115							115	00	0.00	
Upland Spruce Lichen				184					110	294	110	0.37	
Lowland Closed Black Spruce	144	96			2070	238				2548	478	0.19	
Lowland Open Black Spruce	29					1093		82	55	1259	165	0.13	
Fens							230			230	00	0.00	
Recent Burn					86			493		579	86	0.15	
Revegetated Burn		96			86				934	1116	182	0.16	
Column Total	1494	2299	115	230	2414	1379	230	575	1264	10,000			
E_{ci}	259	575	00	46	344	286	00	82	330				
P_{ci}	0.17	0.25	0.00	0.20	0.14	0.21	0.00	0.14	0.26				

Standardized results for NTS-64K map accuracy assessment.

Cover type observed from fly-bys

Cover type delineated on the map.

	Upland Closed Black Spruce	Upland Open Black Spruce	Upland Spruce Lichen	Lowland Closed Black Spruce	Low-land Open Black Spruce	Fens	Recent Burn	Reveg. Burn	Row Total	E_{om}	P_{om}
Upland Closed Black Spruce	813	325	119	24	73		22	125	1501	688	0.46
Upland Open Black Spruce	174	3165		24			45	187	3595	430	0.12
Upland Spruce Lichen	29		297						326	29	0.09
Lowland Closed Black Spruce	87			24		60			171	147	0.86
Lowland Open Black Spruce	87	81		24	2474			62	2728	254	0.09
Fens				23	72	298			393	95	0.24
Recent Burn			60				290		350	60	0.17
Revegetation Burn								936	936	0.0	0.00
Column Total	1190	3571	476	119	2619	358	357	1310	10,000		
E_{ci}	377	406	179	95	145	60	67	374			
P_{ci}	0.32	0.11	0.38	0.80	0.06	0.17	0.19	0.29			

Standardized results for NTS-64N map accuracy assessment.

Cover type observed from fly-bys

Cover type delineated on the map.

	Upland Closed Black Spruce	Upland Open Black Spruce	Upland Spruce Lichen	Lowland Closed Black Spruce	Low-land Open Black Spruce	Fens	Recent Burn	Reveg. Burn	Row Total	E_{om}	P_{om}		
Upland Closed Black Spruce	1085	589	222		44				1940	855	0.44		
Upland Open Black Spruce	155	3535	111	388				133	4322	787	0.18		
Upland Spruce Lichen			333						333	00	0.00		
Lowland Closed Black Spruce	155	295	74	775	133				1432	657	0.46		
Lowland Open Black Spruce			37		709				746	37	0.05		
Fens					44	116			160	44	0.28		
Recent Burn							233		233	00	0.00		
Revegetated Burn			37					797	834	37	0.04		
Column Total	1395	4419	814	1163	930	116	233	930	10,000				
E_{ci}	310	884	481	388	221	00	00	133					
P_{ci}	0.22	0.20	0.59	0.33	0.24	0.00	0.00	0.14					

Standardized results for NTS-64P map accuracy assessment.

Cover type observed from fly-bys.

Cover type delineated on the map.

	Upland Closed Black Spruce	Upland Open Black Spruce	Lowland Closed Black Spruce	Lowland Open Black Spruce	Up-land Lichen Heath	Upland Heath Complex	Low--land Heath Complex	Low-land Sedge Cotton grass	Rock Barrens	Recent Burn	Row Total	E_{om}	P_{om}
Upland Closed Black Spruce	365										365	00	0.00
Upland Open Black Spruce		163									163	00	0.00
Lowland Closed Black Spruce			244								244	00	0.00
Lowland Open Black Spruce				407							407	00	0.00
Upland Lichen Heath		162			4390						4552	162	0.04
Upland Heath Complex						854		390			1244	390	0.31
Lowland Heath Complex			244	203			203				650	447	0.69
Lowland Sedge Cottongrass		163					407	1561			2131	570	0.27
Rock Barrens									122		122	00	0.00
Recent Burn										122	122	00	0.00
Column Total	365	488	488	610	4390	854	610	1951	122	122	10,000		
E_{ci}	00	325	244	203	00	00	407	390	00	00			
P_{ci}	0.00	0.67	0.50	0.33	0.00	0.00	0.67	0.20	0.00	0.00			

Standardized results for NTS-64O map accuracy assessment.

Cover type observed from fly-bys.

Cover type delineated on the map.

	Upland Closed Black Spruce	Upland Open Black Spruce	Upland Spruce Lichen	Lowland Closed Black Spruce	Lowland Open Black Spruce	Upland Lichen Heath	Lowland Sedge Cotton grass	Recent Burn	Reveg. Burn	Row Total	E_{om}	P_{om}	
Upland Closed Black Spruce	250	400								650	400	0.62	
Upland Open Black Spruce	50	1700	188			477				2415	715	0.30	
Upland Spruce Lichen			94							94	94	0.00	
Lowland Closed Black Spruce	150	300	31	2000						2481	481	0.19	
Lowland Open Black Spruce					111				113	224	113	0.50	
Upland Lichen Heath		100	62			1909				2071	162	0.08	
Lowland Sedge Cottongrass					14	239	625			878	253	0.29	
Recent Burn								625	57	682	57	0.08	
Revegetated Burn	50								455	505	50	0.10	
Column Total	500	2500	375	2000	125	2625	625	625	625	10,000			
E_{ci}	250	800	281	00	14	716	00	00	170				
P_{ci}	0.50	0.32	0.75	0.00	0.11	0.27	0.00	0.00	0.37				

APPENDIX XI Summary of snow survey data.

Calculation of the Varrio Snow Index (VSI).[1]

$$VSI = (H_{\frac{1}{2}}\ H_b\ T_b + VT_s + H_h\ T_h)\ T_{ta}/1000$$

where

$H_{\frac{1}{2}}$ = hardness of hardest layer more than halfway between the substrate and the top of the snow cover.

H_bT_b = hardness times thickness of basal layer.

VT_s = vertical hardness of surface times thickness of surface layer.

H_hT_h = hardness times thickness of hardest layer (if not H_bT_b). If basal layer is the hardest then term H_hT_h drops out.

T_{ta} = total thickness of the api.

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[1] Pruitt, W.O., Jr. 1979. A numerical 'Snow Index' for reindeer (Rangifer tarandus) winter ecology (Mammalia, Cervidae). Ann. Zool. Fennici, p.273.

APPENDIX XI. Summary of snow survey data.

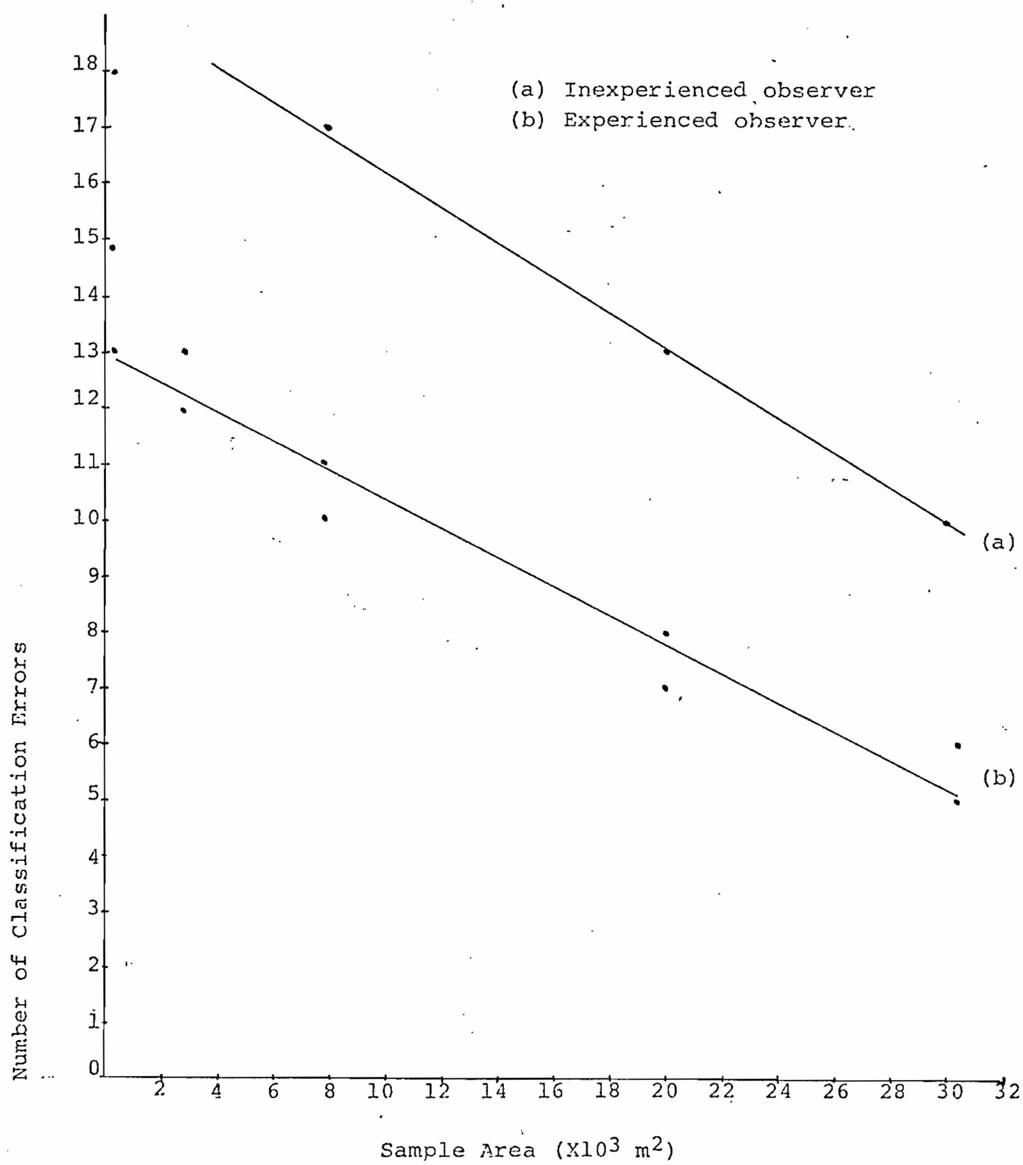
Date	Location	Habitat	Above Snow Temp.	Below Snow Temp.	VSI	log VSI
81.02.02	59°34'N x 98°21'W	FTT-LSeCg	-20°C	-14°C	3784	3.58
81.02.03	59°34'N x 98°21'W	FTT- Lake	-18°C	- 3°C	89,951	4.95
81.02.03	59°34'N x 98°21'W	FTT- Lake	-21°C	- 9°C	10,641	4.03
81.02.03	59°22'N x 99°36'W	SAF- Lake	-17°C	- 6°C	3,053	3.48
81.02.03	59°22'N x 99°36'W	SAF- VOBs	-16°C	- 4°C	115	2.06
81.02.04	59°22'N x 99°36'W	SAF- Fen	-13°C	- 3°C	2064	3.31
81.02.04	59°28'N x 100°15'W	SAF- VOBs	-12°C	- 5°C	907	2.96
81.02.04	59°28'N x 100°15'W	SAF- Lake	-12°C	- 6°C	11,260	4.05
81.02.04	58°28'N x 101°00'W	SAF- Burn	-12°C	- 7°C	81	1.91
81.02.04	58°28'N x 101°00'W	SAF- Lake	-11°C	- 7°C	36236	4.56
81.02.05	58°29'N x 101°30'W	SAF- LOBs	-22°C	-11°C	3519	3.55
81.02.05	58°23'N x 101°40'W	SAF- VOBs	-13°C	- 7°C	177	2.24
81.02.05	58°23'N x 101°40'W	SAF- Lake	-13°C	- 3°C	8565	3.93
81.02.06	57°53'N x 101°41'W	SAF- VOJ_p	-18°C	- 6°C	1372	3.14

FTT - Forest Tundra Transition

SAF - Subarctic Forest

APPENDIX XII

Number of classification errors in relation to sample area (m^2).
Test site located on 1:15,840 aerial photography in Upland
Open Black Spruce



APPENDIX XIII. Chi-square tests for observer bias during fly-by sampling.

TEST #1

H_o: Similarities and differences noted in fly-by observations on tundra vegetation is not dependent on observer experience

H_i: Similarities and differences noted in fly-by observations on tundra vegetation is dependent on observer experience.

Critical $X^2_{.05,1} = 3.84$

	Same	Different	
2 experienced	57	15	72
1 experienced & 1 inexp.	12	15	27
	69	30	99

Calculated $X^2 = 11.40$

Calculated $X^2 = 11.40$ $X^2_{.05,1} = 3.84$

Therefore reject null hypothesis.

APPENDIX XIII. Chi-square tests for observer bias during fly-by sampling.

TEST #2

H_o: Similarities and differences noted in fly-by observations on subarctic forest vegetation is not dependent on observer experience.

H_i Similarities and differences noted in fly-by observations on subarctic forest vegetation is dependent on observer experience.

Critical $X^2_{.05,1} = 3.84$

	Same	Different	
2 experienced	108	15	123
1 experienced & 1 inexp.	33	24	57
	141	39	180

Calculated $X^2 = 22.03$

Calcualted X^2 $X^2_{.05,1}$

Therefore reject null hypothesis

APPENDIX XIII. Chi-square tests for observer bias during fly-by sampling.

TEST #3

H_o: Similarities and differences noted in fly-by observations between 2 experienced observers are not dependent on vegetation conditions (tundra and subarctic forest).

H_i: Similarities and differences noted in fly-by observations between 2 experienced observers are dependent on vegetation conditions.

Critical $X^2_{.05,1} = 3.84$

	Same	Different	
Tundra	57	15	72
Subarctic Forest	108	15	123
	165	30	195

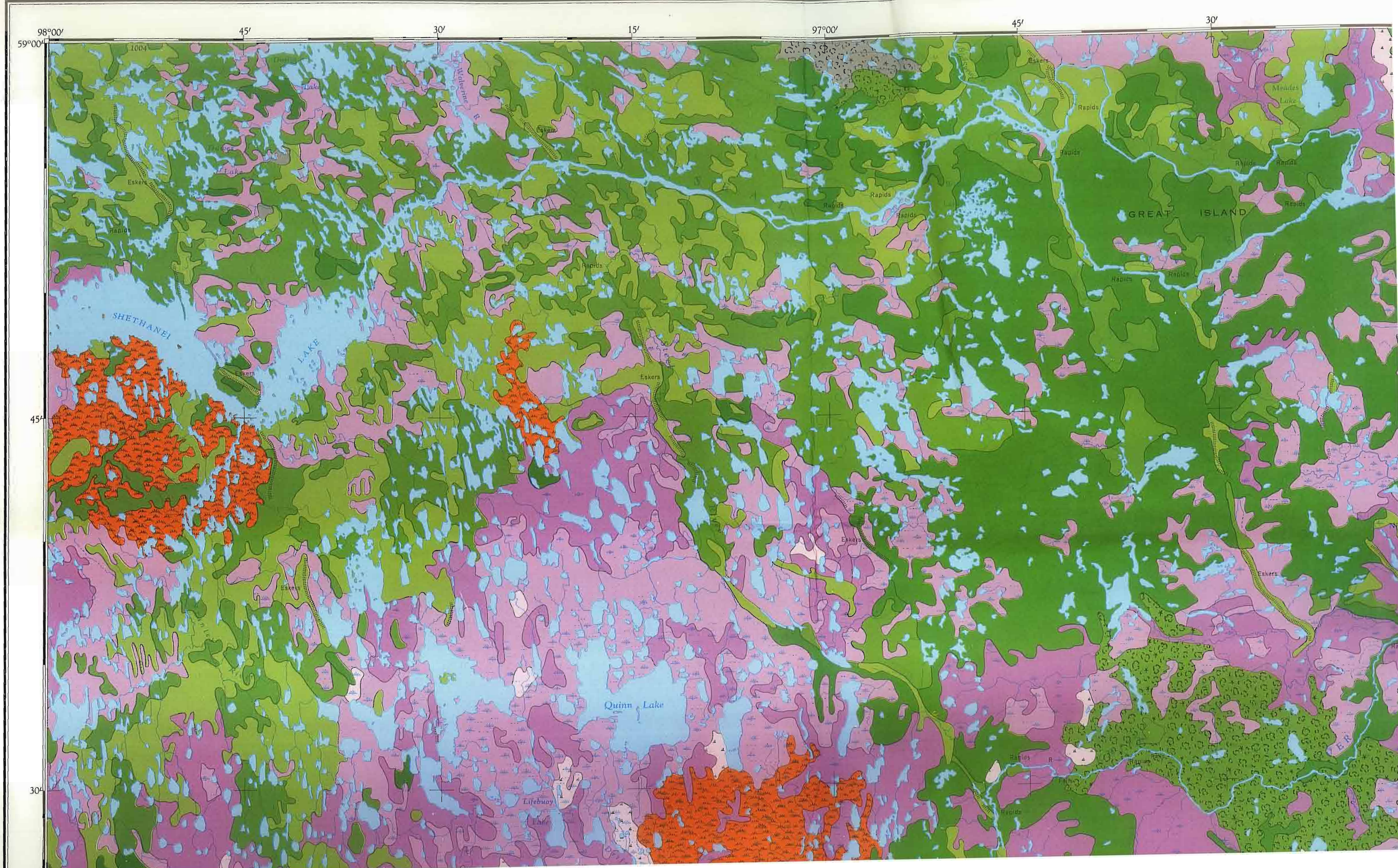
Calculated $X^2 = 2.71$

Calculated X^2 $X^2_{.05,1}$

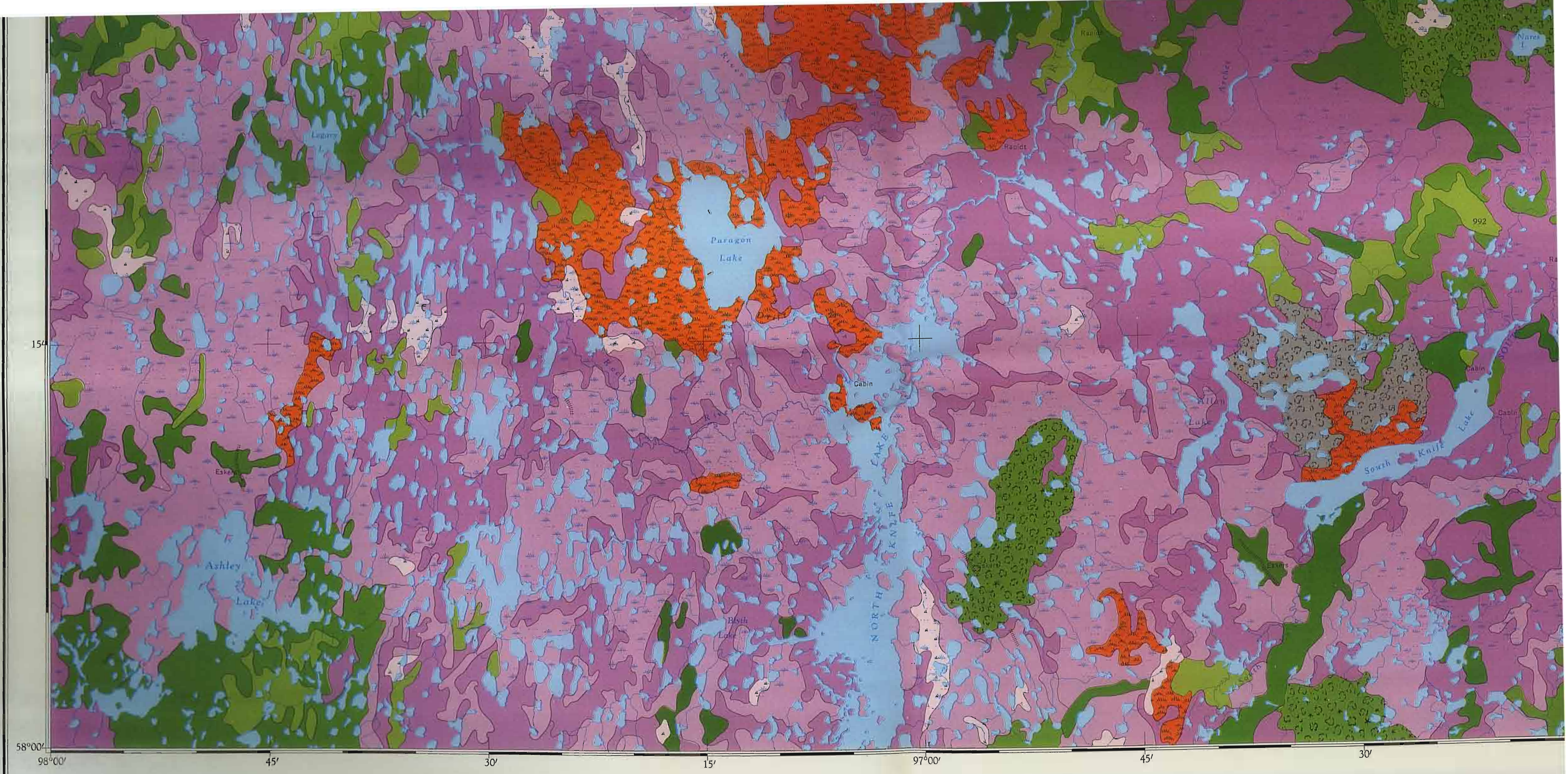
Therefore accept null hypothesis

CANADA

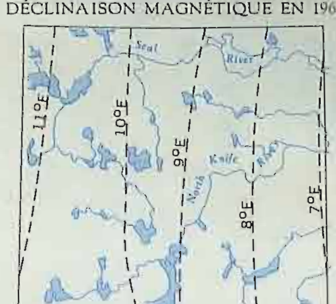
EDITION 1




30′
15′
97°00′
45′
30′
15′
96°00′
59°00′
45′
30′
GREAT ISLAND
Rapids
Eskers
LAKE
Quinn Lake
Lifebuoy Lake



THE DECLINATION OF THE COMPASS NEEDLE 1963
DÉCLINAISON MAGNÉTIQUE EN 1963



The declination of the compass needle is increasing 1.4 minutes annually.
La déclinaison magnétique croît de 1.4 minutes annuellement.

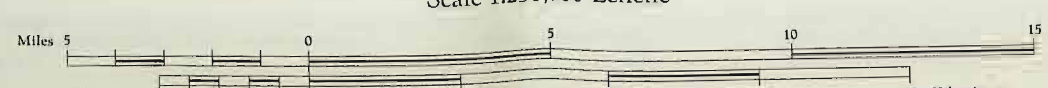
Compiled, 1962, by the SURVEYS AND MAPPING BRANCH, DEPARTMENT OF MINES AND TECHNICAL SURVEYS, from air photographs taken from 1955 to 1957. Field surveys 1959. Printed 1963.

Road, all weather	Chemin, toute saison
Wagon or winter road	Chemin de terre ou d'hiver
Trail or portage	Sentier ou portage
Town	Ville
Village or settlement	Village ou hameau
Post office	Bureau de poste
Horizontal control point	Point géodésique
Boundary monument	Borne frontière

SHETHANEI LAKE

MANITOBA

Scale 1:250,000 Échelle

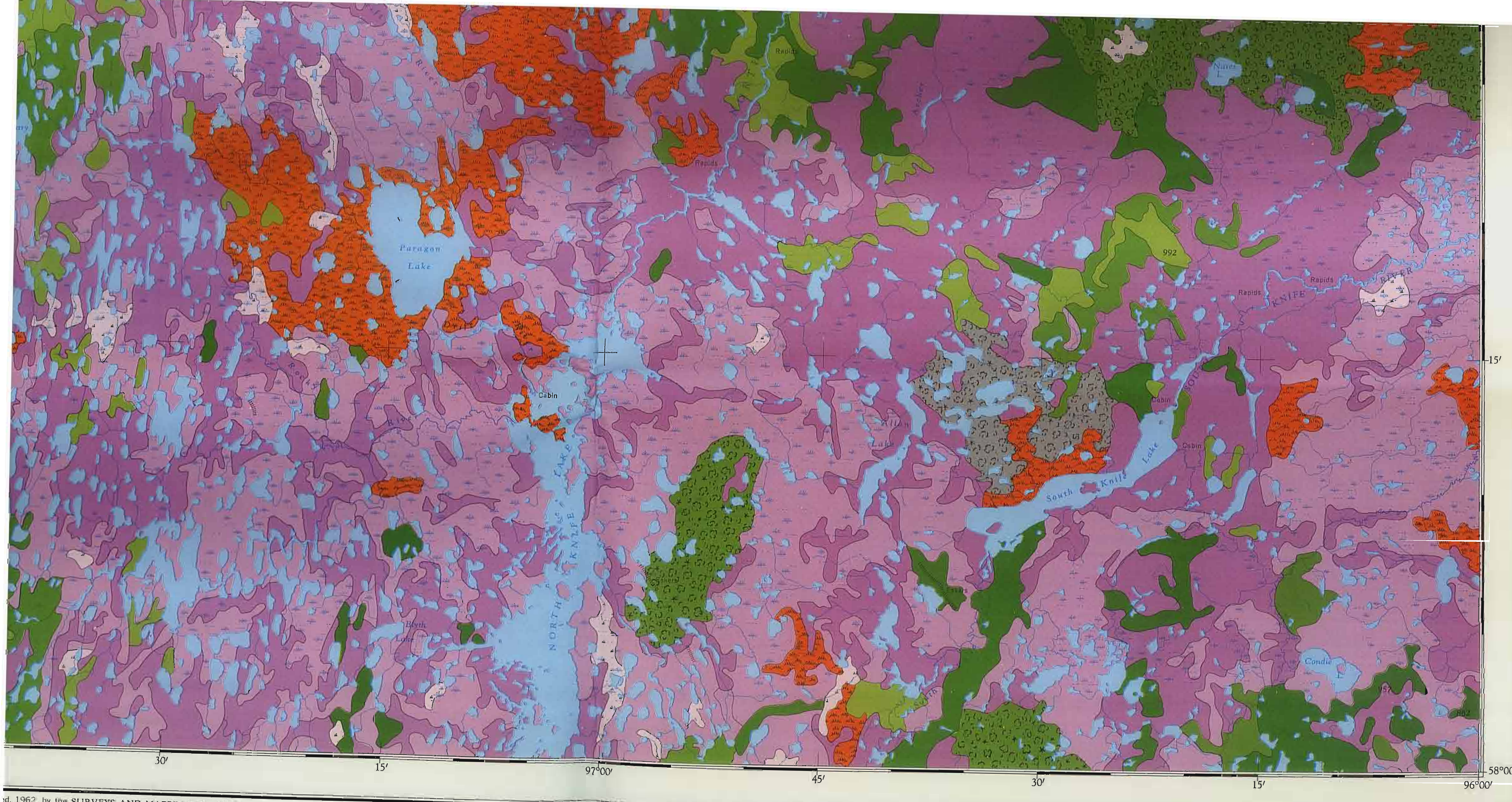


Transverse Mercator Projection
North American Datum 1927 (1956)
Contour Interval 100 feet
Elevations in feet above Mean Sea Level

Projection Transverse de Mercator
Réseau géodésique nord-américain unifié 1927 (1956)
Équidistance des courbes: 100 pieds
Élévations en pieds au-dessus du niveau moyen de la mer

Rédigée en 1962, par la DIRECTION DES LEVÉS ET DE LA CARTOGRAPHIE, MINISTÈRE DES MINES ET DES RELEVÉS TECHNIQUES, d'après les photographies aériennes prises de 1955 à 1957. Travaux exécutés sur le terrain en 1959. Imprimée en 1963.

Stream	Cours d'eau
intermittent or dry	intermittent ou à sec
indefinite	imprécis
Rapids; falls	Rapides; chutes (R F)
Marsh or swamp	Marais ou marécage
Intermittent lake	Lac intermittent
Depression contours	Courbes de cuvette
Spot elevation, in feet	Repère de nivellement en pieds 2550



…ed, 1962, by the SURVEYS AND MAPPING BRANCH, …TMENT OF MINES AND TECHNICAL SURVEYS, …photographs taken from 1955 to 1957. Field surveys 1959. …1963.

SHETHANEI LAKE

MANITOBA

Scale 1:250,000 Échelle

Miles 5 0 5 10 15 Milles

Kilometres 5 0 5 10 15 20 Kilomètres

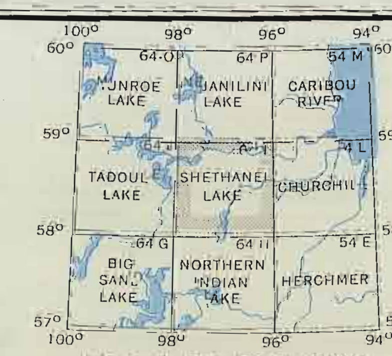
Transverse Mercator Projection
North American Datum 1927 (1956)
Contour Interval 100 feet

Projection Transverse de Mercator
Réseau géodésique nord-américain unifié 1927 (1956)
Équidistance des courbes: 100 pieds

Rédigée en 1962, par la DIRECTION DES LEVÉS ET DE LA CARTOGRAPHIE, MINISTÈRE DES MINES ET DES RELEVÉS TECHNIQUES, d'après les photographies aériennes prises de 1955 à 1957. Travaux exécutés sur le terrain en 1959. Imprimée en 1963.

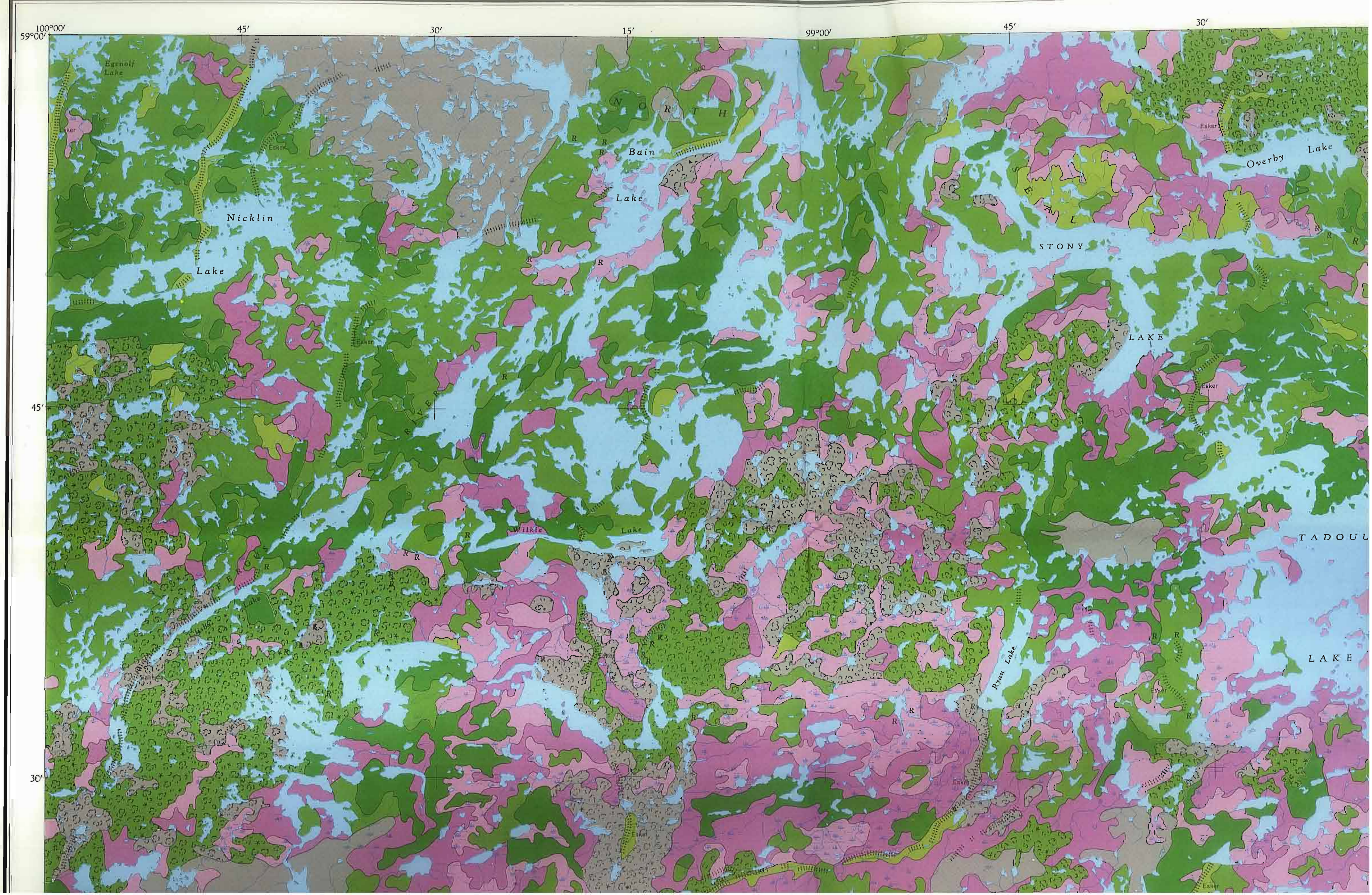
…, all weather	Chemin, toute saison	═══
…n or winter road	Chemin de terre ou d'hiver	— — —
…or portage	Sentier ou portage	- - - -
…	Ville	□
…e or settlement	Village ou hameau	o
…office	Bureau de poste	P
…ontal control point	Point géodésique	△

Stream	Cours d'eau	
intermittent or dry	intermittent ou à sec	
indefinite	imprécis	
Rapids; falls	Rapides; chutes	
Marsh or swamp	Marais ou marécage	
Intermittent lake	Lac intermittent	
Depression contours	Courbes de cuvette	
Spot elevation, in feet	Repère de nivellement en pieds	2550 •



Index to adjoining sheets of National Topographic System

Tableau d'assemblage du Système de Référence Cartographique National


100°00′
59°00′
45′
30′
15′
99°00′
45′
30′
Egenolf Lake
Esker
Nicklin
Lake
N O R T H
Bain
Lake
S E A L
Overby
Lake
STONY
LAKE
45′
Wilkie
Lake
TADOUL
LAKE
Ryan Lake
30′
(Joins Whiskey Jack Lake 64 K)

CANADA

1:250,000

(Joins Munroe Lake 64-O)

EDITION 1

64 J

(Joins Shethanei Lake 64-I)

Compiled, 1960, by the SURVEYS AND MAPPING BRANCH, DEPARTMENT OF MINES AND TECHNICAL SURVEYS, from air photographs taken in 1955 and 1957. Field surveys 1959. Printed 1963.

Transverse Mercator Projection
North American Datum 1927 (1956)
Contour Interval 100 feet
Elevations in feet above Mean Sea Level
Magnetic declination 13°07′ East at centre of map 1963
Annual change (decreasing) 0.2′

(Joins Big Sand Lake 64 G)

TADOULE LAKE
MANITOBA

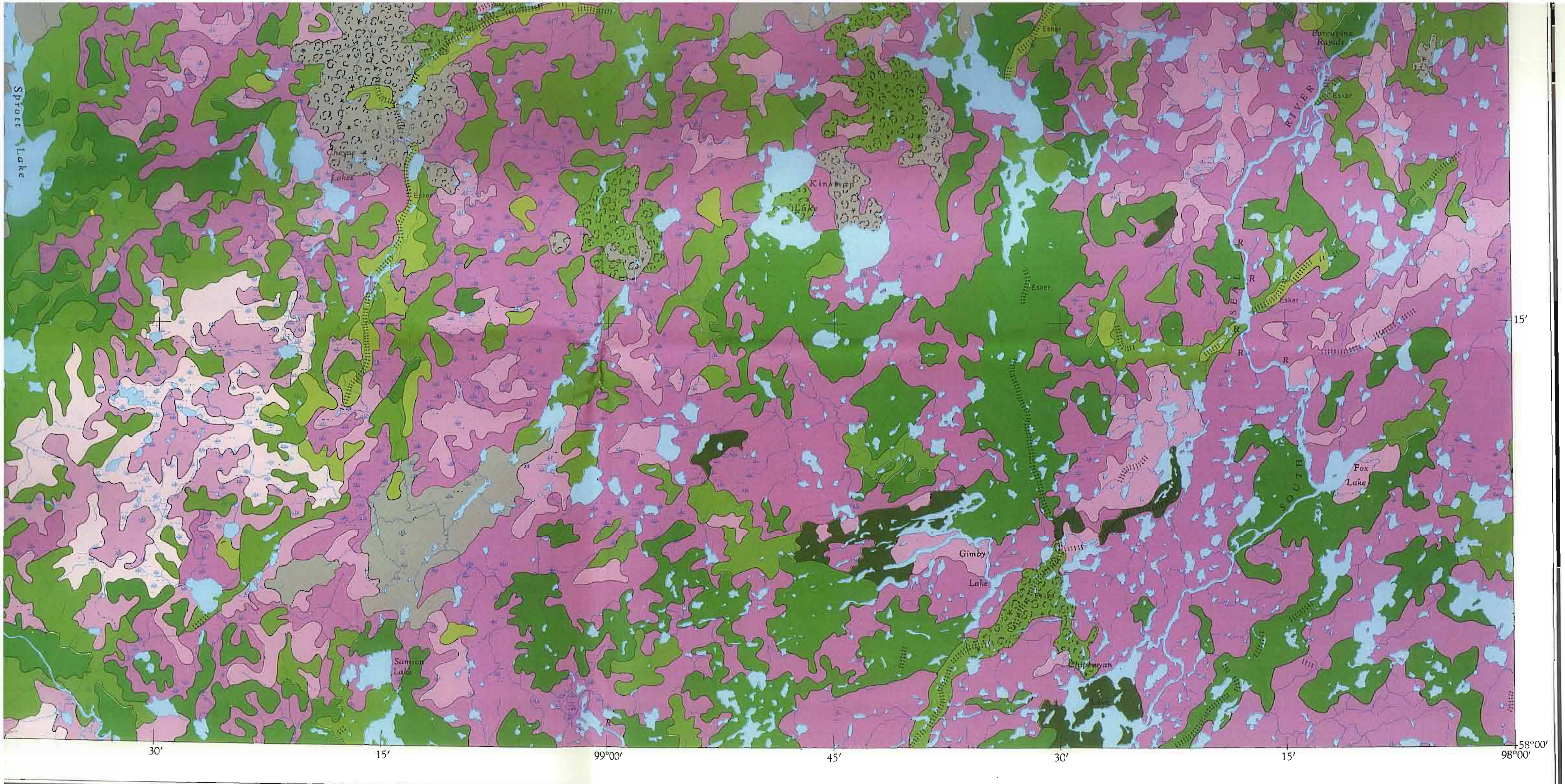
Projection Transverse de Mercator
Réseau géodésique nord-américain unifié 1927 (1956)
Équidistance des courbes: 100 pieds
Élévations en pieds au-dessus du niveau moyen de la mer
Déclinaison magnétique au centre de la feuille en 1963: 13°07′ Est
Variation annuelle (décroissante) 0.2′

Scale 1:250,000 Échelle

Miles 5 0 5 10 15 20 Milles
Kilometres 5 0 5 10 15 20 25 30 Kilomètres

Road, all weather	Chemin, toute saison	
Wagon or winter road	Chemin de terre ou d'hiver	
Trail or portage	Sentier ou portage	
Town	Ville	□
Village or settlement	Village ou hameau	o
Post office	Bureau de poste	P
Building	Bâtiment	•
Horizontal control point	Point géodésique	
Boundary monument	Borne frontière	
Spot elevation, in feet	Repère de nivellement en pieds	
Rapids; falls	Rapides; chutes	
Marsh or swamp	Marais ou marécage	
Depression contours	Courbes de cuvette	
Surveyed line	Ligne arpentée	

PROVISIONAL MAP CARTE PROVISOIRE



Transverse Mercator Projection
North American Datum 1927 (1956)
Contour Interval 100 feet
Elevations in feet above Mean Sea Level
Magnetic declination 13°07′ East at centre of map 1963
Annual change (decreasing) 0.2′

(Joins Big Sand Lake 64 G)

TADOULE LAKE
MANITOBA

Projection Transverse de Mercator
Réseau géodésique nord-américain unifié 1927 (1956)
Équidistance des courbes: 100 pieds
Élévations en pieds au-dessus du niveau moyen de la mer
Déclinaison magnétique au centre de la feuille en 1963: 13°07′ Est
Variation annuelle (décroissante) 0.2′

Rédigée en 1960, par la DIRECTION DES LEVÉS ET DE LA CARTOGRAPHIE, MINISTÈRE DES MINES ET DES RELEVÉS TECHNIQUES, d'après les photographies aériennes prises en 1955 et 1957. Travaux exécutés sur le terrain en 1959. Imprimée en 1963.

e saison................

rre ou d'hiver..........

rlage...................

......................................□

neau ....o

te.......................................P

....•

Scale 1:250,000 Échelle

Miles 5 0 5 10 15 20 Milles

Kilometres 5 0 5 10 15 20 25 30 Kilomètres

Horizontal control point.......Point géodésique.................................△

Boundary monument.........Borne frontière.................................□

Spot elevation, in feet........Repère de nivellement en pieds...................2550 •

Rapids; falls.................Rapides; chutes....................... R F

Marsh or swamp............Marais ou marécage......................

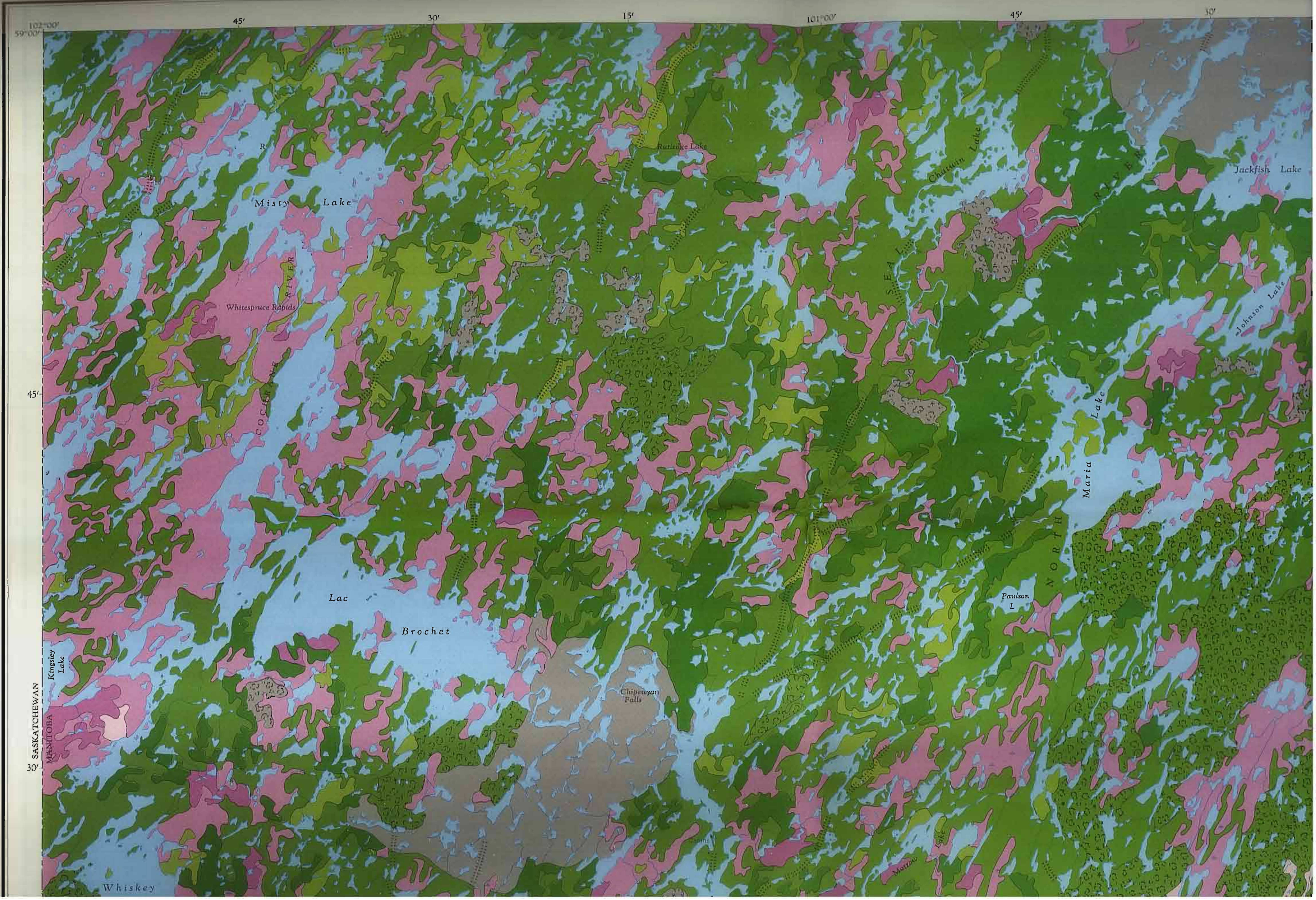
Depression contours.........Courbes de cuvette.......................2000

Surveyed line................Ligne arpentée.......................

PROVISIONAL MAP

CARTE PROVISOIRE

64 K 1:250,000 CANADA EDITION 2



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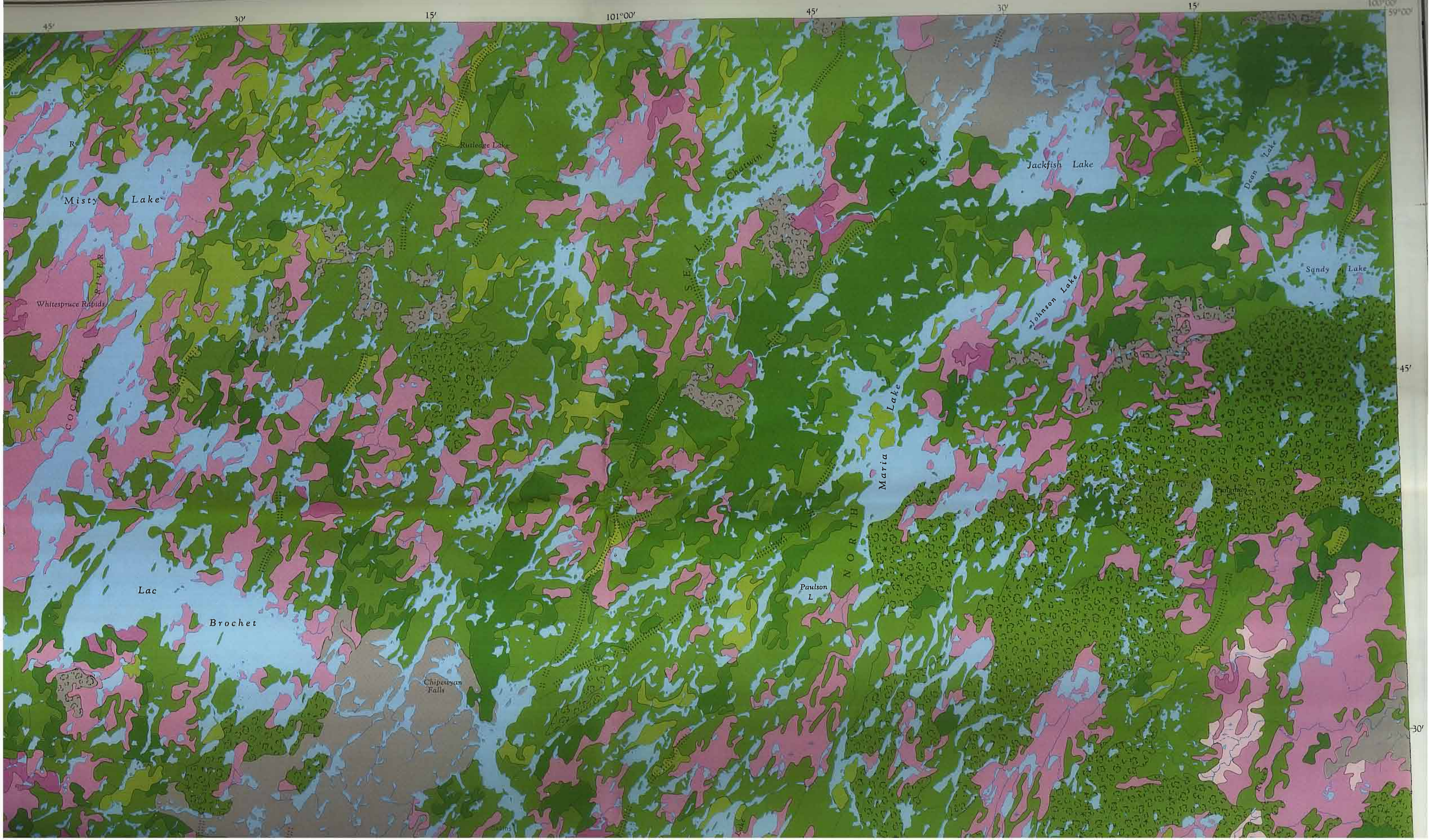

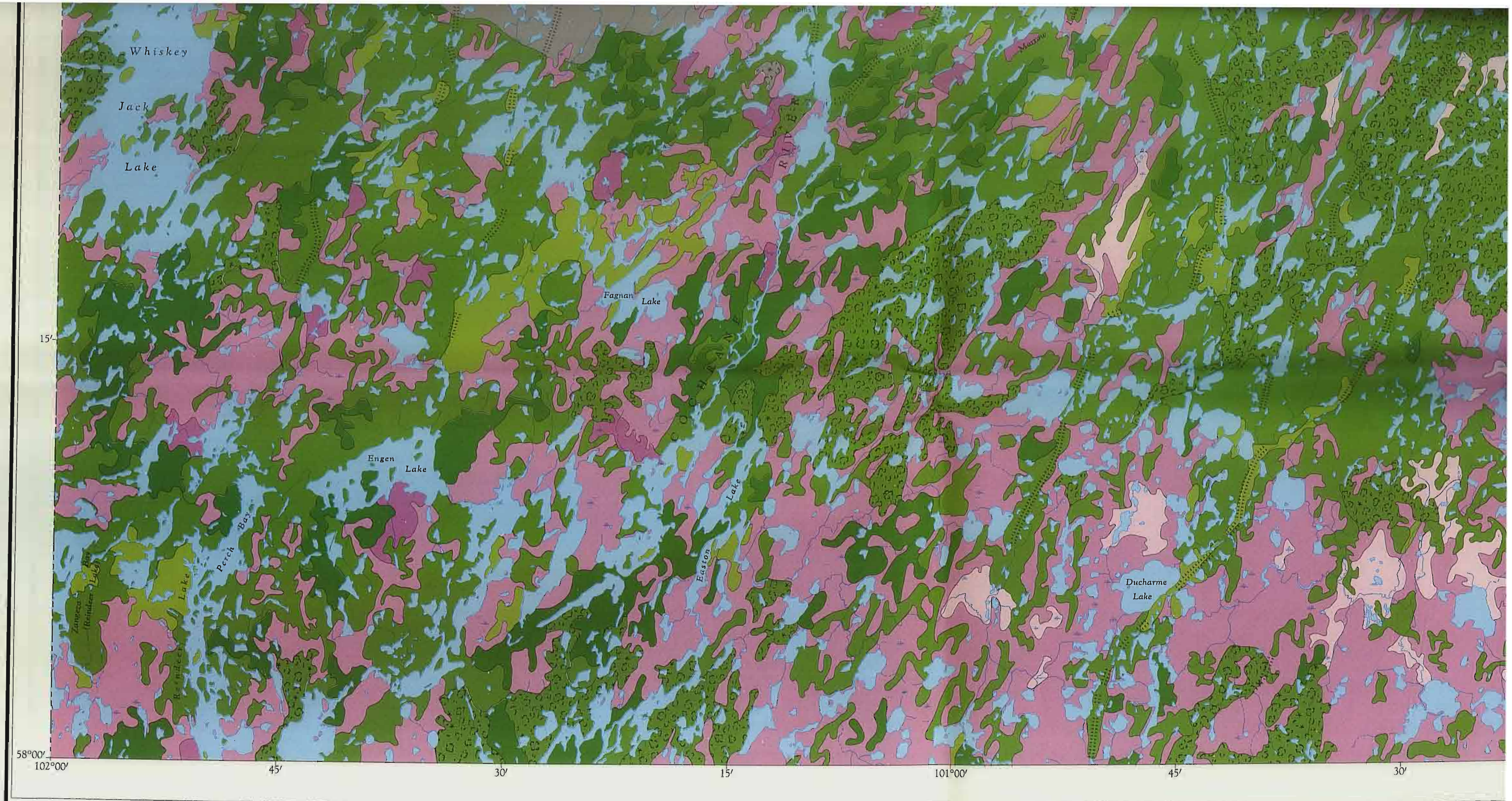

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Transverse Mercator Projection
North American Datum 1927
Contour Interval 100 feet
Elevations in feet above Mean Sea Level

WHISKEY JACK LAKE

MANITOBA

Projection Transverse de Mercator
Réseau géodésique nord-américain unifié 1927
Équidistance des courbes: 100 pieds
Élévations en pieds au-dessus du niveau moyen de la mer

Road, all weather	Chemin, toute saison	═══
Wagon or winter road	Chemin de terre ou d'hiver	— — —
Trail or portage	Sentier ou portage	- - - -
Town	Ville	□
Village or settlement	Village ou hameau	○
Post office	Bureau de poste	P
Building	Bâtiment	▪

Scale 1:250,000 Échelle

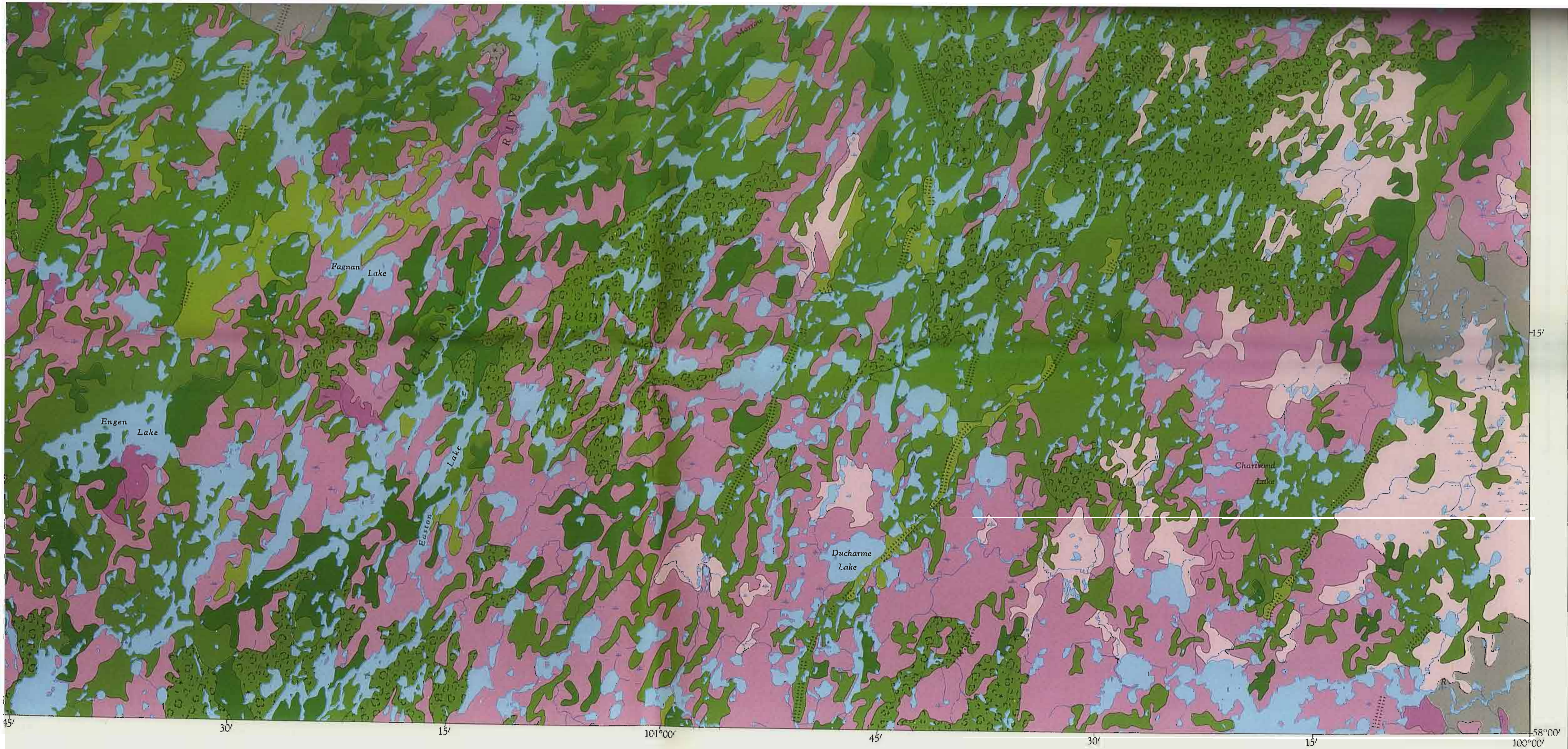
Miles 5 0 5 10 15 20 Miles

Kilometres 5 0 5 10 15 20 25 30 Kilomètres

PROVISIONAL MAP

CARTE PROVISOIRE

Horizontal control point
Boundary monument
Spot elevation, in feet
Rapids; falls
Marsh or swamp
Depression contours
Surveyed line



Transverse Mercator Projection
North American Datum 1927
Contour Interval 100 feet
Elevations in feet above Mean Sea Level

WHISKEY JACK LAKE

MANITOBA

Projection Transverse de Mercator
Réseau géodésique nord-américain unifié 1927
Équidistance des courbes: 100 pieds
Élévations en pieds au-dessus du niveau moyen de la mer

Rédigée en 1960, par la DIRECTION DES LEVÉS ET DE LA CARTOGRAPHIE, MINISTÈRE DES MINES ET DES RELEVÉS TECHNIQUES, d'après les photographies aériennes prises de 1954 à 1956. Travaux exécutés sur le terrain en 1955 et 1958. Imprimée en 1962.

Chemin, toute saison
Chemin de terre ou d'hiver
Sentier ou portage
Ville
Village ou hameau
Bureau de poste ..... P
Bâtiment

Scale 1:250,000 Échelle

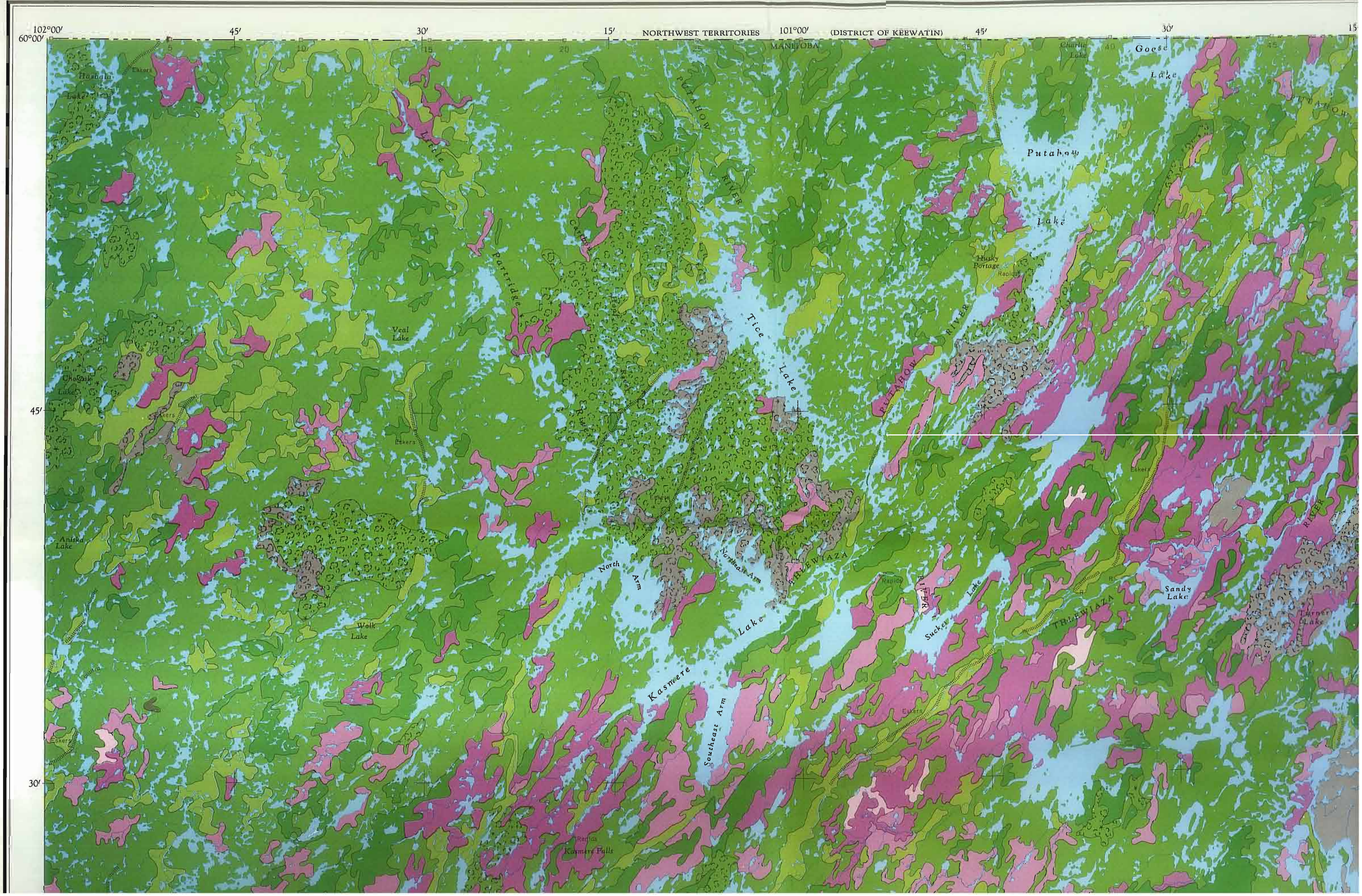
Miles 5 0 5 10 15 20 Milles

Kilometres 5 0 5 10 15 20 25 30 Kilomètres

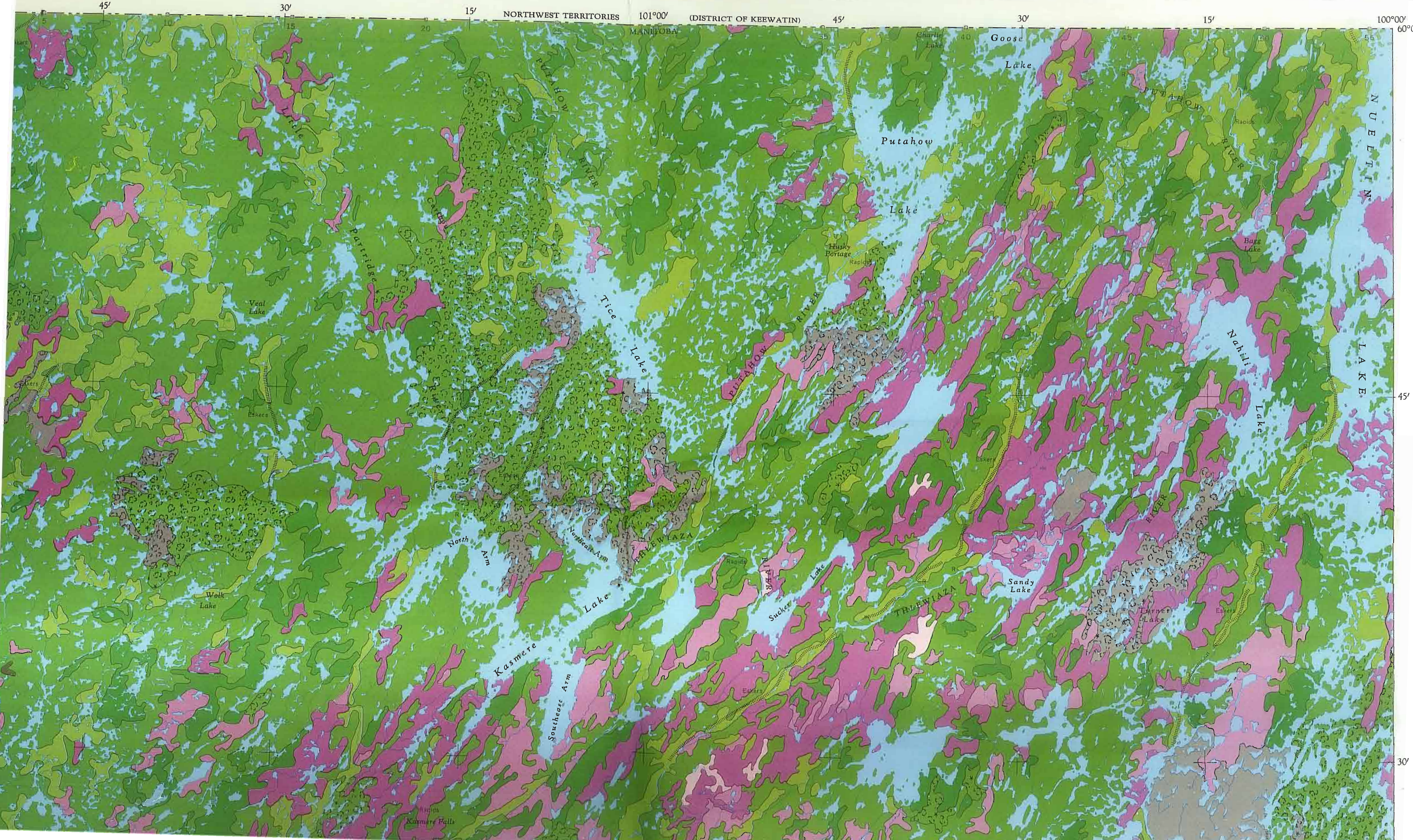
Horizontal control point .... Point géodésique
Boundary monument .... Borne frontière
Spot elevation, in feet .... Repère de nivellement en pieds 2550
Rapids; falls .... Rapides; chutes ..... R F
Marsh or swamp .... Marais ou marécage
Depression contours .... Courbes de cuvette 2000
Surveyed line .... Ligne arpentée

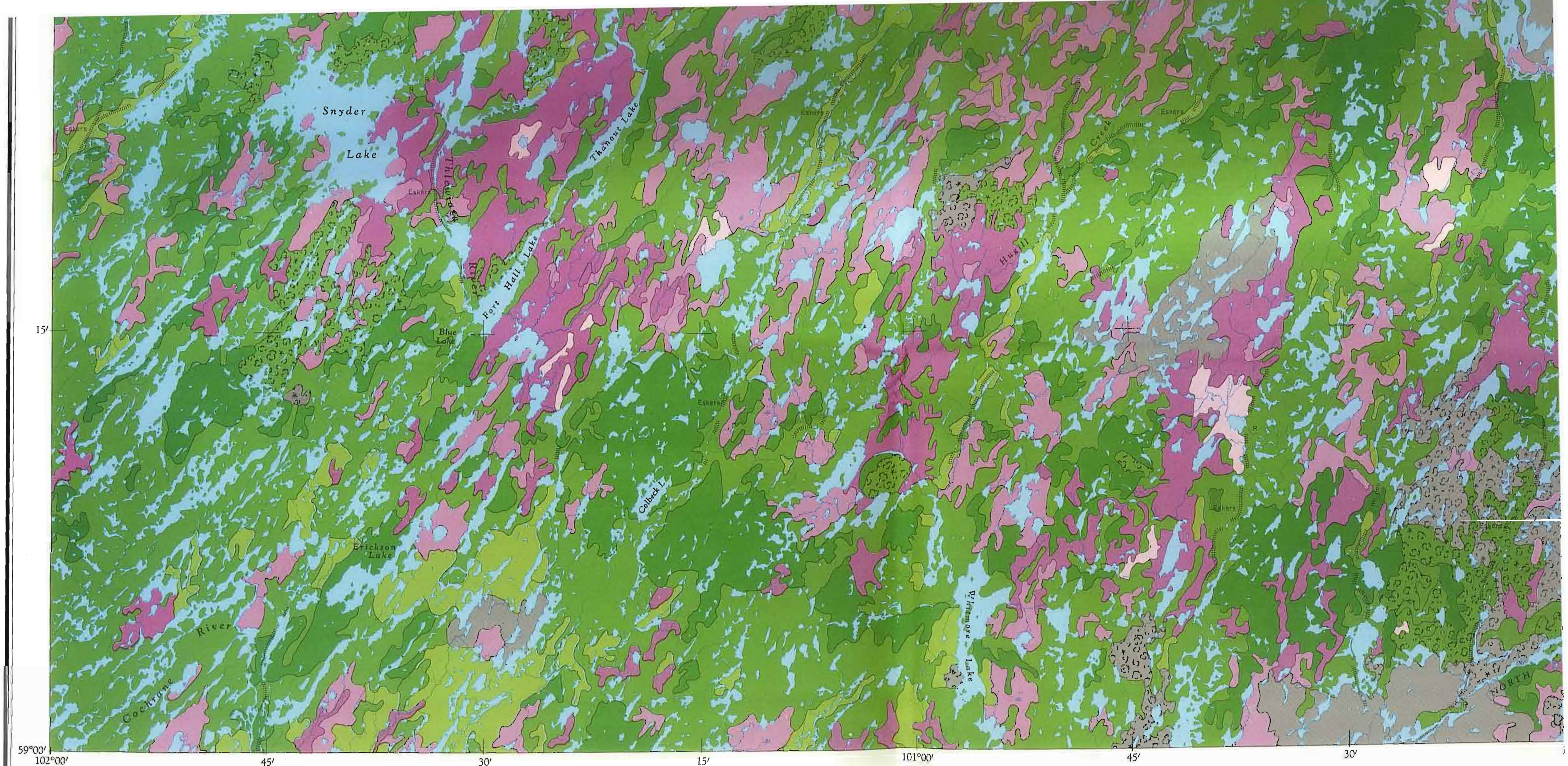
PROVISIONAL MAP

CARTE PROVISOIRE


NORTHWEST TERRITORIES
(DISTRICT OF KEEWATIN)
MANITOBA
Tice Lake
Putahow Lake
Goose Lake
Kasmere Lake
North Arm
Northeast Arm
Southeast Arm
Veal Lake
Wolk Lake
Sandy Lake
Turner Lake
Sucker Lake
Husky Portage
Kasmere Falls
PUTAHOW RIVER
THLEWIAZA
Partridge
Eskers
Rapids

1:250,000 CANADA EDITION 1 64 N





Compiled, 1960, by the SURVEYS AND MAPPING BRANCH, DEPARTMENT OF MINES AND TECHNICAL SURVEYS, from air photographs taken in 1956 and 1957. Field surveys 1955 and 1958. Printed 1963

Transverse Mercator Projection
North American Datum 1927
Contour Interval 100 feet
Elevations in feet above Mean Sea Level
Magnetic declination 16°15′ East at centre of map 1963
Annual change (decreasing) 1.1′

KASMERE LAKE
MANITOBA

Projection Transverse de Mercator
Réseau géodésique nord-américain unifié (1927)
Équidistance des courbes: 100 pieds
Élévations en pieds au-dessus du niveau moyen de la mer
Déclinaison magnétique au centre de la feuille en 1963: 16°15′ Est
Variation annuelle (décroissante) 1.1′

Scale 1:250,000 Échelle

Miles 5 0 5 10 15 20 Milles

Kilometres 5 0 5 10 15 20 25 30 Kilomètres

Road, all weather	Chemin, toute saison	
Wagon or winter road	Chemin de terre ou d'hiver	
Trail or portage	Sentier ou portage	
Town	Ville	□
Village or settlement	Village ou hameau	o
Post office	Bureau de poste	P
Building	Bâtiment	▪

PROVISIONAL MAP

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CARTE PROVISOIRE

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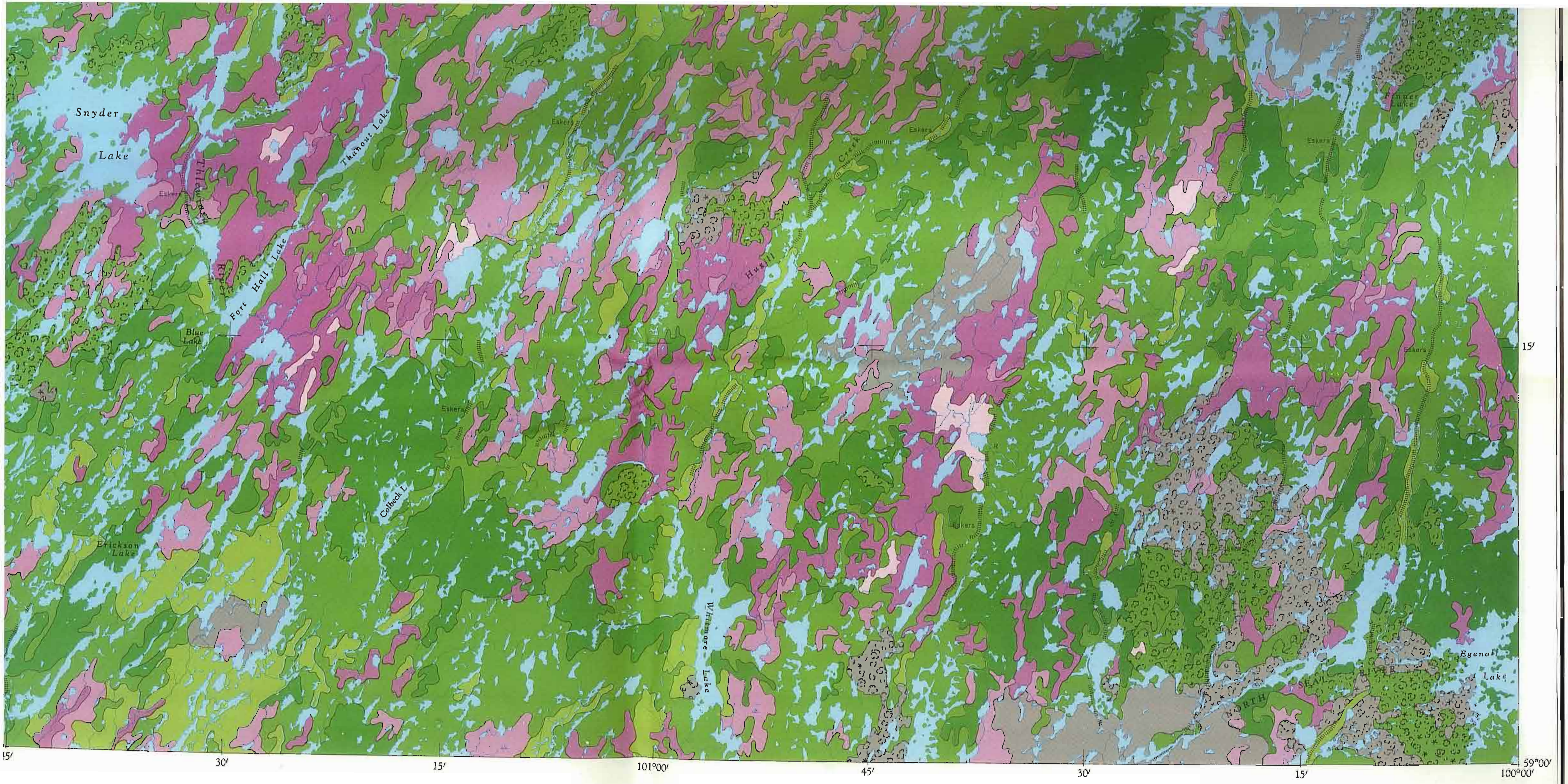
Horizontal control point	Point géodésique
Boundary monument	Borne frontière
Spot elevation, in feet	Repère de nivellement en pieds
Rapids; falls	Rapides; chutes
Marsh or swamp	Marais ou marécage
Depression contours	Courbes de cuvette
Surveyed line	Ligne arpentée



Transverse Mercator Projection
North American Datum 1927
Contour Interval 100 feet
Elevations in feet above Mean Sea Level
Magnetic declination 16°15′ East at centre of map 1963
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KASMERE LAKE
MANITOBA

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Déclinaison magnétique au centre de la feuille en 1963: 16°15′ Est
Variation annuelle (décroissante) 1.1′

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.....Chemin, toute saison
.....Chemin de terre ou d'hiver
.....Sentier ou portage
.....Ville
.....Village ou hameau
.....Bureau de poste
.....Bâtiment

Scale 1:250,000 Échelle

Miles — Milles
Kilometres — Kilomètres

Horizontal control point ...... Point géodésique
Boundary monument .... Borne frontière
Spot elevation, in feet .... Repère de nivellement en pieds 2550
Rapids; falls .... Rapides; chutes
Marsh or swamp .... Marais ou marécage
Depression contours .... Courbes de cuvette 2000
Surveyed line .... Ligne arpentée

PROVISIONAL MAP

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CARTE PROVISOIRE

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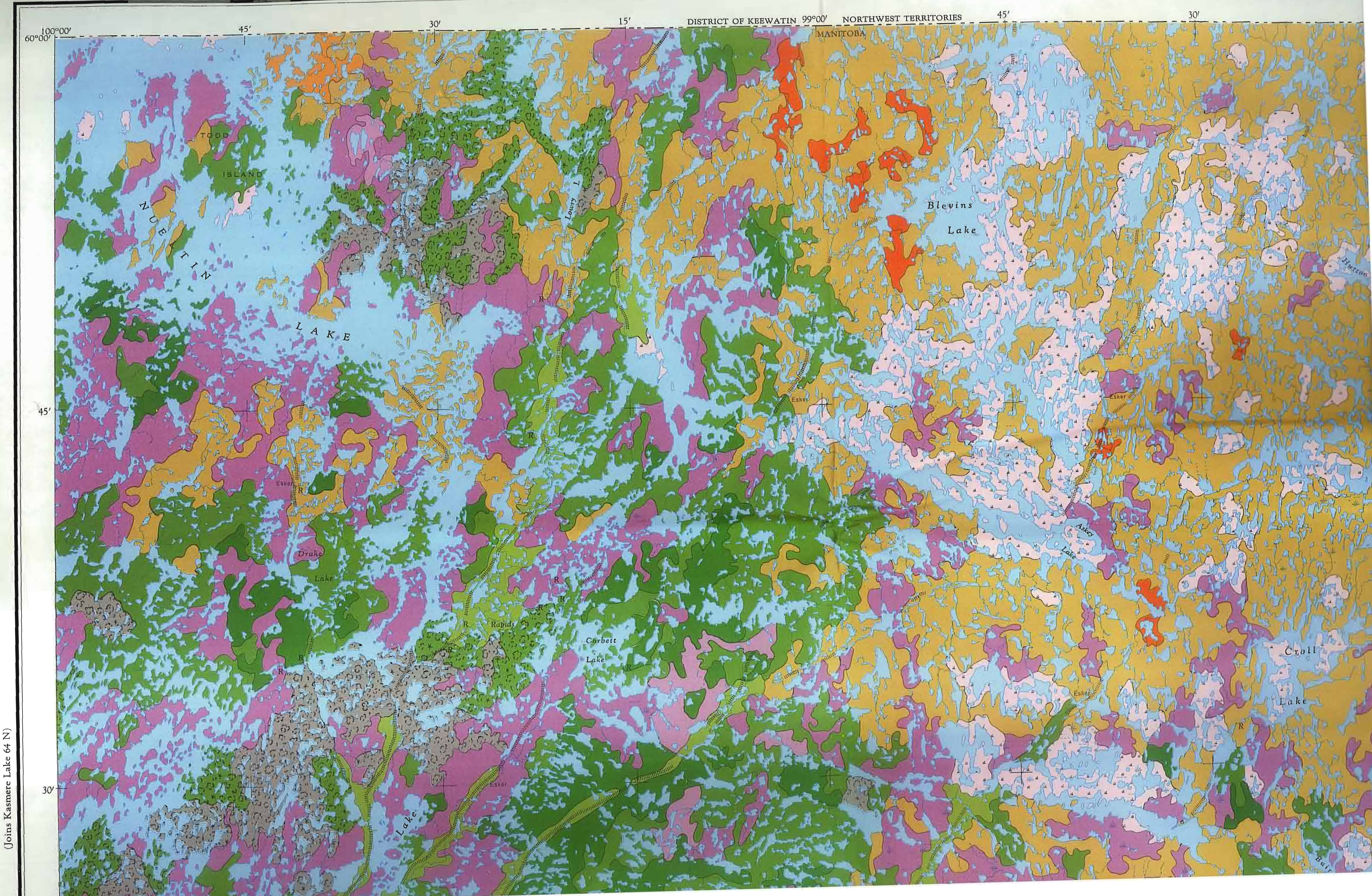
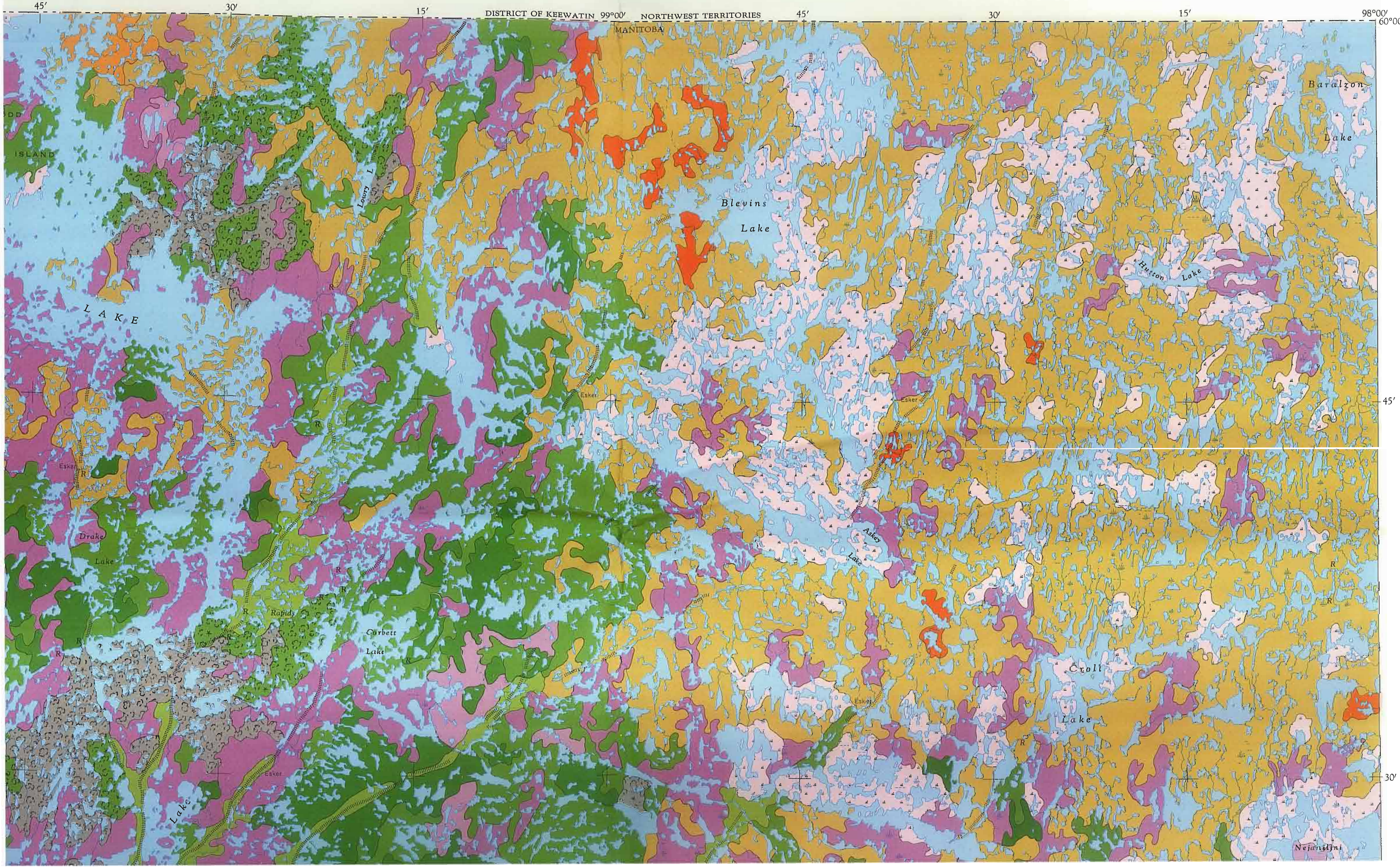
64-O 1:250,000 (Joins Nueltin Lake 65 B) EDITION 1

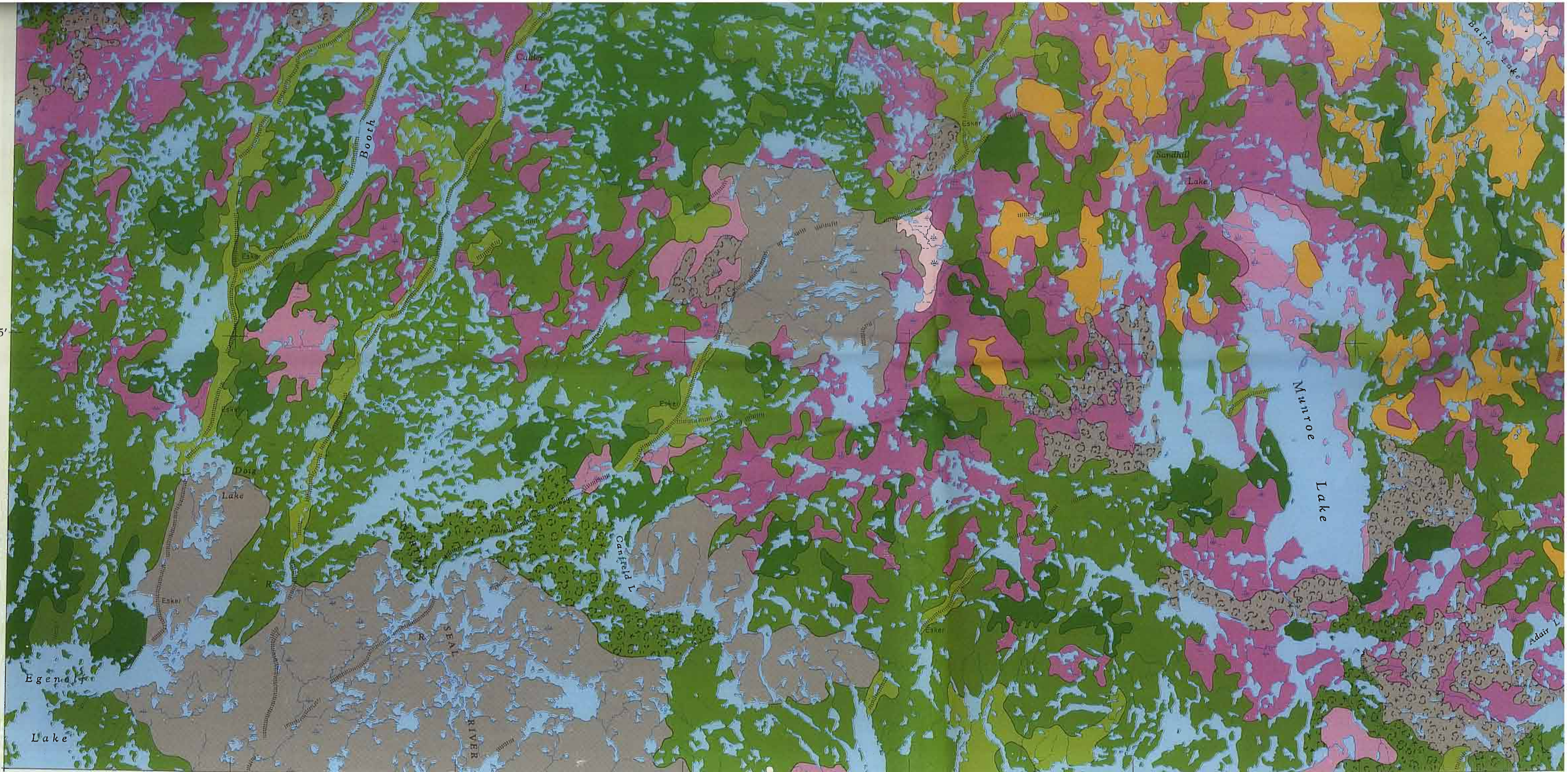


(Joins Nueltin Lake 65 B)

EDITION 1



(Joins Nejanilini Lake 64 P)



Compiled, 1960, by the SURVEYS AND MAPPING BRANCH, DEPARTMENT OF MINES AND TECHNICAL SURVEYS, from air photographs taken in 1956-57. Field surveys 1959. Printed 1963.

Transverse Mercator Projection
North American Datum 1927 (1956)
Contour Interval 100 feet
Elevations in feet above Mean Sea Level
Magnetic declination 13°04′ East at centre of map 1963
Annual change (decreasing) .0′

(Joins Tadoule Lake 64 J)

MUNROE LAKE

MANITOBA

Projection Transverse de Mercator
Réseau géodésique nord-américain unifié 1927(1956)
Équidistance des courbes: 100 pieds
Élévations en pieds au-dessus du niveau moyen de la mer
Déclinaison magnétique au centre de la feuille en 1963: 13°04′ Est
Variation annuelle (décroissante).0′

Road, all weather............Chemin, toute saison...............
Wagon or winter road........Chemin de terre ou d'hiver..........
Trail or portage..............Sentier ou portage..................
Town.........................Ville...................................
Village or settlement.........Village ou hameau......................
Post office...................Bureau de poste.......................P
Building......................Bâtiment...............................

Scale 1:250,000 Echelle

Miles 5 0 5 10 15 20 Miles

Kilometres 5 0 5 10 15 20 25 30 Kilomètres

PROVISIONAL MAP

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CARTE PROVISOIRE

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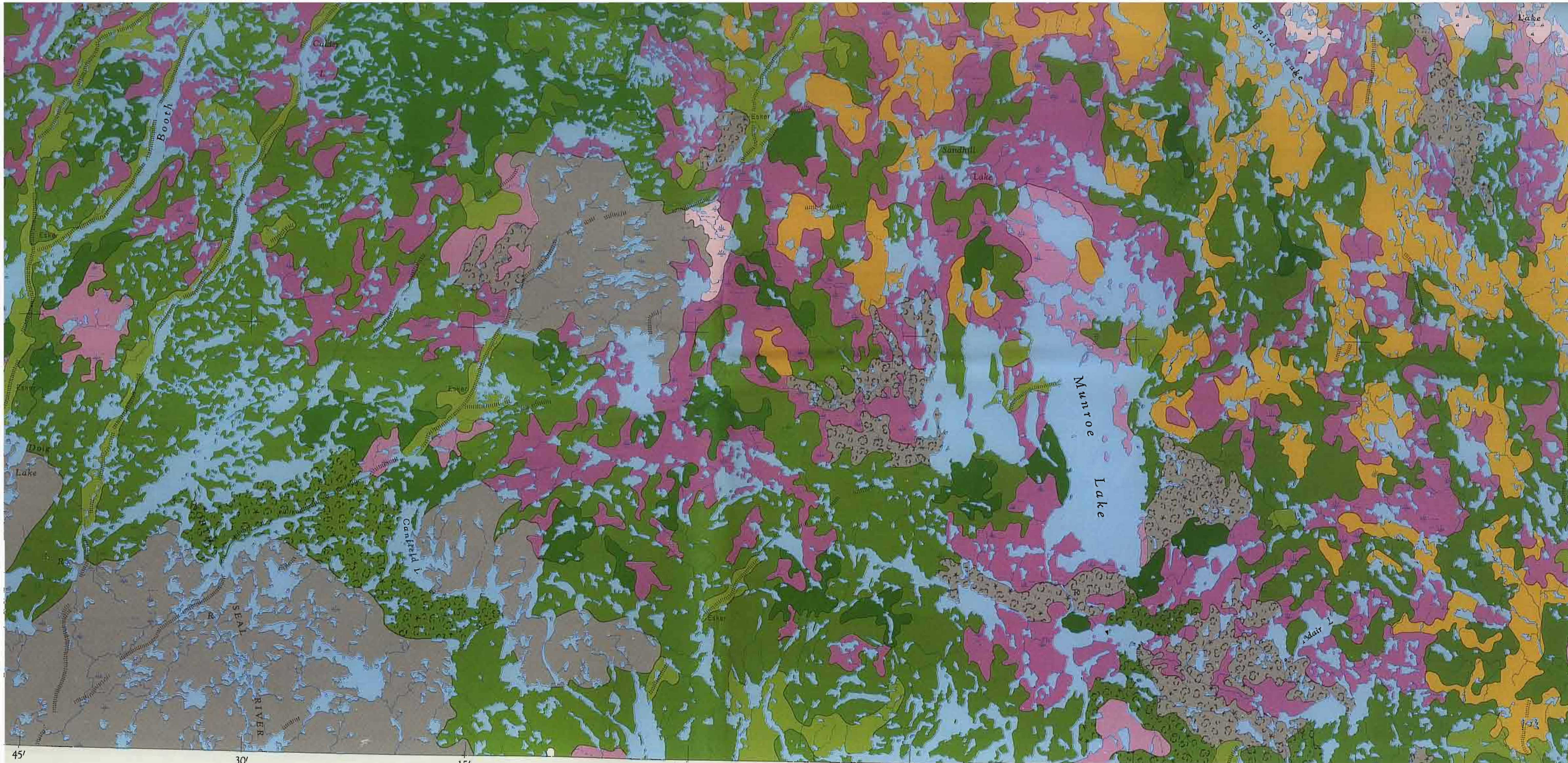
Horizontal control point.......Point géodésique.......
Boundary monument.........Borne frontière.........
Spot elevation, in feet........Repère de nivellement en
Rapids; falls...................Rapides; chutes........
Marsh or swamp...............Marais ou marécage....
Depression contours..........Courbes de cuvette.....
Surveyed line..................Ligne arpentée.......



NCH,
VEYS,

Transverse Mercator Projection
North American Datum 1927 (1956)
Contour interval 100 feet
Elevations in feet above Mean Sea Level
Magnetic declination 13°04′ East at centre of map 1963
Annual change (decreasing) .0′

(Joins Tadoule Lake 64 J)

MUNROE LAKE

MANITOBA

Projection Transverse de Mercator
Réseau géodésique nord-américain unifié 1927 (1956)
Équidistance des courbes: 100 pieds
Élévations en pieds au-dessus du niveau moyen de la mer
Déclinaison magnétique au centre de la feuille en 1963: 13°04′ Est
Variation annuelle (décroissante) .0′

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Scale 1:250,000 Echelle

Miles 5 — 0 — 5 — 10 — 15 — 20 Milles

Kilometres 5 — 0 — 5 — 10 — 15 — 20 — 25 — 30 Kilomètres

.......Chemin, toute saison
.......Chemin de terre ou d'hiver
.......Sentier ou portage
.......Ville
.......Village ou hameau
......Bureau de poste ... P
......Bâtiment

Horizontal control point.......Point géodésique
Boundary monument.........Borne frontière
Spot elevation, in feet........Repère de nivellement en pieds ... 2550
Rapids; falls.........Rapides; chutes ... R F
Marsh or swamp.........Marais ou marécage
Depression contours.........Courbes de cuvette ... 2000
Surveyed line.........Ligne arpentée

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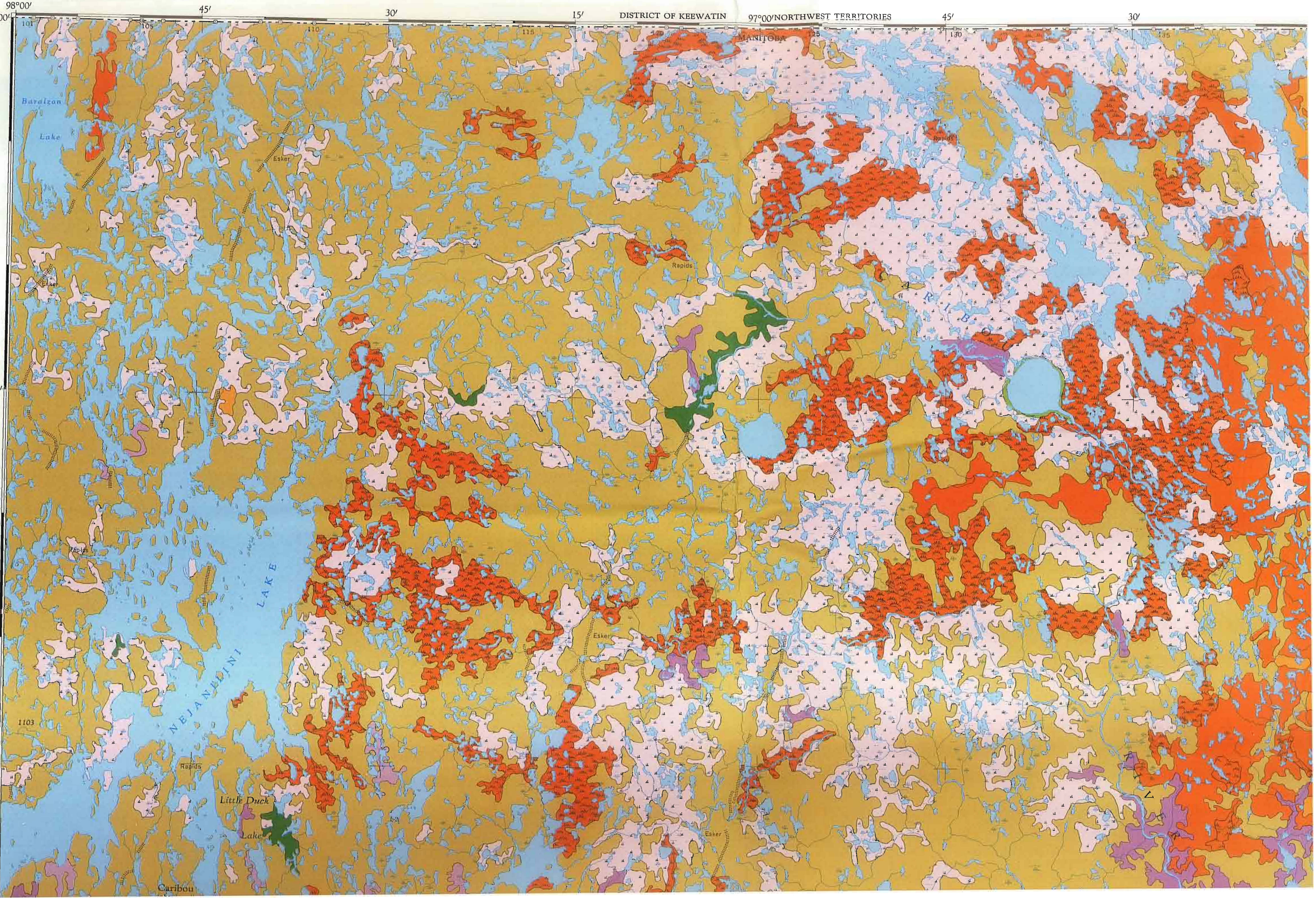
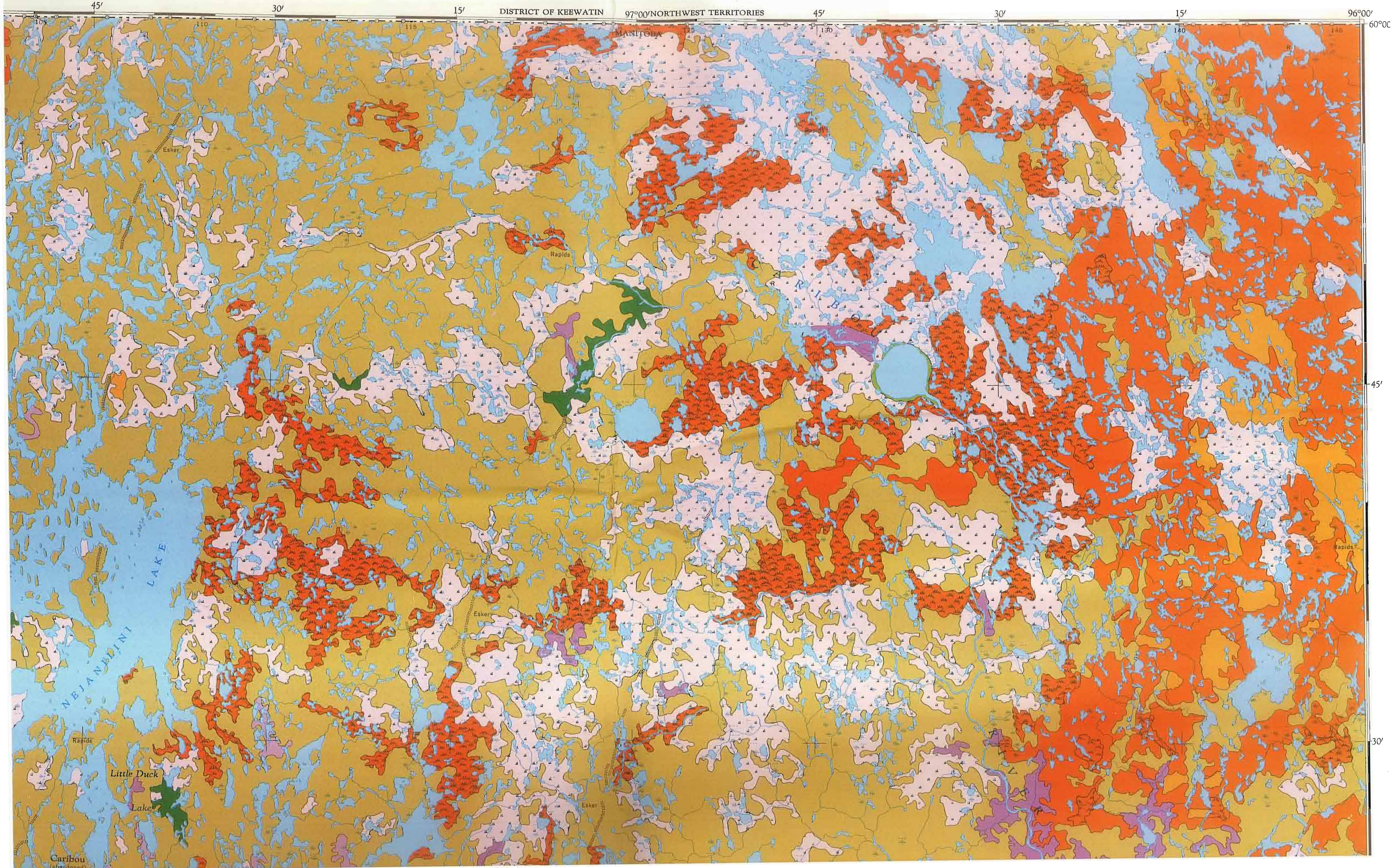
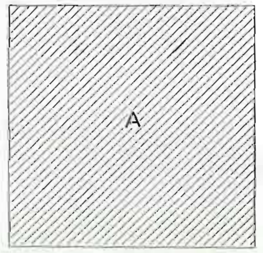
EDITION 1


98°00′
60°00′
45′
30′
15′
DISTRICT OF KEEWATIN
97°00′ NORTHWEST TERRITORIES
MANITOBA
45′
30′
Baralzon
Lake
Esker
Rapids
NEJANELINI LAKE
1103
Little Duck
Lake
Caribou


45′
30′
15′
DISTRICT OF KEEWATIN
97°00′
NORTHWEST TERRITORIES
MANITOBA
45′
30′
15′
96°00′
60°00′
45′
30′
Esker
Rapids
NEJANILINI
LAKE
Little Duck
Lake
Caribou

RELIABILITY DIAGRAM - CROQUIS D'EXACTITUDE



A - Stereo-compiled from 1955 - 1957 aerial photographs.
Établie par Stéréo restitution d'après des photos aériennes prises en 1955-1957.

Compiled 1962, by the SURVEYS AND MAPPING BRANCH, DEPARTMENT OF MINES AND TECHNICAL SURVEYS. Horizontal and vertical control 1959. Printed 1964.

Magnetic declination 1964 varies from 11°34′ easterly at centre of west edge to 07°41′ easterly at centre of east edge. Mean annual change: 1.8′ easterly.

Road, dry weather......Route, temps sec	
Wagon or winter road. Chemin de terre ou d'hiver	
Trail or portage........Sentier ou portage	
Town......Ville	□
Village or Settlement. Village ou hameau	o
Post Office.......Bureau de poste	P
Horizontal control point. Point géodésique	△
Boundary monument. Borne frontière	▫

NEJANILINI LAKE

MANITOBA

Scale 1:250,000 Échelle

Miles 5 0 5 10 15 Milles

Kilometres 5 0 5 10 15 20 Kilomètres

Transverse Mercator Projection
North American Datum 1927 (1956)
Contour Interval 100 feet
Elevations in feet above Mean Sea Level

Projection Transverse de Mercator
Niveau de référence nord-américain, 1927 (1956)
Équidistance des courbes: 100 pieds
Élévations en pieds au-dessus du niveau moyen de la mer

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Ces cartes sont en vente au Bureau de distribution des cartes, ministère des Mines et des Relevés techniques, Ottawa.

Rédigée en 1962 par la DIRECTION DES LEVÉS ET DE LA CARTOGRAPHIE, MINISTÈRE DES MINES ET DES RELEVÉS TECHNIQUES. Canevas planimétrique et altimétrique 1959. Imprimée en 1964.

La déclinaison magnétique pour 1964 varie de 11°34′ Est au centre de la limite Ouest à 07°41′ Est au centre de la limite Est. Variation moyenne annuelle: 1.8′ Est.

Stream	Cours d'eau
intermittent or dry	intermittent ou à sec
indefinite	imprécis
Rapids; falls	Rapides; chute
Marsh or swamp	Marais ou marécage
Intermittent lake	Lac intermittent
Depression contours	Courbes de cuvette
Spot Elevation, in feet	Repère de nivellement en pieds.....2550

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MANITOBA

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Road, dry weather......Route, temps sec..............

Wagon or winter road. Chemin de terre ou d'hiver......

Trail or portage........Sentier ou portage..............

Town.....................Ville...

Village or Settlement. Village ou hameau.............................

Post Office.............Bureau de poste...............................P

Horizontal control point. Point géodésique..............................△

Boundary monument.. Borne frontière...................................

Scale 1:250,000 Échelle

Miles 5 0 5 10 15 Milles

Kilometres 5 0 5 10 15 20 Kilomètres

Transverse Mercator Projection
North American Datum 1927 (1956)
Contour Interval 100 feet
Elevations in feet above Mean Sea Level

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Niveau de référence nord-américain, 1927 (1956)
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Stream / Cours d'eau

intermittent or dry......intermittent ou à sec........

indefinite.................imprécis.........................

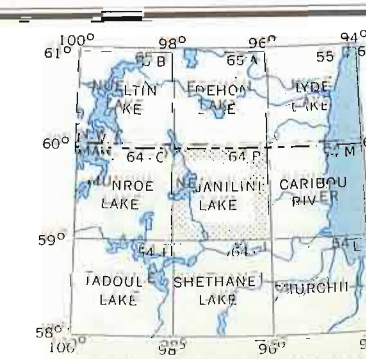
Rapids; falls.............Rapides; chute..............

Marsh or swamp.........Marais ou marécage............

Intermittent lake........Lac intermittent.................

Depression contours...Courbes de cuvette..............

Spot Elevation, in feet..Repère de nivellement en pieds.....2550.



Index to adjoining sheets of National Topographic System

Tableau d'assemblage du Système National de Référence Cartographique

VEGETATION COVER
Barren-ground Caribou Winter Range

SUBARCTIC FOREST

Upland Closed Spruce Forest
Occurs on moderately drained summits and upper slopes. Black spruce (*Picea mariana*) is the dominant tree. Density of forest canopy is > 50%.*
Arboreal lichens (*Usnea* spp., *Alectoria* spp.) are abundant.
Shrub stratum(speckled alder, *Alnus crispa*) is sparse.**
Field stratum(labrador tea, *Ledum groenlandicum*· bilberry, *Vaccinium uliginosum;* rock cranberry, *V. vitis-idaea*) is abundant.
Ground stratum(lichens, *Cladonia alpestris, C. Mitis, C. rangiferina;* and mosses, *Pleurosium* spp., *Sphagnum* spp.) is very abundant.

Upland Open Spruce Forest
Occurs on well drained summits and upper slopes. Black spruce is the dominant tree. Density of forest canopy is 15-50% Arboreal lichens (*Usnea* spp., *Alectoria* spp.) are sparse.
Shrub stratum (speckled alder, *Alnus crispa;* birch, *Betula glandulosa, B. occidentalis*) is sparse.
Field stratum (rock cranberry, *V. Vitis-idaea;* bilberry, *V. uliginosum;* crowberry *Empetrum nigrum*) is abundant.
Ground stratum (lichens, *C. alpestris, C. rangiferina, C. mitis*) is very abundant.

Upland Open Spruce-Lichen Forest
Occurs on well drained eskers as well as summits and upper slopes. Black spruce is the dominant tree with a rare association of birch (*Betula papyrifera*). Density of forest canopy is <15%. Arboreal lichens (*Usnea* spp., *Alectoria* spp.) are sparse.
Shrub stratum (birch, *B. glandulosa, B. occidentalis*) is rare.
Field stratum (rock cranberry, *V. Vitis-idaea;* bilberry, *V. uliginosum;* labrador tea, *L. groenlandicum;* crowberry, *E. nigrum*) is abundant.
Ground stratum (lichens, *C. alpestris, C. mitis, C. rangiferina*) is very abundant.
Open patches of sand and till are frequently found.

Upland Open Birch
Occurs on well drained sandy eskers and upper slopes. Paper birch (*B. papyrifera*) is the dominant tree. Density of forest canopy is 25-50%.
Shrub stratum (birch, *B. glandulosa, B. occidentalis*) is abundant.
Field stratum (common bearberry, *Arctostaphylos uva-ursi;* blueberry, *V. myrtilloides;* bilberry, *V. uliginosum;* rock cranberry, *V. vitis-idaea;*) is sparse.
Ground stratum (lichens, *C. alpestris, C. rangiferina, C. mitis*) is very abundant.
Cover type is found only in the extreme southeastern corner of Tadoule Lake (64J) map sheet.

Lowland Closed Spruce Forest
Occurs on imperfectly to poorly drained gentle slopes. Black spruce is the dominant tree. Density of forest canopy is >40% Arboreal lichens (*Alectoria* spp.) are abundant.
Shrub stratum (birch, *B. glandulosa,* willow, *Salix* spp.) is sparse.
Field stratum (labrador tea, *L. groenlandicum;* bilberry, *V. uliginosum*) is very abundant.
Ground stratum (mosses, *Sphagnum* spp., *Pleurosium* spp.) is very abundant.

Lowland Open Spruce Forest
Occurs on poorly drained to saturated flat peatlands. Black spruce is the dominant tree with a rare association of tamarack (*Larix laricina*). Density of forest canopy is 15-40%. Arboreal lichens (*Alectoria* spp.) are abundant.
Shrub stratum (birch, *B. glandulosa;* speckled alder, *A. rugosa;* willow, *Salix* spp.) is sparse.
Field stratum (labrador tea, *L. groenlandicum;* bilberry, *V. uliginosum;* bog apple, *Rubus chamaeomorous*) is very abundant.
Ground stratum (mosses, *Sphagnum* spp.) is very abundant.

Fens
Occurs on saturated peatlands in water filled depressions. Black spruce and tamarack are the dominant trees. Density of forest canopy is <15%.
Shrub stratum (birch, *B. nana;* willow, *Salix* spp.) is abundant.
Field stratum (leather leaf, *Chamaedaphne calyculata;* bog laurel, *Kalmia polifolia;* bilberry, *V. uliginosum;* sedges, *Carex* spp.) is very abundant.
Ground stratum (mosses, *Sphagnum* spp.) is very abundant.

SUBARCTIC FOREST-TUNDRA TRANSITION

Upland Lichen Heath
Occurs on well drained summits and upper slopes. Black spruce is the dominant tree. Density of forest canopy is <5%.
Shrub stratum (birch, *B. nana*) is rare.
Field stratum (*L. decumbens;* rock cranberry, *V. vitis-idaea; V. uliginosum* var. *alpinum;* crowberry, *E. nigrum*) is very abundant.
Ground stratum (lichens, *C. alpestris, C. mitis, Cetraria nivalis*) is very abundant.

Upland Heath Complex
Occurs on moderately drained summits and upper slopes. Black spruce is the dominant tree. Density of forest canopy is < 5%.
Shrub stratum (birch, *B. nana*) is sparse.
Field stratum (*L. decumbens;* rock cranberry, *V. vitis-idaea; V. uliginosum* var. *alpinum;* crowberry, *E. nigrum*) is abundant.
Ground stratum (lichens, *C. alpestris, C. mitis, Cetraria nivalis*) is abundant.
Boulders, till and sand patches are frequently found here.

Rock Barrens
Occurs on well drained summits and upper slopes. Trees are not found in these areas.
Shrub stratum (birch, *B. nana*) is rare.
Field stratum (*V. uliginosum* var. *alpinum;* rock cranberry, *V. vitis-idaea; L. decumbens;* crowberry, *E. nigrum*) is sparse.
Ground stratum (lichens, *C. rangiferina, Cetraria* spp.) is sparse. These areas are characterized by an overwhelming amount of boulders, stones and exposed till.

Lowland Sedge/Cottongrass
Occurs on poorly drained to saturated peatlands. Black spruce is the dominant tree. Density of forest canopy is < 5%.
Shrub stratum (birch, *B. nana*) is rare.
Field stratum (bog laurel, *Kalmia polifolia; L. decumbens;* sedges, *carex* spp.; cottongrass, *Eriophorum angustifolium*) is very abundant.
Ground stratum (mosses, *Sphagnum* spp.) is very abundant.

Lowland Heath Complex
Occurs on poorly drained flat peatlands. Black spruce is the dominant tree. Density of forest canopy is < 5%.
Shrub stratum (birch, *B. nana*) is rare.
Field stratum (*L. decumbens;* bog laurel, *K. polifolia;* billberry, *V. uliginosum*) is very abundant.
Ground stratum (mosses, *Sphagnum* spp., lichens, *C. alpestris, C. mitis*) is very abundant.

BURNS

Recent Burn

Any burn which took place between Spring 1977 and fall 1980. Regenerative activity is not readily apparent. Forest canopy has been destroyed by fire and all that remains are standing deadwood and scorched trees.
Shrub stratum has been destroyed and all that remains are charred above-ground stems.
Field stratum has been destroyed, although fireweed (*Epilobium angustifolium*) may be found.
Ground stratum has been burned and all that remains are charred peatlands, burned vegetative matter and exposed till.

Revegetated Burn

Forest canopy has been destroyed and only standing deadwood and scorched trees remain. Black spruce is the dominant tree regeneration. Black spruce seedlings are less than 30 cm tall.
Shrub stratum (speckled alder, *A. rugosa*) is rare.
Field stratum (labrador tea, *L. groenlandicum;* bilberry, *V. uliginosum*; fireweed, *E. angustifolium*) is sparse.
Ground stratum (mosses, *Polytrichum* spp., *Dicranum* spp., *Bryum* spp.) is sparse.
Between 50 and 75% of the ground is burned peatland or exposed sand and till.

Revegetated Burn with Residual Forest

Patches of unburned forest, usually ± 100 hectares, remain standing. Standing deadwood and scorched trees are found in the burned areas. Black spruce is the dominant tree regeneration. Black spruce seedlings are less than 30 cm tal
Birch (*B. papyrifera*) exhibits suckering.
Shrub stratum (speckled alder, *A. rugosa*) is rare.
Field stratum (labrador tea, *L. groenlandicum;* bilberry, *V. uliginosum;* sedges, *Carex* spp.; fireweed, *E. angustifolium*) is abundant.
Ground stratum (mosses, *Polytrichum* spp., *Dicranum* spp., *Bryum* spp.) is sparse.

VEGETATION STRATA DEFINED

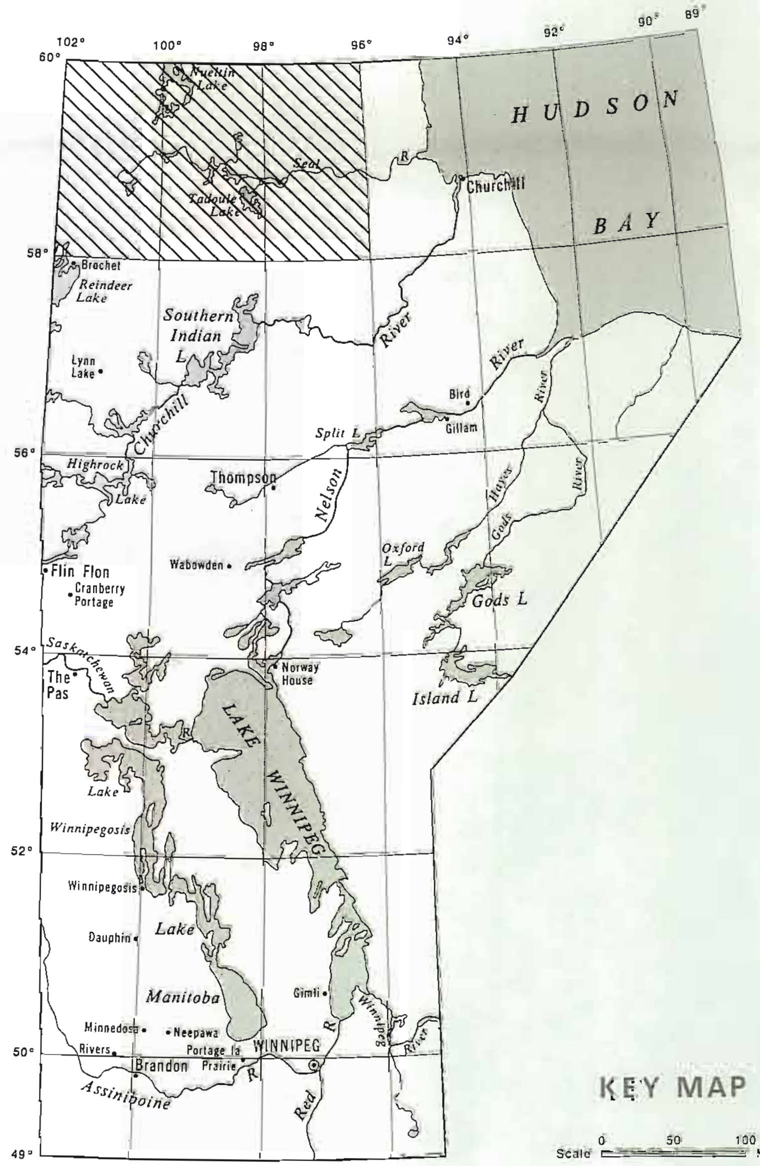
Forest Canopy:	The coverage of branches and foliage formed by tree crowns.
Shrub Stratum:	Shrubs and saplings which exceed 75 cm in height and would be considered as an element of the supranivian (above snow cover) environment.
Field Stratum:	Includes ericaceaous shrubs, herbaceous plants, and sedges which do not exceed 75 cm in height and would be considered as elements of the subnivian (below snow cover) environment.
Ground Stratum:	Lichens and / or mosses.

VEGETATION ABUNDANCE DEFINED

Only the most abundant plants of each vegetation strata are listed. Abundance is determined by the cover and the frequency with which a plant may be expected to occur in each vegetation cover class (i.e. Upland Closed Spruce Forest).
The cover-abundance categories are as follows:

Cover Abundance	Area of Cover	Frequency
Very Abundant	>50%	>75%
Abundant	25-50%	50-75%
Sparse	10-25%	25-50%
Rare	<10%	<25%

For example, in the Upland Closed Spruce Forest the field stratum is sparse. The most abundant plants of this stratum are *L. groenlandicum, V. uliginosum* and *V. vitis-idaea.* Their combined density is 10-25% and the frequency with which they will occur is 25-50%.



KEY MAP

Scale 0 50 100 Miles

Cartography by Surveys&Mapping Branch, Manitoba 1981
Remote Sensing Data supplied by The Manitoba Remote Sensing Centre
Project funded under The Canada-Manitoba Northlands Agreement

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