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THOR LAKE AREA (NWT) ENVIRONMENTAL BASELINE SURVEY

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for

SENES Consultants Limited

by

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CHEMICAL ELEMENTS

actinium	(Ac)
aluminum	(Al)
americium	(Am)
antimony	(Sb)
argon	(Ar)
arsenic	(As)
astatine	(At)
barium	(Ba)
berkelium	(Bk)
beryllium	(Be)
bismuth	(Bi)
boron	(B)
bromine	(Br)
cadmium	(Cd)
calcium	(Ca)
californium	(Cf)
carbon	(C)
cerium	(Ce)
cesium	(Cs)
chlorine	(Cl)
chromium	(Cr)
cobalt	(Co)
copper	(Cu)
curium	(Cm)
dysprosium	(Dy)
einsteinium	(Es)
erbium	(Er)
europium	(Eu)
fermium	(Fm)
fluorine	(F)
francium	(Fr)
gadolinium	(Gd)
gallium	(Ga)
germanium	(Ge)
gold	(Au)
hafnium	(Hf)
helium	(He)
holmium	(Ho)
hydrogen	(H)
indium	(In)
iodine	(I)
iridium	(Ir)
iron	(Fe)
krypton	(Kr)
lanthanum	(La)
lawrencium	(Lr)
lead	(Pb)
lithium	(Li)
lutetium	(Lu)
magnesium	(Mg)
manganese	(Mn)
mendelevium	(Md)
mercury	(Hg)
molybdenum	(Mo)
neodymium	(Nd)
neon	(Ne)
neptunium	(Np)
nickel	(Ni)
niobium	(Nb)
nitrogen	(N)
nobelium	(No)
osmium	(Os)
oxygen	(O)
palladium	(Pd)
phosphorous	(P)
platinum	(Pt)
plutonium	(Pu)
polonium	(Po)
potassium	(K)
praseodymium	(Pr)
promethium	(Pm)
protactinium	(Pa)
radium	(Ra)
radon	(Rn)
rhenium	(Re)
rhodium	(Rh)
rubidium	(Rb)
ruthenium	(Ru)
samarium	(Sm)
scandium	(Sc)
selenium	(Se)
silicon	(Si)
silver	(Ag)
sodium	(Na)
strontium	(Sr)
sulphur	(S)
tantalum	(Ta)
technetium	(Tc)
tellurium	(Te)
terbium	(Tb)
thallium	(Tl)
thorium	(Th)
thulium	(Tm)
tin	(Sn)
titanium	(Ti)
tungsten	(W)
unnilhexium	
unnilpentium	(Unp)
unnilquadium	(Unq)
uranium	(U)
vanadium	(V)
xenon	(Xe)
ytterbium	(Yb)
yttrium	(Y)
zinc	(Zn)
zirconium	(Zr)

1 SUMMARY

This environmental baseline survey was undertaken in September, 1988, in response to a request from Senes Consultants Ltd., regarding the development of the Thor Lake Joint Venture ore body. The Thor Lake project is located approximately 100 km east-southeast of Yellowknife, near the north shore of Great Slave Lake, NWT. Beryllium (Be) and rare earth elements are found in the ore deposits targeted for mining. The proposed mine is relatively small in size.

Aquatic Studies

From an aquatic aspect, the two objectives of greatest immediate interest are characterization of the water quality and large-fish populations in lakes in close proximity to the mine development site. Other aquatic components considered include lake morphometrics, interlake surface water improvements, phytoplankton biomasses and arthropod zooplankton communities. Additional work will be carried out in 1989.

There are four watersheds of concern in this study. The first involves drainage from small Cressy Lake, the prospective tailings disposal area. Fred Lake, Fred Stream and Lake "A" are situated in this watershed. The second is the watershed downstream from Den Lake, which begins adjacent to both the intended open pit and waste rock dump. "B" Lake and others occur below Den Lake; drainage from this watershed enters large Blachford Lake to the north. A third watershed consists of Thor Lake and many smaller water bodies which drain into it. Thor Lake is one of the two largest lakes in close proximity to the mine development area. Ring Lake, the proposed alternate tailings area, is part of this watershed. The other larger lake is Elbow, the fourth "watershed." Elbow Lake is the lake to which Thor Lake is compared.

Thor and Elbow Lakes are generally similar in terms of their small sizes. However, the mean depth of Elbow Lake is twice that of Thor Lake, because Elbow has a deep north basin. Thus, the volume of Elbow Lake is approximately double the volume of Thor Lake. The other four study lakes (Cressy, Ring, A, B) have very small surface areas, much smaller than the areas of Thor and Elbow Lakes. Cressy and A Lakes are relatively deep for their surface areas. Ring and B Lakes are very shallow, and undoubtedly freeze to the bottom in many years.

Lake A develops a pronounced thermocline (thermo-density gradient with depth), while Elbow Lake appears to develop a thermocline as well. Ring and B Lakes are far too shallow to develop thermoclines; Thor and Cressy Lakes are probably too shallow as well.

O_2 concentrations in the upper waters of all lakes were near saturation. Concentrations were low only near lake bottoms, or below thermoclines where they occurred. All lake waters were moderately hard to hard, and moderately well to well buffered. Trace element and radionuclide concentrations were generally low to very low. They were often below detection limits and Canadian guidelines for aquatic life, where guidelines exist.

A very low rate of discharge was obtained for tiny Fred Stream. No flowing water was observed immediately below Cressy, Ring and B Lakes. Continuous peatland made up shorelines where one could otherwise expect outflow from these lakes; the same was true of Elbow Lake. No open water occurred in the peatland between Cressy and Fred Lakes. This area was investigated on foot.

Chlorophyll a concentrations suggest that Cressy Lake is eutrophic (nutrient rich), Thor Lake is mesotrophic and the other lakes are oligotrophic (nutrient poor).

Each of the study lakes contains one of two basic arthropod zooplankton community types. The communities in Cressy, Ring and B Lakes are characterized by large-bodied zooplankters, while small-bodied zooplankters predominate in Thor, Elbow and A Lakes. The difference between the two types can be attributed largely to a difference in the degree of fish predation. The presence of the copepod Limnocalanus macrurus, a glacial opportunist (found in glacial remnant systems) in Elbow and A Lakes is noteworthy.

The large-fish species were lake whitefish, cisco and northern pike in Thor and Elbow Lakes. No large fish were caught in Cressy Lake with intensive fishing. It may be referred to as fishless. When ice covered, this little lake could be devoid of O_2 in some years; this winterkill characteristic, plus isolation which prevents immigration, would explain the absence of fish there. Tiny Ring and B Lakes also appear fishless. However, Lake A may contain fish, although this possibility is yet to be confirmed.

Large fish in Thor Lake were much more abundant, in terms of biomass and numbers, than in Elbow Lake. These results are explained by the fact that Thor Lake is a warmer, more nutrient rich system than Elbow Lake. Whitefish made up two thirds to three quarters of the catch, while pike made up most of the remainder.

Large-fish populations were made up primarily of larger individuals within narrow size ranges. There were very few older juvenile whitefish and pike. The populations are typical of the pattern predominant in unexplained arctic and subarctic large-fish populations.

Large-fish in Elbow Lake grew at greater rates, in terms of biomass accumulation, than did large-fish in Thor Lake. These results suggest that more intraspecific competition occurs in Thor Lake than in Elbow Lake.

Data on reproductive condition suggest that not all mature whitefish in Thor and Elbow Lakes spawn, or reproduce, every year.

Analyses of flesh and bone from Thor Lake whitefish and pike indicate that most trace elements and radionuclides are below the limits of detection.

The lakes in the Thor Lake area are generally similar to many lakes near Yellowknife, NWT, in terms of all the components studied.

2 Terrestrial Plant Studies

From the aspect of terrestrial plants, the objectives are to: 1) characterize the vegetation communities and prepare a biophysical map, 2) identify the presence of rare plants in the development area, and 3) describe the elements found in a representative lichen of the region. The biophysical map is important for identifying wildlife habitats and sensitive areas for wildlife. A survey for rare plants is necessary for the purpose of protecting sites that may be important for the maintenance of a species. Lichens largely derive their nutrients from the air and, therefore, are useful for monitoring fine particulates which are emitted to the atmosphere, and then settle out.

Three species of plants of restricted range in the Northwest Territories were identified near Thor Lake: Prunus pennsylvanica, Chamaerhodos erecta and Campanula rotundifolia. All are species occurring at the northern edge of their ranges; none are endemic to the NWT. They occurred in areas with warm micro and local climates. Prunus pennsylvanica and Campanula rotundifolia may be widespread on suitable rock outcrops along the shore of Great Slave Lake. Chamaerhodos erecta is an inconspicuous species and may be easily missed in plant surveys. Thus its occurrence may be understated in collections from the area, particularly from crumbly rock substrates.

Elevated concentrations of some elements of interest (Ce, also La, Nd and Sm) occurred in the Cladina samples collected at the Den Lake site, nearest the ore deposit. These levels may occur naturally because of proximity to the ore body. Anthropogenic causes of elevated element levels cannot be ruled out because of the exploration activity. Concentrations of other elements, including radionuclides, were comparable to data in the literature.

Upon decommissioning of the mine site, caution must be taken to prevent mixing of mine rock wastes with replaced soils, or problems with reestablishing vegetation could occur. Beryllium is known to inhibit germination of seeds and the uptake of Ca and Mg by roots.

A mapped biophysical classification is arrived at, based on the vegetation, landforms and soils in the Thor Lake area. Eight vegetation communities are delineated, based on a field survey. The soils are described based largely on available literature but in combination with observations made in the field and from air photos. Seven biophysical units are described.

Wildlife Studies

The purpose of the wildlife study is to characterize the wildlife potential of the Thor Lake mine lease. Investigations completed to date include aerial surveys for active beaver lodges and fall waterfowl. Studies to be completed include winter ungulate and spring raptor aerial surveys.

The region to the immediate west of the mine lease appears more attractive to beaver, with over 200% more lodges observed. The large number of inactive lodges there compared to the mine lease area also suggests that the habitat supports a more dynamic population with greater fluctuations. No suitable shallow water bodies or other features were observed during the survey which would indicate muskrat activity.

The distribution of waterfowl was not uniform, as twice as many birds were observed to the west of the mine lease area.

The habitats within the mine lease could support diverse resident wildlife. However, a more detailed assessment must wait until surveys for ungulates and raptors have been completed.

Archaeology Studies

The objectives of the archaeology study were to: 1) review the relevant literature, 2) examine, on foot, areas which might have been used as campsites, whether in the historic period in precontact times, 3) record the locations of archaeological sites discovered, 4) record the characteristics of sites found, and 5) recover samples of exposed artifacts. The study location consisted of, primarily, areas to be affected by construction, as well as ones where disturbances had already occurred.

The north shore of Great Slave Lake immediately south of Thor Lake is of special archaeological interest. There are few protected locations conducive to camping along the shore because it is marked by sudden relief. The beach and point of land, marking the start of the road from Great Slave Lake to Thor Lake, could have provided one of few accessible camp spots in this section of shoreline.

Three sites were recorded. The Reg Site (KaPb-4) consists of prehistoric and recent material found at the docking area and adjacent road at Great Slave Lake. Four artifacts were collected; three white quartz biface fragments and one bone hide flesher. The biface fragments were from about 200 to 1500 years old, based on the distances between the current shoreline and the locations where the artifacts were found. The hide flesher, made from a large ungulate bone, is probably of recent vintage.

The second, or Lori site (KaPb-3), is a prehistoric lithic debitage scatter on the crest of the high ridge south of Den Lake and east of the mine site. The Strathcona site (KaPb-2) is the disused diamond-drilling exploration camp at the west end of Thor Lake.

The Reg site on Great Slave Lake seems to have been seldom used, perhaps because it lies half way between McKinley Point to the east and the mouth of the Francois River to the west. These latter landmarks are within a day's travel of each other. It was not expected that material would be found at the mine site, since it is situated on low-lying ground. People probably made little use of the area because there were excellent access routes into the interior by means of the nearby Francois and Beaulieu Rivers.

No further work is recommended at the Reg site, Great Slave Lake, because of the sparsity of artifacts. However, since cultural materials were found under the lichen cover on the north half of the beach, this area should be avoided by future development. Any further development should be placed in the south half of the beach, where development has already taken place.

2 GENERAL INTRODUCTION

This environmental baseline survey was undertaken in response to a request from Senes Consultants Ltd., regarding the development of the Thor Lake Joint Venture ore body. The Thor Lake project is located approximately 100 km east-southeast of Yellowknife, near the north shore of Great Slave Lake, NWT. Access to the property is by float or ski plane, and barge or winter road on Great Slave Lake. Eight kilometres of road connect Great Slave Lake and the site of the proposed mine.

Beryllium (Be) and rare earth elements are found in the ore deposits targeted for mining, part of the Blachford Lake alkaline complex. Syenites, granites and various phases of these rocks, including pegmatites, comprise the principal rock types. The geology of the area is Precambrian, of the Aphebian age.

The proposed mine site is relatively small in size, and will include: a small open pit mine, ore stock piles, waste rock piles, concentrator, effluent monitoring ponds and a tailings disposal site. A 520 m test adit exists, established for bulk ore sampling. The road to Great Slave Lake must also be considered in an environmental survey.

This report is organized into sections dealing with studies of aquatic environments (abiotic and biotic), terrestrial plants, wildlife and archaeology in the Thor Lake area. Specific objectives are outlined under major section headings.

3 AQUATIC STUDIES

3.1 Introduction

3.1.1 Objectives

The two objectives of greatest immediate interest are characterization of the water quality and large-fish populations in lakes in close proximity to the mine development site. Uncontaminated water is essential to the good health of life, while large fish are an important human food source.

Other aquatic components are also considered. These include lake morphometrics, interlake surface water movements, phytoplankton biomasses and arthropod zooplankton communities. Lake morphometrics are essential to the understanding of biological productivity in lakes. Phytoplankton constitute part of the base of an aquatic food web, while zooplankton are an intermediate link. Many crustacean zooplankton eat phytoplankton, and in turn are eaten by very young and small fish. Additional studies are to be carried out in 1989 (Melville et al. 1988).

Recent data for lakes near Yellowknife (e.g., Ostrofsky and Rigler 1987) provide a basis for comparison with all aspects of this study.

3.1.2 Objectives in Relation to Study Area

There are four watersheds of concern in this study (Figure 3.1). The first involves drainage from small Cressy Lake, the prospective tailings disposal area. The second is the watershed downstream from Den Lake, which begins adjacent to both the intended open pit and waste rock dump. A third watershed consists of Thor Lake and many smaller water bodies which drain into it. Thor Lake is one of the two largest lakes in close proximity to the mine development area. Ring Lake, the propos-

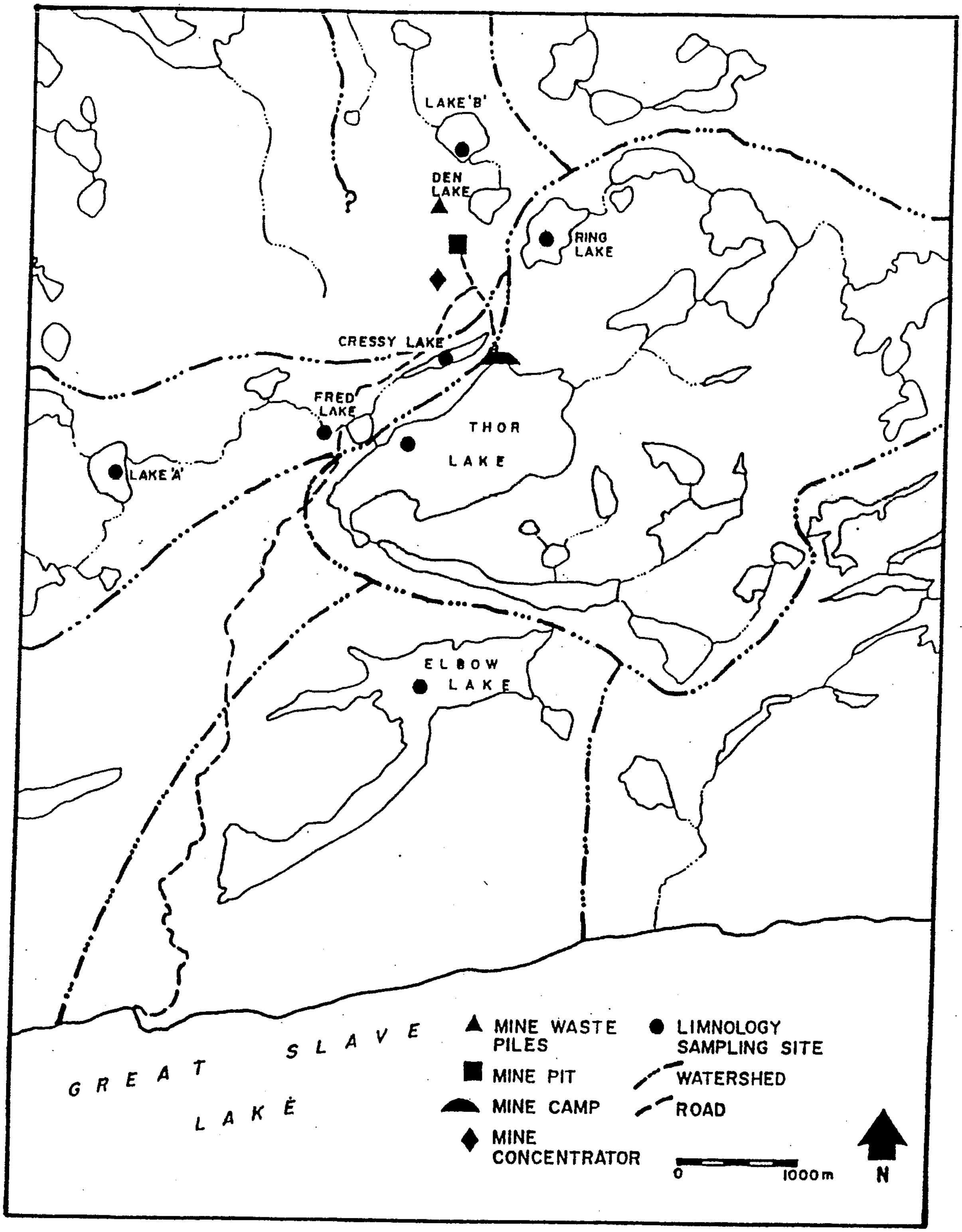


Figure 3.1 Map of the Watersheds in the Thor Lake Area. Major Proposed Mine Installations and Limnology Sampling Sites are Included. Camp and Roads are Already in Place.

ed alternate tailings area, is part of this watershed. The other larger lake is Elbow, the fourth "watershed." Water from Elbow Lake seeps into Great Slave Lake over a distance of 1.1 km.

3.1.2.1 Cressy Lake Drainage

Water from Cressy Lake seeps southwest through peatlands into tiny Fred Lake, 0.4 km away (Figure 3.1). From Fred Lake, the water moves west through small Fred Stream and extensive peatlands into another small lake, "A". Beyond Lake A, the water travels southwest through many small lakes and peatlands, and eventually into Great Slave Lake.

Material to be discharged into the tailings disposal area will include treated tailings, discharge from the concentrator and excess mine drainage which cannot be used in the concentrator. Therefore, description of the water quality in the path of drainage from Cressy Lake, prior to the discharge of tailings, is a prime consideration in this study.

3.1.2.2 Thor Lake Inflow System

The water quality objective applies to Thor Lake, which is downstream of Ring Lake (Figure 3.1), the alternate tailings disposal area. Thor Lake also abuts the mining camp area. This lake is big enough to have substantial large-fish populations, so characterization of such populations, and a description of the elemental composition of key species, are of immediate interest as well. Elbow Lake was chosen as a reference for Thor Lake.

3.1.2.3 Watershed Below Den Lake

In addition, the water quality downstream from Den Lake (Figure 3.1) is described. This watershed contains the rock waste piles, in addition to the open pit and ore storage piles. The system could receive runoff from these features. The four lakes in the system are very small, but they lead to large Blachford Lake.

All lakes in the watershed are separated by peatlands.

3.1.3 Limnology Sampling Sites

Seven sites were selected, six lakes and one stream.

3.1.3.1 Cressy Lake Drainage

Three sampling sites were chosen (Figure 3.1): Cressy Lake, Fred Stream just downstream of Fred Lake, and Lake A. The Fred Stream site is close to the area where water seeps through from Cressy Lake. The Cressy water is diluted in Fred Lake by inflow from Thor Lake. Lake A provides an indication of the overall quality of the water downstream of the proposed tailings.

3.1.3.2 Thor Lake Inflow System

Two sites were chosen in this system, Ring and Thor Lakes (Figure 3.1). The Thor Lake water quality site is adjacent to the point of outflow into Fred Lake. This site provides an indication of the quality of the "dilution" water, which will mix with water in the area of Fred Lake where tailings water will seep through from Cressy Lake. A third sampling site was selected outside the Thor Lake drainage system, on Elbow Lake, for comparison with Thor Lake.

3.1.3.3 Watershed Below Den Lake

A single site, Lake "B" adjacent to Den Lake, was selected in this watershed. Both of these tiny lakes could receive runoff directly from the waste rock piles, ore storage piles and the periphery of the open pit mine. Lake B also receives seepage from Den Lake.

3.2 Methods

All fieldwork was done in September 1988.

3.2.1 Abiotic

3.2.1.1 Lake Morphometry

Depth profiles on almost 40 transects were obtained for Elbow Lake. The lake was sounded using a Furuno F21 echo sounder, mounted in a motorized canoe driven at constant speed. Several hand-line soundings were made in all study lakes.

Elbow Lake depth profiles were transferred to an outline lake map of known scale. A bathymetric map was then produced, by determining depth contours from the sounding profiles.

Bathymetric maps of Thor, Cressy and Ring Lakes were obtained from Strathcona Mineral Services Limited by way of Senes Consultants Limited. Lake morphometry variables were calculated from the bathymetric maps.

3.2.1.2 Temperature and Water Quality

In situ measurements included temperature, oxygen (O_2), and conductivity profiles. These were obtained using commercial electronic meters. Transparency data for lakes were obtained using a Secchi disc.

Grab samples were taken of surface waters (ca. 1.0 m), while bottom waters in deeper lakes were sampled with a Kemnerer bottle. pH and alkalinity measurements were made in the field, by meter and titration (APHA 1975) respectively. Water for laboratory analyses were treated according to methods specified by the SRC analytical laboratory (1988). The SRC laboratory analyzed the samples for solids, major ions, micro-nutrients, trace elements and radionuclides.

3.2.1.3 Stream Flow

Depths and current speeds were measured at 0.1 m intervals in Fred Stream, just downstream of the road between the mine site and Great Slave Lake. A discharge rate was calculated from these data. The composition of the stream bed was also noted.

A stream gauge was installed and surveyed at the sampling site.

3.2.2 Biotic

3.2.2.1 Phytoplankton

Chlorophyll samples were taken as indicators of phytoplankton biomass in lakes. Untreated portions of the water quality samples were filtered by hand-operated suction pump, and the (Whatman GF/C) filters, with algae, preserved in methanol. Samples were refrigerated until they could be processed further.

In the laboratory, filters were removed, and sample absorbances at 650, 665 and 750 nm read on a spectrophotometer. Absorbance data were then converted to equivalent concentrations of chlorophyll.

3.2.2.2 Zooplankton

Zooplankton samples were taken with a 0.25 m diameter Wisconsin net fitted with No. 20 mesh. Duplicate total vertical lifts were taken at water quality sampling sites. Zooplankton were preserved in about 10% formalin.

Arthropod zooplankton were processed by microscope and identified to species, using Edmondson (1959), Pennak (1978) and Johannsen (1970). Abundance estimates of these zooplankters, and of rotifers grouped together, were also made. Samples were diluted and subsampled for the abundance counts, with the degree of dilution varying according to the size and density of the taxon involved. The efficiency of the sampling net was not considered.

3.2.2.3 Fish

Large-fish populations in Thor and Elbow Lakes were sampled with Rawson standard gang gillnets. One gang consists of six, 46 m nylon mesh panels connected in series. The panel mesh sizes are 38, 51, 76, 102, 127 and 140 mm respectively. Two net sets were placed in Thor Lake, one in Elbow. Two "half standard" gang net sets were carried out in Cressy Lake. Each panel in a half standard gang is 23 m long. All gang net sets were left in the water for 24 hours.

Single gill net pieces of two different mesh sizes were placed in Ring Lake for 48 hours. Four such nets were set in Thor Lake as well, prior to gang gillnetting, in order to make a preliminary assessment of the reproductive condition of whitefish. These nets were left in the water overnight.

The gill net panel length(s), mesh size(s) and duration of each net set varied according to lake morphometry. Figure 3.5 illustrates net set locations.

Fish caught were processed according to species and mesh size. Fork length and wet weight measurements of all individuals were collected in the field. Aging materials taken included otoliths for whitefish and cleithra for pike. Scales were taken for all ciscoes, and for many pike and whitefish. Sex and reproductive condition were determined for all fish. Stomach contents were enumerated according to major taxonomic groupings.

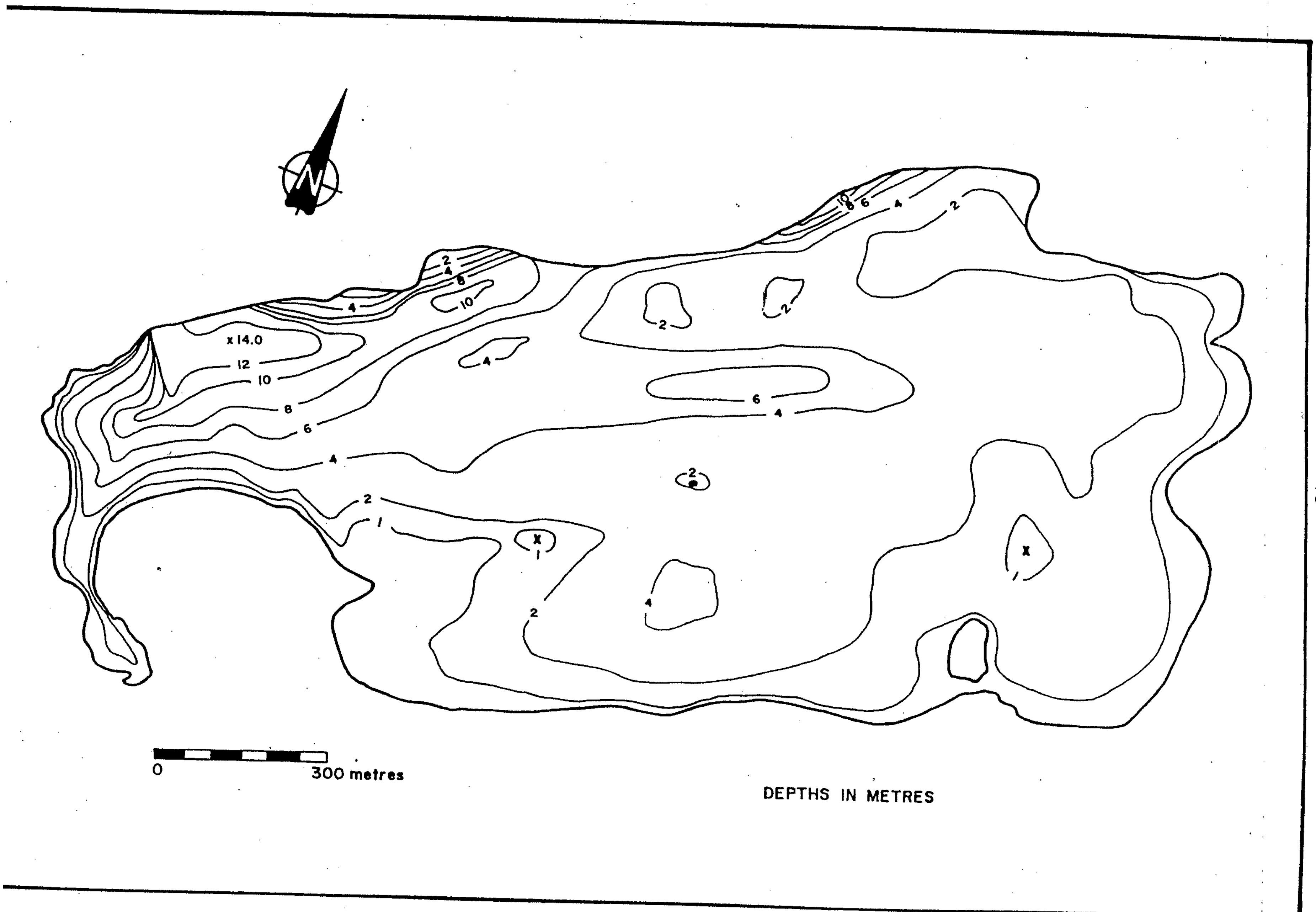
Some large fish from Thor Lake were kept for elemental analyses of tissues. Field preparations consisted of wiping the fish with paper towels, eviscerating them, then wiping the body cavities. Lengths and weights were recorded. Fish were frozen, one per plastic bag, and kept as such until they could be processed further in the SRC analytical laboratory.

3.3 Results and Discussion

3.3.1 Abiotic

3.3.1.1 Lake Morphometry

Thor and Elbow Lakes (Figures 3.2, 3.3) are generally similar in terms of size, although there are some noteworthy differences (Table 3.1). The mean depth of Elbow Lake is twice that of Thor Lake, because Elbow has a deep north basin. Thus, the volume of Elbow Lake is approximately double the volume of Thor Lake. Also, the shoreline of Elbow Lake is much more irregular than the shoreline of Thor Lake, resulting in a high value for shore development. Both lakes are very similar to



ure 3.2 Bathymetric Map of Thor Lake.

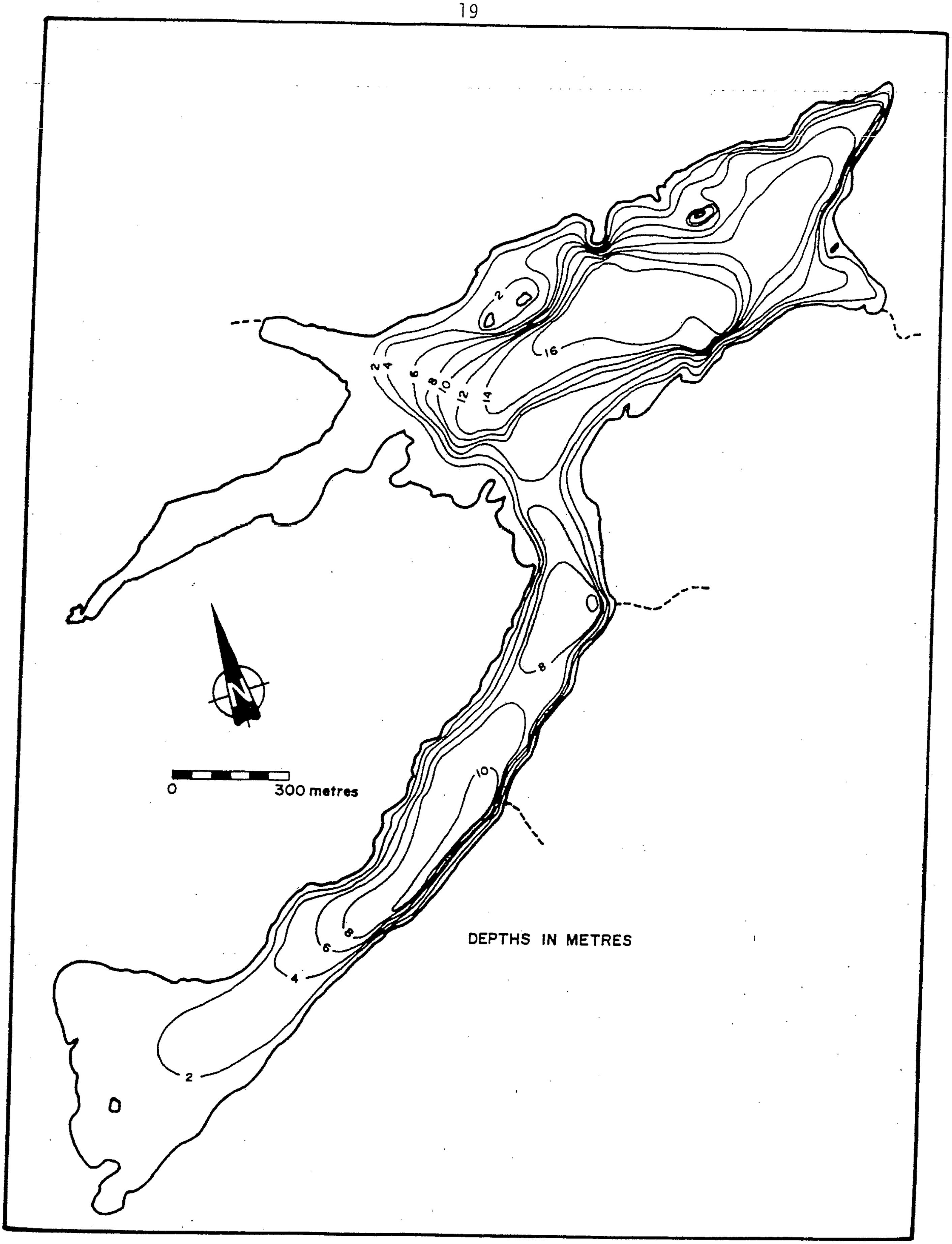


Figure 3.3 Bathymetric Map of Elbow Lake.

Table 3.1 Summary of Morphometric Characteristics of Four Lakes in the Thor Lake Area, September 1988.

	Thor	Elbow	Cressy	Ring
Mean depth (m)	3.2	5.9	3.4	0.56
Maximum depth (m)	13.5	18.9	6.5	1.2
Water area (ha)	136	125	6.16	11.5
Water volume ($x10^6$ m^3)	4.37	7.35	0.210	0.064
Shoreline length (km)	7.16	12.9	1.83	1.64
Number of islands	2	5	0	0
Island shore length (km)	0.582	4.34	0	0
Total shore length (km)	7.74	13.3	1.83	1.64
Shore development	1.87	3.35	2.09	1.36
Volume development	0.70	0.99	1.58	0.21

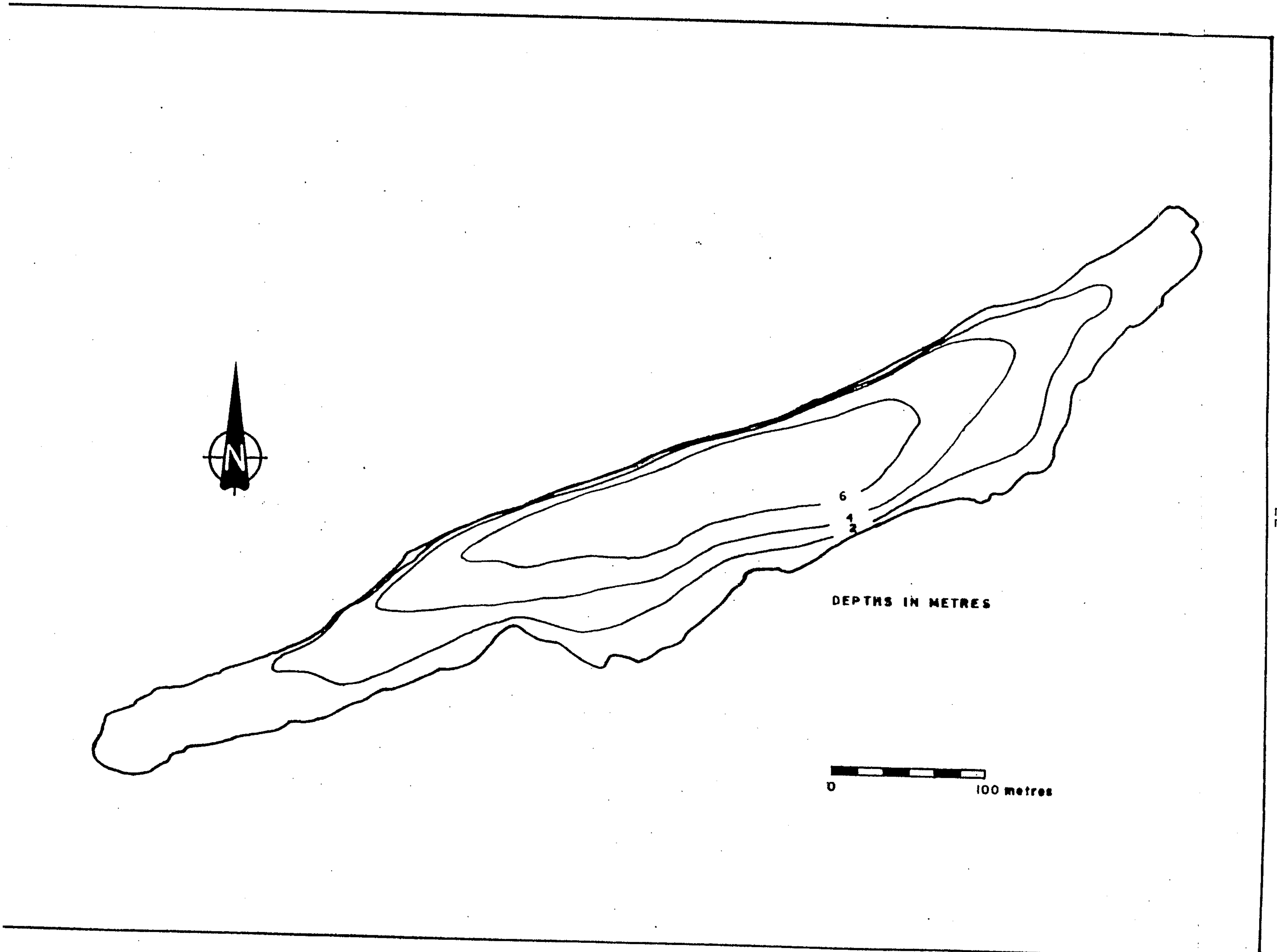
three lakes studied by Moore (1980), 100 km to the west near Yellowknife.

The other four study lakes have very small surface areas (Table 3.1 or Figure 3.1), much smaller than the areas of Thor and Elbow Lakes (Table 3.1). Cressy (Figure 3.4) and A Lakes are relatively deep for their surface areas. Lake A, at least 15 m deep, appears almost as deep as Elbow Lake, the deepest of the six study lakes. Cressy Lake has moderately high volume development, because the lake basin has concave walls. Lake A may also exhibit a higher level of volume development if it is deep over most of its area. Further sounding of Lake A will take place in late spring of 1989.

Ring Lake is very shallow (Table 3.1), and undoubtedly freezes to the bottom in many years. Only a few hand-line soundings were made in Lake B (maximum depth 1.5 m), but the macrophyte Potamegeton grew to the surface over the whole lake. These observations indicate that Lake B must also be very shallow, freezing to the bottom in many years.

3.3.1.2 Lake Thermal Regimes

Temperature, oxygen (O_2) and conductivity data suggest that fall turnover or mixing was about to be completed in Elbow Lake (Table 3.2); this lake probably develops a thermocline (stable summertime thermo-density gradient), at least in the north basin. Data for all three variables are essentially constant for the first 10 m of depth, below which the data begin to change. One of the three similar lakes near Yellowknife develops a thermocline about 10 m deep, and undergoes fall overturn in September (Moore 1980).



gure 3.4 Bathymetric Map of Cressy Lake.

Table 3.2 Temperature (°C), Dissolved Oxygen (O_2, mg/L) and Specific Conductivity (SC, umhos/cm)* for Thor and Elbow Lakes, September 12-14, 1988.

Depth (m)	Thor °C	Thor O_2	Thor SC	Elbow °C	Elbow O_2	Elbow SC
Surface	10.5	9.7	307	12.9	9.2	310
1	10.5	9.6	307	12.9	9.3	310
2	10.5	9.6	307	12.9	9.2	310
3	10.5	9.6	307	12.9	9.1	310
4	10.5	9.6	307	12.9	9.2	310
5	10.5	9.6	307	12.9	9.2	310
6	10.8	9.6	305	12.9	9.1	310
7	10.9	9.6	304	12.9	9.1	310
8	10.9	9.4	304	12.9	9.1	310
9	10.9	9.4	304	12.9	8.4	310
10	10.6	6.2	341	12.8	8.2	311
11				12.5	8.1	313
12				12.2	7.3	315
12.5				12.2	1.0	381

*Corrected to 25°C

Thor Lake probably does not develop a thermocline, since it is, on average, half as deep as Elbow Lake. Thor Lake too has a thermal regime similar to one of the NWT lakes studied by Moore (1980).

A distinct thermocline still existed in Lake A, at only 5.5 m (Table 3.3). This lake probably does not heat up as quickly, and to the same extent, as Thor and Elbow Lakes. It is deep for its very small surface area, and it is protected from the wind by large rock ridges.

Cressy Lake (Table 3.2) is too shallow to develop a thermocline.

3.3.1.3 Water Quality

O_2 concentrations in the upper waters of all lakes were near saturation. Concentrations were low only near lake bottoms, or below thermoclines where they occurred. Moore's (1980) lakes are similar in these respects.

All lake waters were moderately hard to hard (Table 3.4). They were also moderately well to well buffered, as is indicated by pH and alkalinity data (Table 3.4). Lakes A and, in particular, B, were tea coloured. Levels of all general water quality variables (Table 3.4) were well within the ranges reported for lakes near Yellowknife (Moore 1980; Ostrofsky and Rigler 1987).

Of the major cations, Ca was highest, although Mg was high as well. Bicarbonate was by far the most abundant anion. These lakes differed from those of Moore (1980), in that sulfate levels were lower. Na and Cl concentrations were higher in one of the lakes studied by Moore (1980).

Trace element concentrations (Appendix A) were low to very low; levels of Be, Ce, Nb, Ta and Y were all below detection limits, i.e.,

Table 3.3 Temperature (°C), Dissolved Oxygen (O_2, mg/L) and Specific Conductivity (SC, umhos/cm)* for Lake "A" and Cressy Lake, September 13, 1988.

Depth (m)	"A" °C	"A" O_2	"A" SC	Cressy °C	Cressy O_2	Cressy SC
Surface	10.1	9.6	282	11.5	9.1	211
1	10.1	9.6	282	11.5	9.0	211
2	10.5	9.4	280	11.3	8.9	212
3	10.5	9.6	280	11.3	8.8	212
4	10.8	9.5	278	11.0	8.0	213
5	10.2	9.2	282	11.0	7.6	213
5.5				10.0	7.0	299
6	4.5	5.6	299			
7	3.0	5.5	315			
8	3.0	5.6	315			
9	3.0	5.4	315			
10	3.0	5.1	315			
11	3.0	5.1	315			
12	3.0	2.4	315			

*Corrected to 25°C

Table 3.4 Some General Water Quality Characteristics of Selected Lakes in the Thor Lake Area, September 1988.

		Thor	Elbow	Cressy	A	Ring	B
pH	surface	7.9	7.6	7.5	8.0	7.5	7.7
	bottom	7.8	7.7	--	--	--	--
Alkalinity (mg/L $CaCO_3$)	surface	73	84	51	71	63	40
	bottom	78	83	51	--	--	--
Hardness* (mg/L $CaCO_3$)	surface	149	161	105	142	133	89.4
	bottom	149	161	105	--	--	--
Total dissolved solids (mg/L)	surface	190	188	152	188	204	164
	bottom	199	194	157	--	--	--
Total suspended solids (mg/L)	surface	2	2	4	1	8	2
	bottom	2	3	3	--	--	--
Transparency depth (m)		2.8	3.3	2.0	2.0	1.3 (B)	1.3 (B)

*Hardness = Ca + Mg, corrected according to APHA (1975).

<0.001 mg/L. Element concentrations were also below or equal to Canadian guidelines for aquatic life, where guidelines exist (CCREM 1987), with one exception. This is Cr, which was present at concentrations that can have deleterious effects on zooplankton (CCREM 1987).

Radionuclide levels were all at or below 0.04 Bq/L in terms of radioactivity (Appendix A). Ra^{226} levels were below the limits of detection, much lower than naturally occurring Ra^{226} concentrations in two larger lakes in northern Saskatchewan (Swanson 1985). Pb^{210} concentrations were lower than in Swanson's (1985) lakes, while U (as ug/L) levels were as low or lower. While U levels were below detection limits in five of six lakes in this study, they were as high as 1.9 ug/L in Cressy Lake; no explanation is offered for these differences in occurrence.

The water quality of Fred Stream (Appendix A Table A.3) was similar to that of the study lakes.

3.3.1.4 Stream Flow

A discharge rate of 0.091 m^3/s was obtained for Fred Stream, just below the road to Great Slave Lake. The rate is very low, compared to the average summer discharge rate of 3.0 m^3/s in a shallow stream emanating from Grace Lake, NWT (Moore 1980). Fred Stream is tiny, 1.3 m wide by <0.5 m deep, which explains the low flow rate. The stream bed was silt over clay, with occasional pieces of broken bedrock embedded in the banks. There were no stream bed macrophytes in the area investigated.

No flowing water was observed immediately below Cressy, Ring and B Lakes. Continuous peatland made up shorelines where one could otherwise expect outflow from these lakes; the same was true of Elbow Lake. No open water occurred in the peatland between Cressy Lake and Fred Lake. This area was investigated on foot. Reg Savage, the caretaker on site, showed us a minute trickle of water flowing south across the road south of Elbow Lake. He thought that the water originated in Elbow Lake and eventually found its way into Great Slave Lake. The flow was too small to measure.

Two of the three lakes studied by Moore (1980) did not discharge through streams, similar to most of the lakes in the Thor Lake area.

3.3.2 Biotic

3.3.2.1 Phytoplankton and Lake Trophic Status

Chlorophyll a concentrations (Table 3.5) suggest that Cressy Lake is eutrophic (nutrient rich), Thor Lake is mesotrophic and the other lakes are oligotrophic (nutrient poor). Trophic categorizations are based on the data of Shortreed and Stockner (1986) for 19 larger sub-arctic lakes in the Yukon territory. The oligotrophic designation may be questionable for Ring Lake, which contained large amounts of suspended organic material (Appendix A.3).

The range of lake trophy observed in the Thor Lake area corresponds to that observed by Ostrofsky and Rigler (1987), who studied 49 small to very small lakes near Yellowknife. They include chlorophyll a data for the lakes studied by Moore (1980).

3.3.2.2 Zooplankton Abundance and Community Structure

Each of the study lakes contains one of two basic arthropod zooplankton community types. The communities in Cressy, Ring and B Lakes

Table 3.5 Algal Chlorophyll Concentrations (ug/L) of Selected Lakes in the Thor Lake Area, September 1988.

Lake		Chlorophyll a	b	Total
Thor	surface	3.45	3.20	6.60
	bottom	3.98	2.18	6.15
Elbow	surface	0.68	4.10	4.78
	bottom	0.78	2.00	2.78
Cressy	surface	5.08	2.78	7.85
	bottom	6.48	4.63	11.1
A	surface	0.95	2.45	3.40
Ring		0.60	1.56	2.18
B		1.63	4.25	5.88

(Table 3.6) are characterized by large-bodied zooplankton, particularly the predators Chaoborus americanus and Hetercope septrionalis, and the primarily herbivorous Daphnia galeata mendotae. Smaller zooplankters tend to predominate in Thor and Elbow Lakes and, to a lesser extent, Lake A (Table 3.7). These zooplankters include the copepods Diaptomus sicilis and Cyclops spp., and the cladocerans Bosmina longirostris and Daphnia longiremis. The copepods Limnocalanus macrurus, Epischura lacustris and Diaptomus pribilofensis in Thor, Elbow and A Lakes are intermediate in size, but they are less abundant than the small zooplankters. Small-bodied zooplankton are less diverse and less abundant in Cressy, Ring and B Lakes, while Diaptomus pribilofensis is much more abundant in them.

The difference between the two zooplankton community types can be attributed largely to a difference in the degree of fish predation. Generally, there is an inverse relationship between the maximum body size attained by zooplankton, and the degree of fish predation (e.g., Vanni 1988). The reason for this is that fish prefer to eat larger zooplankton. Small zooplankters are less abundant in the absence of fish predation, because the largest zooplankters, such as Chaoborus and Heterocope, are voracious predators of small zooplankters.

The presence in Elbow and A Lakes of Limnocalcanus macrurus, a glacial opportunist (Dadswell 1974), is of interest. It is found only in lakes that were once inundated by proglacial lakes during Pleistocene glaciation, or in those that occurred near the former margins of proglacial lakes (here glacial Lake McConnell, see section 4.4.3.2). The species requires cold water as habitat. This condition is met in Lake A, below the thermocline in summer. It is probably met in Elbow Lake as

Table 3.6 Zooplankton Densities (/L) for Three Lakes in the Thor Lake Area, NWT, September 1988.

Species/Groups	Thor	Lake Elbow	A
Copepoda			
Calanoida			
Limnocalanus macrurus	--	0.033	0.006
Epischura lacustris	0.002	--	--
Diaptomus sicilis			
- adults	0.055	0.027	--
- juveniles	0.024	0.019	
Diaptomus pribilofensis			
- adults	0.002	--	0.033
- juveniles	--	--	0.035
Cyclopoida			
Cyclops scutifer	0.749	0.146	--
Cyclops bicuspidatus thomasi*	3.60	0.243	--
Total naupliar juveniles	0.600	1.94	--
Cladocera			
Daphnia longiremis	--	0.024	--
Bosmina longirostris	3.30	0.243	--
Rotifera			
Kellicottia longispina	3.00	--	7.28
Other small rotifers	27.0	12.1	72.8

*May include juvenile copepodids of Cyclops scutifer.

Table 3.7 Zooplankton Densities (/L) for Three Lakes in the Thor Lake Area, NWT, September 1988.

Species/Groups	Lake		
	Cressy	Ring	B
Diptera			
<u>Chaoborus</u> <u>americanus</u>	0.036	0.005	0.010
Copepoda			
Calanoida			
<u>Hetercope</u> <u>septrionalis</u>	0.026	0.082	0.010
<u>Diaptomus</u> <u>pribilofensis</u>			
- adults	1.72	4.34	0.51
- juveniles	1.08	1.02	--
Cyclopoida			
<u>Cyclops</u> <u>bicuspidatus</u> <u>thomasi</u>	--	3.83	--
Total naupliar juveniles	9.57	1.28	--
Cladocera			
<u>Daphnia</u> <u>galeata</u> <u>mendotae</u>	0.036	0.041	--
Rotifera			
<u>Kellicottia</u> <u>longispina</u>	14.6	--	1.28
Other small rotifers	87.4	--	--

well, which appears to develop a thermocline. Cold temperatures may also help reduce fish predation on Limnocalanus, at least in Elbow Lake. The presence of Limnocalanus could potentially serve as a quality maintenance indicator for water below the tailings area of the mine lease.

3.3.2.3 Fish Communities

The fish community in Thor Lake (Table 3.8) is typical of fish communities in similar lakes in this region of the NWT. Healey (1980) found lake trout, burbot and the small forage fish lake chub, in addition to the species outlined in Table 3.8. Thor and Elbow Lakes are somewhat smaller (shallower) than his study lakes, which would explain the absence of lake trout in this study. Some burbot could exist in the deeper holes in Thor Lake, and perhaps a few lake chub occur in the lake as well.

The fish community in Elbow Lake appears virtually identical to that in Thor Lake, although only the large fish portion has been effectively sampled. Lake whitefish, northern pike and cisco were caught in the gill net set. Ninespine sticklebacks were found in whitefish and pike stomachs.

No large fish were caught in Cressy Lake with intensive fishing effort. While Cressy Lake is deep enough to contain large fish, these results suggest that none occur there. Large zooplankton body sizes indicate that zooplanktivorous fish, including small forage fish such as stickleback, are probably absent. Since gill nets can catch all species of large fish irrespective of diet, and most small northern fish species can eat zooplankton, Cressy Lake may be referred to as fishless. When ice-covered, this eutrophic little lake could be devoid of oxygen in

Table 3.8 Fish Species Identified in Thor Lake, 1988.

Common Name	Scientific Name
Large Fish:	
Lake whitefish	Coregonus clupeaformis
Cisco	Coregonus artedii
Northern pike	Esox lucius
Small Fish:	
Ninespine stickleback	Pungitius pungitius
Troutperch	Percopsis omyscomaycus
Sculpin species	Cottus sp.

some years; this winterkill characteristic, plus isolation which prevents immigration, would explain the absence of fish there.

No fish were taken from Ring Lake. Gillnetting results, the extremely shallow depths of Ring Lake, and the large zooplankton body sizes all indicate that it too is fishless. Similar observations (zooplankton, depths) suggest that Lake B does not contain fish either. Gill nets will be set in Lake B in 1989 in order to obtain more direct evidence for this conclusion.

Lake A may contain some fish, although this is yet to be determined. Although small in surface area, it is twice as deep as Cressy Lake, thus less susceptible to winterkill conditions. The zooplankton community is more characteristic of lakes that contain fish than those without. Moreover, the zooplankton are not abundant, which could be explained in part by fish predation. Lake A will also be gillnetted in 1989.

A map of all gill net sets in the Thor Lake area is presented in Figure 3.5.

3.3.2.4 Large-Fish Relative Abundance

Large-fish in Thor Lake (Table 3.9) were three times more numerous than large fish in Elbow Lake (Table 3.10). They also had twice as much biomass as large fish in Elbow Lake. Whitefish made up two thirds to three quarters of the total catch in terms of both numbers and biomass. Whitefish were caught mostly by meshes of intermediate size, although large fish were taken in all mesh sizes (Tables 3.9 and 3.10). Pike were taken largely in smaller intermediate mesh sizes, while cisco, as expected, were caught only in the smallest mesh size.

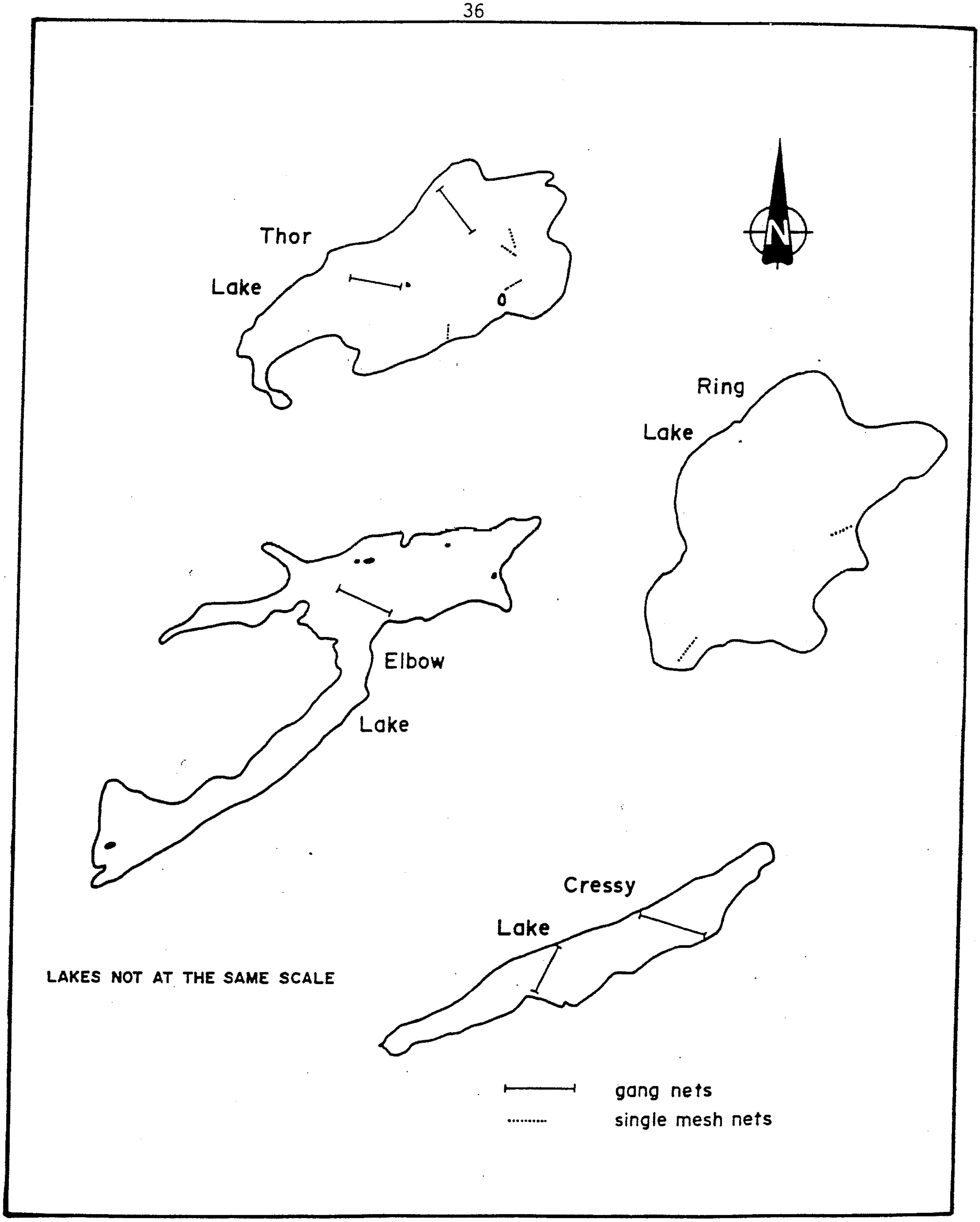


Figure 3.5 Map of Gill Net Sets in Thor Lake Area Lakes, September 1988. Gang Nets are of Standard Length in Thor and Elbow Lakes, Half Standard in Cressy Lake.

Table 3.9 Summary of Fish Caught in Thor Lake, September 1988. Two Standard Gang Gill Net Sets. All Weights are in g.

Species		Mesh Size (mm) 30	51	76	102	127	140	Total	Average /Set	Percent of Total
Northern pike	No.	6	24	40	1	0	1	72	36	19.7
	Wt.	4185	17030	31930	860	0	860	54860	27430	23.5
Lake whitefish	No.	33	49	67	87	13	8	257	129	70.4
	Wt.	24490	36900	41000	55850	11590	7125	176900	88470	75.7
Cisco	No.	36	--	--	--	--	--	36	18	9.9
	Wt.	1817	--	--	--	--	--	1817	909	0.8
Total	No.	75	73	107	88	13	9	365	183	100
	Wt.	30490	53930	72930	56710	11590	7985	233600	116800	100

Table 3.10 Summary of Fish Caught in Elbow Lake, September 1988. One Standard Gang Gill Net Set. All Weights are in g.

Species		Mesh Size (mm) 38	51	72	102	127	140	Total	Percent of Total
Northern pike	No.	--	2	17	--	--	--	19	28.7
	Wt.	--	2075	15510	--	--	--	17590	31.4
Lake whitefish	No.	4	11	10	7	11	--	43	65.2
	Wt.	2835	8965	8330	6930	11180	--	38240	68.4
Cisco	No.	4	--	--	--	--	--	4	6.1
	Wt.	181	--	--	--	--	--	181	3.2
Total	No.	8	13	27	7	11	--	66	100
	Wt.	3016	11040	23840	6930	11180	--	56010	100

Large fish are more abundant in Thor Lake than in Elbow Lake, for reasons that are related in large part to its morphometry. It is half as deep, and has less rocky substrate than Elbow Lake. Consequently, Thor Lake is a warmer and more nutrient rich system than the latter lake. Thor Lake is probably not deep enough to develop a thermocline. Thus, the whole lake mixes, warming the lake and circulating chemical micronutrients needed for plant growth. Warmer temperatures promote growth. Soft bottom material also provides chemical micronutrient reserves for plants (algae, macrophytes), and physical habitat for macroinvertebrates, upon which many fish feed. The plants, in turn, provide food and additional substrate habitat for the invertebrates. These conditions are particularly suitable for lake whitefish.

Large fish are at least as abundant in Thor Lake as in similar lakes in northern Saskatchewan (Pipe et al. 1980). Data for Elbow Lake represent an intermediate level of abundance in relation to northern Saskatchewan lakes. Whitefish were generally less abundant in the lakes studied by Pipe et al. (1980), while walleye and white sucker were often present and as abundant as whitefish.

3.3.2.5 Large-Fish Growth

Large-fish populations in Thor Lake and, in particular, Elbow Lake are made up primarily of larger individuals (Table 3.11). In Thor Lake, for example, 72% of the pike (Table 3.11) were four years old, and most of the remainder were five years old. Pike in Elbow Lake were, on average, two years older than those in Thor Lake. There were very few older juvenile whitefish and pike. The populations are typical of the

Table 3.11 Body Length Frequency Distributions for Lake Whitefish and Northern Pike in Thor and Elbow Lakes, September 1988.

Length (cm)	Thor Females	Thor Males	Thor Total	Elbow Females	Elbow Males	Elbow Total
Lake Whitefish						
30	1	2	3			
33	4	2	6			
36	3	8	11	1		1
39	38	33	71	7	10	17
42	34	18	52	9	10	19
45	4	1	5	2	2	4
48	1	1	2			
Total			150			42
Northern Pike						
44		2	2		1	1
46	1	10	11			
48	12	3	15	2		2
50	10	5	15	3	1	4
52	7	1	8	2		2
54	5		5	3		3
56	1		1	3	1	4
58				2		2
Total			57			18

pattern predominant in unexploited arctic and subarctic large-fish populations (Johnson 1976).

Whitefish and cisco growth rates in terms of biomass accumulation (weight versus length) are generally similar in comparisons between the sexes within lakes (Figures 3.6 to 3.12). However, comparisons between the lakes within sexes for each species (Figures 3.6 to 3.15) indicate that fish in Elbow Lake acquired biomass at greater rates than fish in Thor Lake. The growth rate differences suggest that more intraspecific competition is occurring in Thor Lake populations than in Elbow Lake populations, lake standing crop differences not withstanding (section 3.3.2.4). All biomass growth rates are within the ranges for these species in the north Saskatchewan lakes studied by Pipe et al. (1980).

3.3.2.6 Large-Fish Feeding

The feeding of both the whitefish and pike (Table 3.12) is typical for these species (Scott and Crossman 1973; Pipe et al. 1980). The whitefish ate predominantly benthic invertebrates, while pike ate smaller fish. Noteworthy is the fact that whitefish in both lakes consumed the forage fish, ninespine stickleback, at levels that have been termed unusually high in other subarctic systems (Pipe et al. 1980).

3.3.2.7 Coregonid Reproductive Condition

A slightly greater proportion of female whitefish was both mature and "green" (almost ready to spawn) in Elbow Lake, relative to Thor Lake (Table 3.13). This difference can probably be attributed to the slightly lower temperatures in Elbow Lake. More importantly, only two thirds of all mature females were green. The majority of the remaining mature

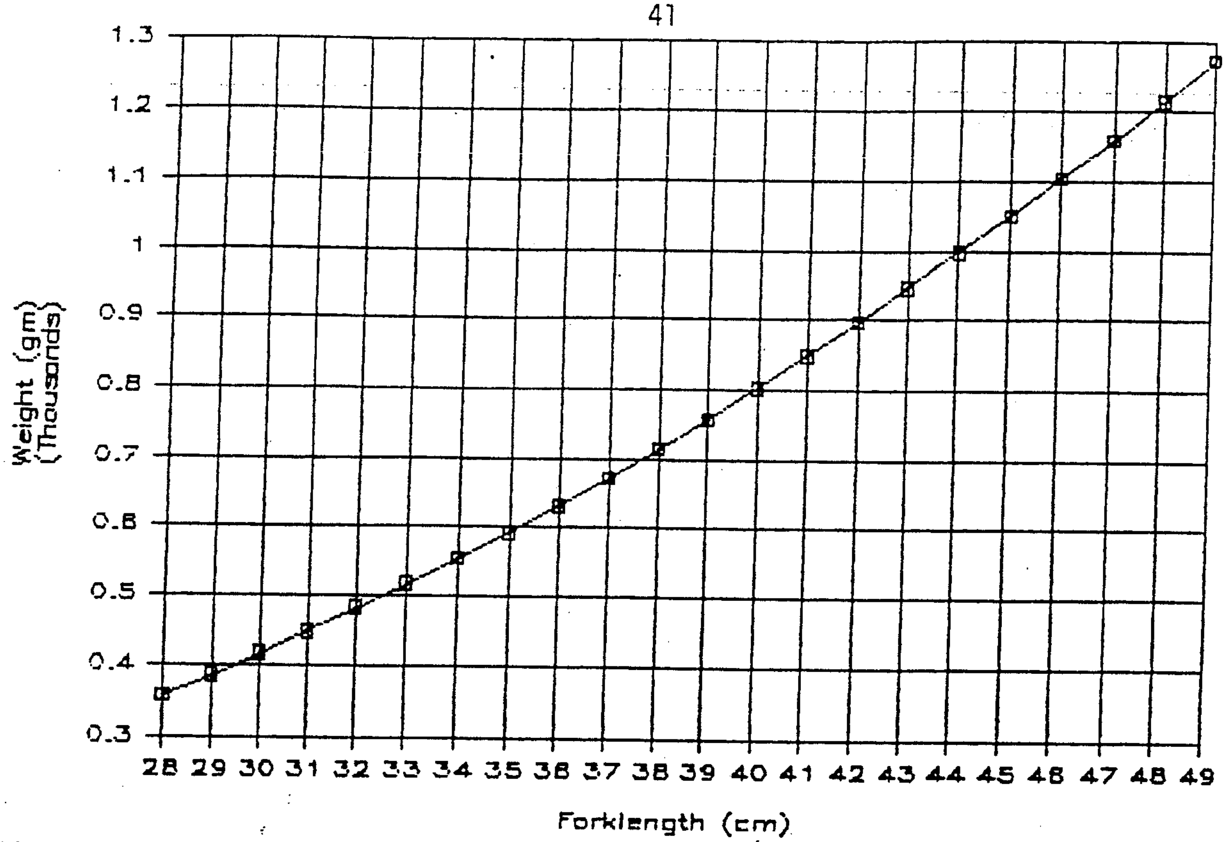


Figure 3.6 Wet Weight vs Fork Length for Female Lake Whitefish, Thor Lake. $Y = aX^b$, a = 0.18, b = 2.28, c (correlation) = 0.77.

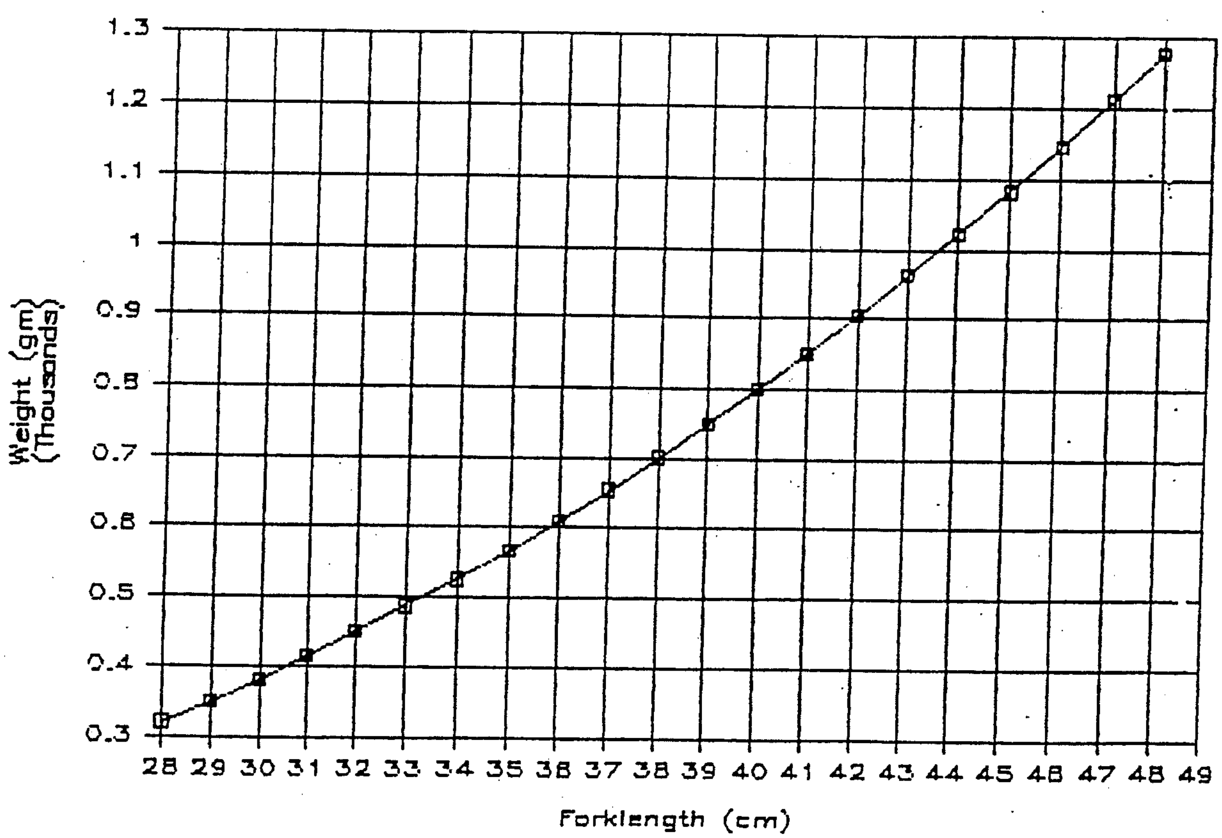


Figure 3.7 Wet Weight vs Fork Length for Male Lake Whitefish, Thor Lake. $Y = aX^b$, a = 0.06, b = 2.57, c (correlation) = 0.87.

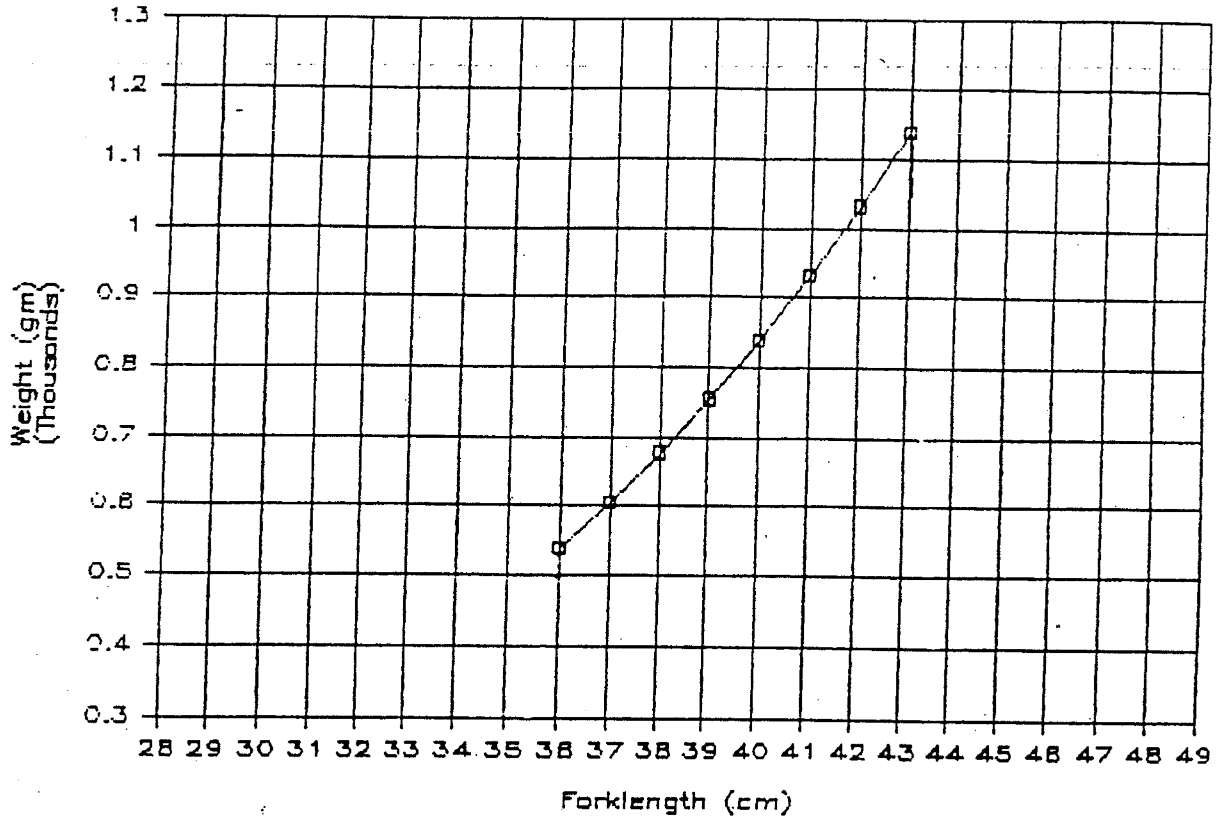


Figure 3.8 Wet Weight vs Fork Length for Female Lake Whitefish, Elbow Lake. $Y = aX^b$, a = 0.00, b = 4.20, c (correlation) = 0.79.

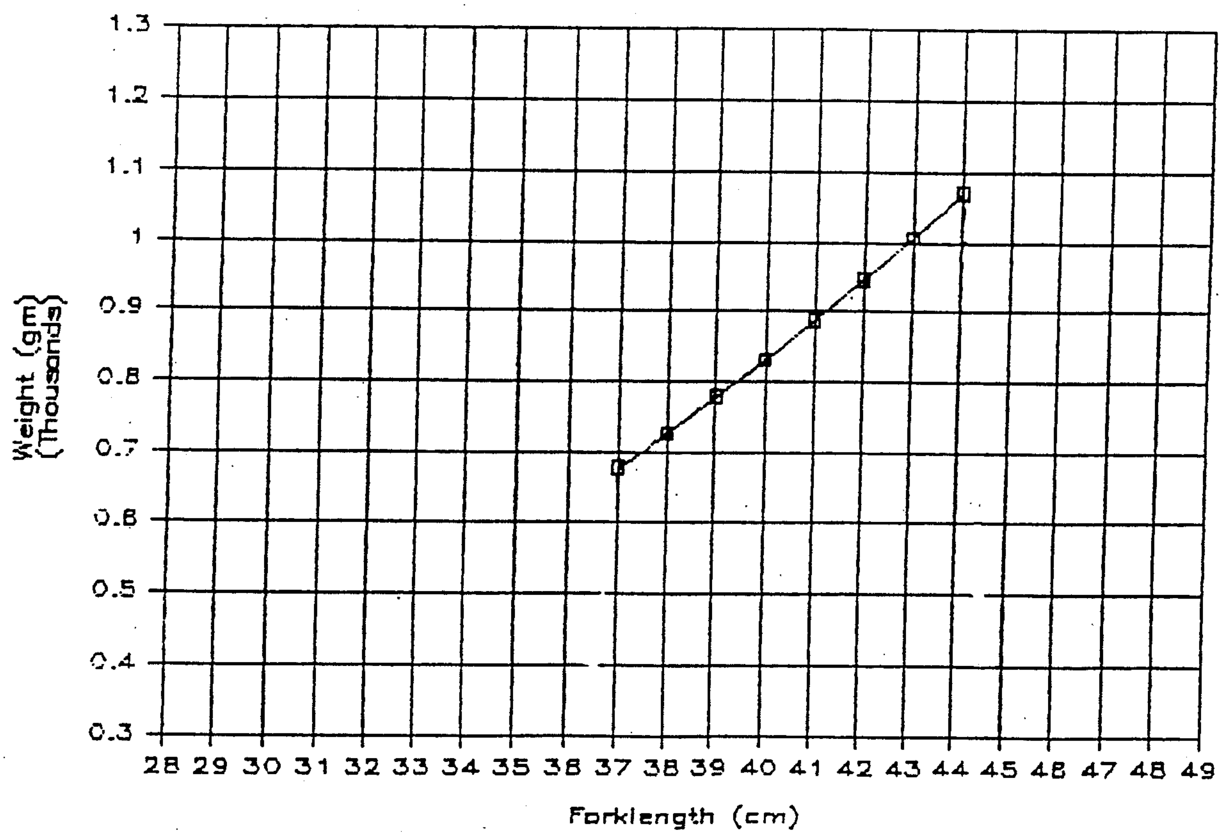


Figure 3.9 Wet Weight vs Fork Length for Male Lake Whitefish, Elbow Lake. $Y = aX^b$, a = 0.05, b = 2.64, c (correlation) = 0.72.

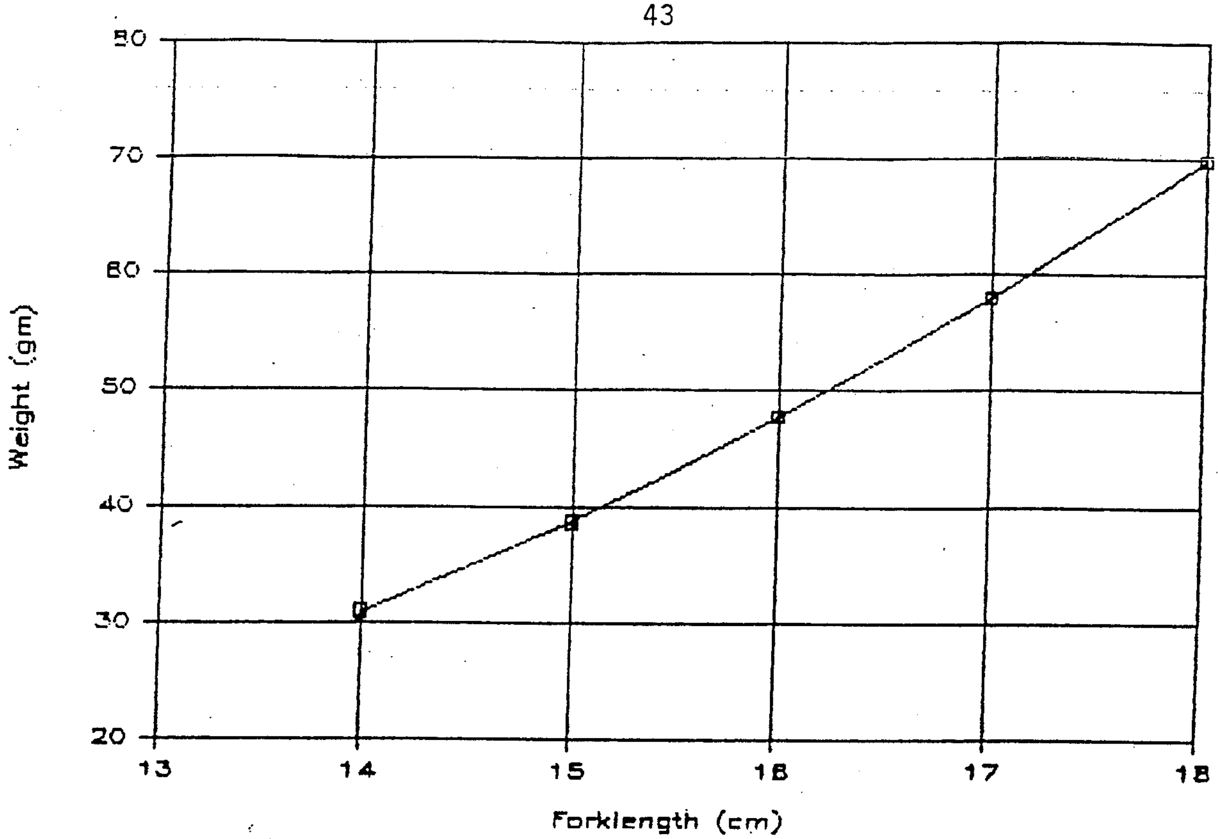


Figure 3.10 Wet Weight vs Fork Length for Female Ciscoes, Thor Lake.
$Y = aX^b$, a = 0.01, b = 3.22, c (correlation) = 0.83.

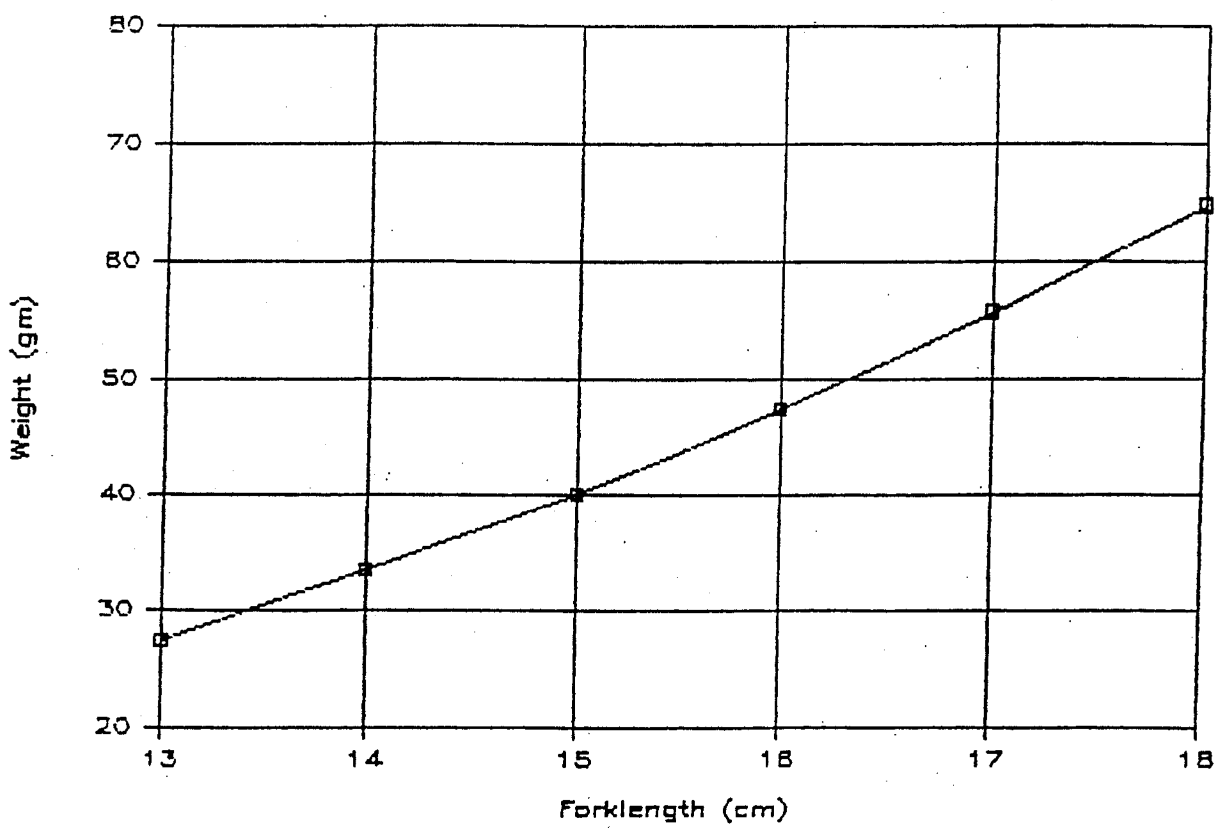


Figure 3.11 Wet Weight vs Fork Length for Male Ciscoes, Thor Lake.
$Y = aX^b$, a = 0.03, b = 2.64, c (correlation) = 0.84.

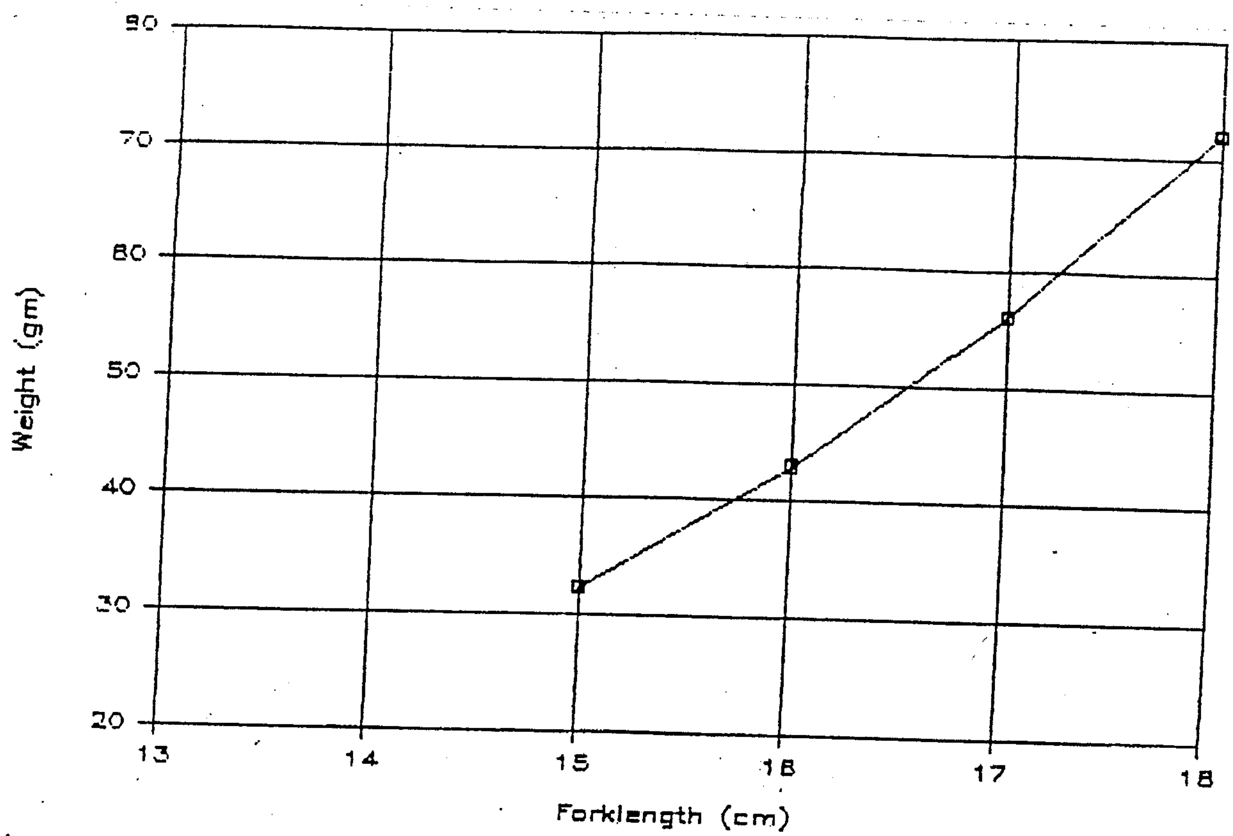


Figure 3.12 Wet Weight vs Fork Length for Female Ciscoes, Elbow Lake. $Y = aX^b$, a = 0.00, b = 4.42, c (correlation) = 0.98.

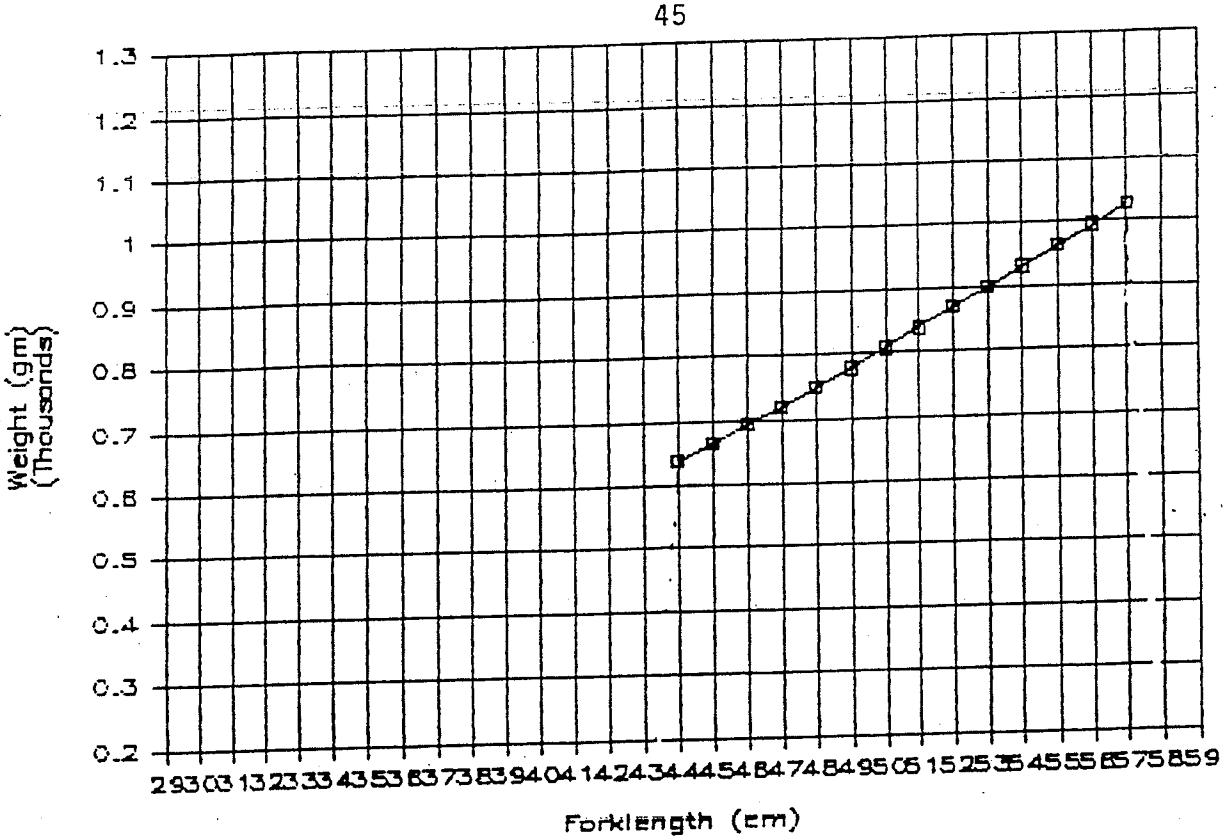


Figure 3.13 Wet Weight vs Fork Length for Female Northern Pike, Thor Lake. $Y = aX^b$, a = 0.60, b = 1.84, c (correlation) = 0.72.

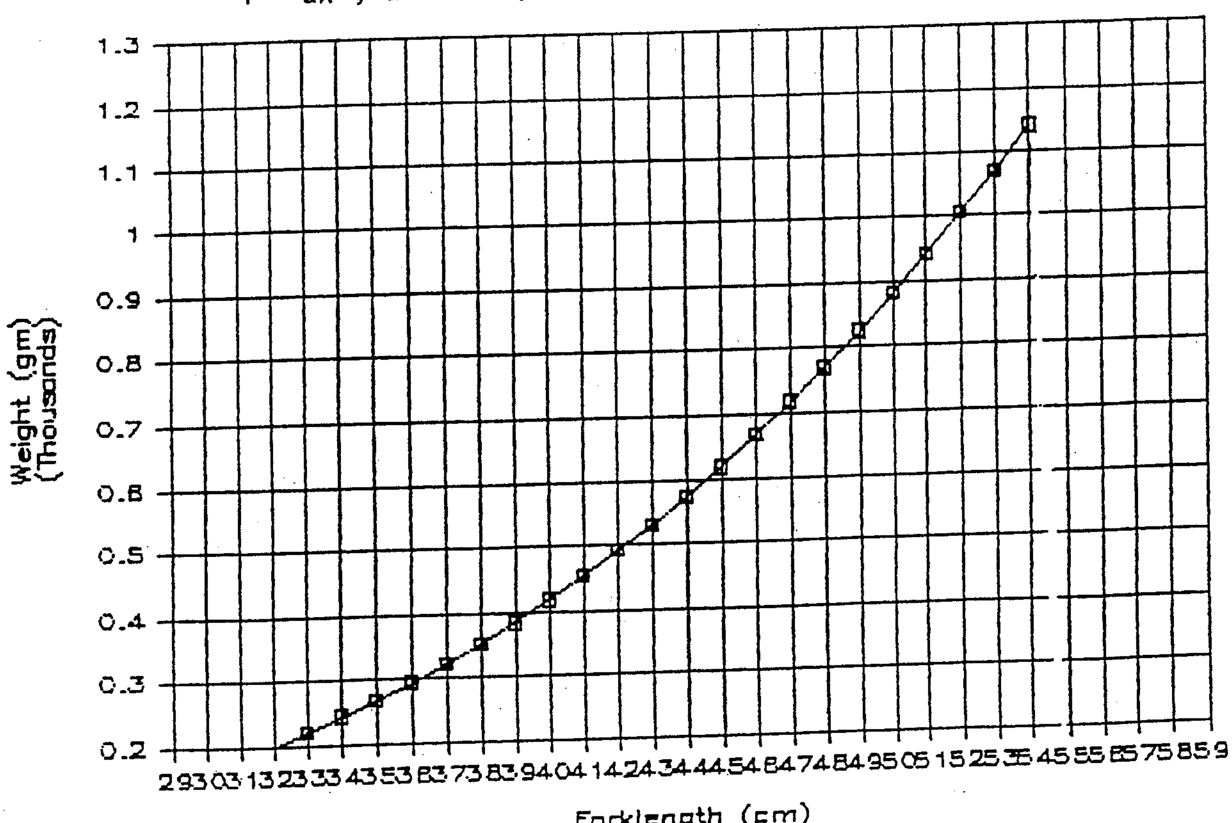


Figure 3.14 Wet Weight vs Fork Length for Male Northern Pike, Thor Lake. $Y = aX^b$, a = 0.00, b = 3.34, c (correlation) = 0.97.

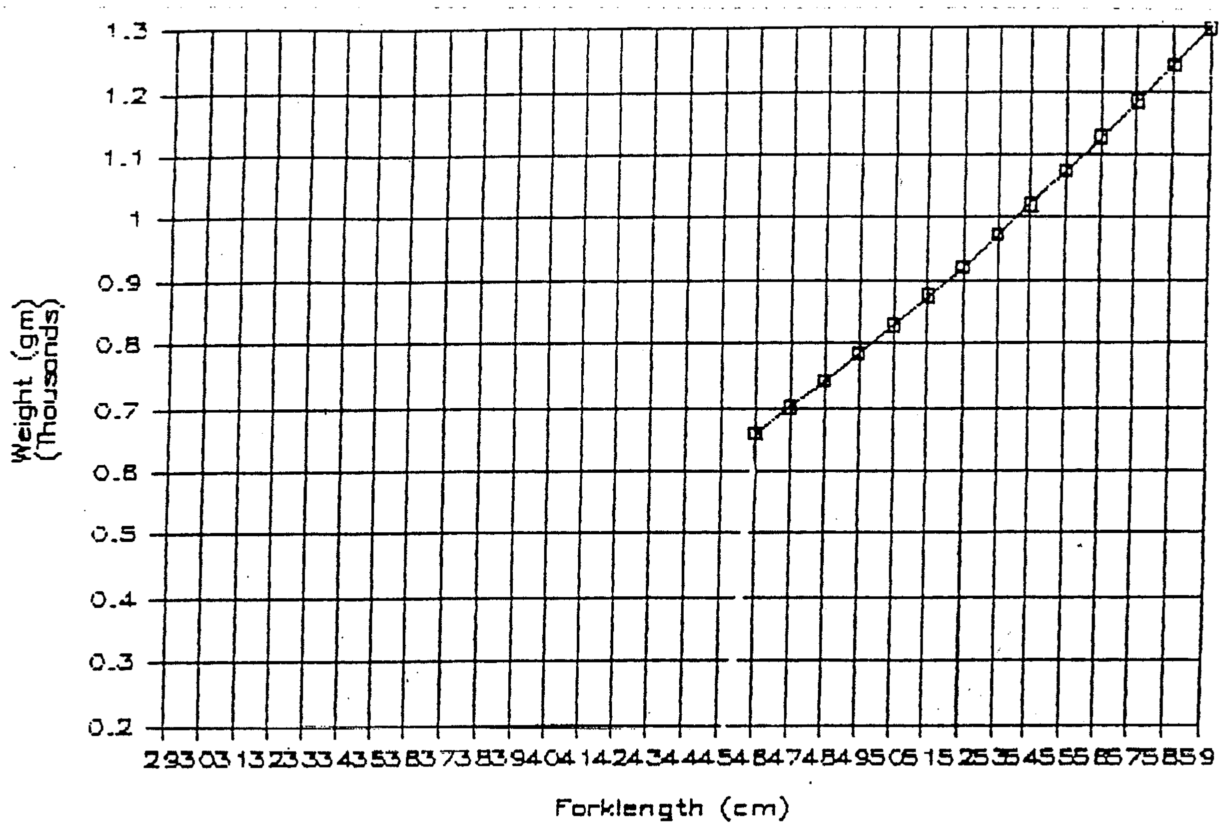


Figure 3.15 Wet Weight vs Fork Length for Female Northern Pike, Elbow Lake. $Y = aX^b$, a = 0.02, b = 2.71, c (correlation) = 0.90.

Table 3.12 Stomach Contents of the Two Major Fish Species in Thor and Elbow Lakes, September 1988. Shown as Percent Composition by Taxonomic Group.

	Thor Lake		Elbow Lake	
	Lake whitefish	Northern pike	Lake whitefish	Northern pike
No. of fish analyzed	137	71	41	19
No. of stomachs with food	86	33	24	18
Fish:				
Northern pike	--	12.2	--	--
Cisco	1.2	4.8	--	--
Ninespine stickleback	10.6	64.8	19.2	97.2
Digested remains	--	9.1	8.3	2.8
Insecta:				
Chironomids	19.2	--	32.2	--
Caddisflies	23.7	--	12.4	--
Crustacea:				
Amphipods	2.8	--	--	--
Mollucea:				
Sphaeriids	33.0	--	10.2	--
Gastropods	6.9	--	--	--
Hirudena:	--	--	4.2	--
Unidentified:	2.6	9.1	13.5	--
Total	100.0	100.0	100.0	100.0

Table 3.13 Reproductive Condition of Lake Whitefish in Thor and Elbow Lakes, September 1988. "Green" Refers to Females Which are Almost Ready to Spawn.

		No. Fish	Mature	"Green"
<u>Thor Lake</u>				
Females	No.	85	62	42
	%	100	73	49
Males	No.	19	56	--
	%	100	86	--
<u>Elbow Lake</u>				
Females	No.	19	15	12
	%	100	79	63
Males	No.	22	21	--
	%	100	95	--

females carried eggs which were an order of magnitude smaller than those in the green females. It is highly probable that such eggs were not viable, i.e., would not have developed enough to spawn. There is evidence that not all mature fish spawn every year in other northern whitefish populations (Scott and Crossman 1973).

On the other hand, all ciscoes in both lakes were almost ready to spawn. Ciscoes usually spawn a week or two after lake whitefish (Scott and Crossman 1973), further evidence that many mature whitefish females would not have spawned in Thor and Elbow Lakes in 1988.

3.3.2.8 Elemental Analysis of Large-Fish Tissue

The analyses were done on flesh and bone from lake whitefish and northern pike. Pike are top carnivores in aquatic food webs, while lake whitefish feed at all carnivorous trophic levels.

Virtually all radionuclide activity data for Thor Lake are below the limits of detection (Appendix B). However, there is variation, since one value of Pb^{210} in whitefish flesh was relatively high, as high as levels in whitefish flesh from a lake affected by U mill effluents in northern Saskatchewan (Swanson 1985). Whitefish flesh in this study contained U levels which were at least two thirds to one tenth times lower than U concentrations in whitefish flesh from unimpacted lakes in Swanson's (1985) study. U levels in whitefish bone were even lower than levels in whitefish bone from the Saskatchewan lakes (Swanson 1985).

Trace elements varied widely in concentration (Appendix B), with such essential elements as Ca, Mg and Na being, as one would expect, by far the highest. No attempt was made to compare the data with the literature.

3.4 Conclusions and Recommendations

This study was designed to describe late summer, primarily chemical, water quality variables at key points in the watersheds associated with the Thor Lake mine project. It was also designed to describe aspects of the biota, particularly large-fish populations, associated with the waters for which quality variables were to be described. The other components examined are part of the open-water food chain.

Ranking the watersheds, the main system of concern is the drainage system below Cressy Lake, the proposed tailings area. Also of concern, runoff from the mine could eventually enter the drainage system below Den Lake, which flows northward towards Blachford Lake. The water quality of Thor Lake is of more general interest, unless Ring Lake is chosen for tailings disposal. It is currently considered the alternate tailings receiving water. However, Ring Lake appears fishless and, in terms of Thor Lake, is separated by extensive peatlands and other tiny lakes.

This survey indicates that additional aquatic studies to be undertaken in 1989 (Melville et al. 1988) should be expanded slightly to include several tasks. Fishing by way of gill nets and larval net-tows should be done along the beach of Great Slave Lake, where the mine road meets the beach. The beach area could be prime lake trout habitat, particularly during early spring and late fall. The fishing would determine the general level of use of the beach area by lake trout and other fish. Water quality samples (surface and bottom) should also be taken at this site. In addition, it is recommended that the open water components (water quality plankton, fish) be sampled in Den and Fred Lakes in 1989.

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4 TERRESTRIAL PLANT STUDIES

4.1 Introduction

The objectives of this section of the study are to:

1) characterize the vegetation communities and prepare a biophysical map,

2) identify the presence of rare plants in the development area, and

3) describe the elements found in a representative lichen of the region.

The vegetation communities are described as a step in preparing a biophysical map. The biophysical map is important for identifying wildlife habitats and sensitive areas for wildlife. The production of this map involves consideration of features such as substrate, topographical relief, slope and slope aspect as well as plant community composition. Rare plants were defined as those listed in Cody's (1979) National Museum of Natural Sciences publication entitled "Vascular Plants of Restricted Range in the Continental Northwest Territories, Canada." A survey for rare plants is necessary for the purpose of protecting sites that may be important for the maintenance of a species.

Elemental composition of a lichen is determined prior to site development for pollution monitoring purposes. Lichens largely derive their nutrients from the air and, therefore, are useful for monitoring fine particulates which are emitted to the atmosphere, and then settle out. A species of the genus Cladina is preferred. Species in this genus lack a cortex. Consequently they have a rough surface. They are also extensively branched. These two features increase surface area, enhancing the ability to intercept air particulates.

4.2 Plants of Restricted Range in the Northwest Territories

4.2.1 Introduction

The survey of vascular plants of restricted range was performed in conjunction with the survey of plant community types. The survey area was generally limited to the area immediately surrounding the proposed Thor Lake mine. However, because some community types in the area to be mapped did not occur immediately adjacent to the development area, several sites were examined at greater distances from Thor Lake.

4.2.2 Methods

Representative vegetation community types were visited. These had been identified from large scale (1:5000) air photo mosaics. A survey was made of each community type for species present, and collections were made of many species, particularly those that were unidentifiable in the field.

Collections were identified in the laboratory and all specimens are filed with the Fraser Herbarium, University of Saskatchewan, Saskatoon. A list of species was compiled and compared with Cody (1979).

4.2.3 Results and Discussion

Three species of plants considered to be of restricted range in the Northwest Territories (Cody 1979) were identified during the survey. These are: *Prunus pennsylvanica* L., *Chamaerhodos erecta* (L.) *Bge*. spp. *nuttallii* (T & G), and *Campanula rotundifolia* L.

Cody (1979) states that *Prunus pennsylvanica* is known only from the banks of the MacKenzie River north to Fort Simpson. However, there are at least two more recent records. Jasieniuk and Johnson (1979) report its presence at Snowdrift on a burned bedrock site and at Alcantara Lake on a sandy esker. The occurrence on bedrock at Snowdrift may indicate the presence of this species on rock around the eastern arm of Great Slave Lake. Bradley et al. (1982) have separated the land area adjacent to the east arm of Great Slave Lake for several kilometres inland into a separate ecodistrict. They state that the ameliorating effect of the large water body on the local climate creates a more favourable environment than is found on the surrounding terrain. This may explain the apparent northern extension of *Prunus pennsylvanica*.

Chamaerhodos erecta spp. *nuttallii* in the Northwest Territories is known from a single site in the Central MacKenzie Mountains (Cody 1979). At Thor Lake it was occasionally found on a crumbly rock outcrop east of the mine site. It is commonly found on dry sites of sandy or gravelly nature in West Central North America.

Of *Campanula rotundifolia*, Cody says it is found "in (the) south-western district of Mackenzie, north down the Mackenzie River to near Norman Wells." At Thor Lake it was relatively common on rock outcrop, and it also occurred on disturbed glacial till sites near the mine exploration area. This species was also recorded by Jasieniuk and Johnson (1979), in the Northwest Territories just north of the Uranium City (Saskatchewan) area.

Specimens of *Chamaerhodos erecta* and *Campanula rotundifolia* are filed with the Fraser Herbarium at the University of Saskatchewan. *Prunus pennsylvanica* was not collected.

4.2.4 Conclusions

Three species of plants of restricted range in the Northwest Territories were identified near Thor Lake: Prunus pennsylvanica, Chamaerhodos erecta, and Campanula rotundifolia. All are species occurring at the northern edge of their ranges; none are endemic to the Northwest Territories. They occurred in areas with warm micro and local climates. The ameliorating influence of Great Slave Lake may contribute to their presence in the area. Prunus pennsylvanica and Campanula rotundifolia may be widespread on suitable rock outcrops along the shore of Great Slave Lake. Chamaerhodos erecta is an inconspicuous species and may be easily missed in plant surveys. Thus its occurrence may be understated in collections from the area, particularly from crumbly rock substrates.

4.3 Elemental Analysis of Lichens

4.3.1 Introduction

Lichens were collected for elemental analysis to determine the levels of trace metals, radionuclides, and rare earths in a component of the vegetation community. Studies have shown (Sheard et al. 1988) that different species of lichens accumulate elements differently. For this reason, a single species of lichen, Cladina mitis, was collected from all sites so that comparisons between sites and through time would be precise.

4.3.2 Methods

Lichens were collected at three sites in the Thor Lake area (Figure 4.1). Three samples were collected at each site. Site one was north of the east end of Cressy Lake. The three samples were collected between

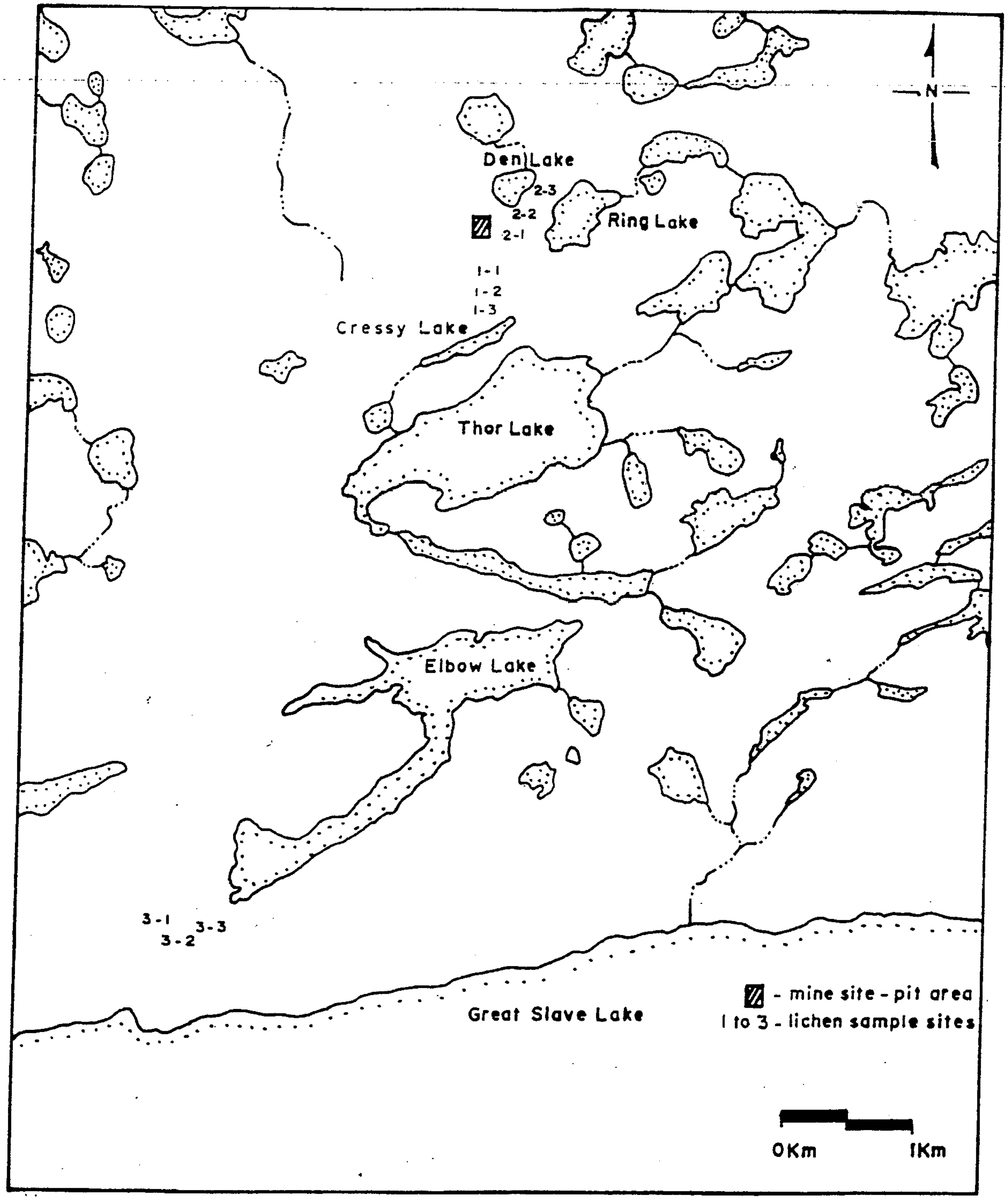

Figure 4.1 Locations of Sites Where Cladina mitis Was Sampled for Elemental Analysis.

300 and 500 m south of the proposed pit area. Site two was east of the pit area. The three replicates were collected between 300 and 600 m from the pit area, to the south and east of Den Lake. Site three was situated near the road to Great Slave Lake, 6 km to the south-southeast of the pit area.

At each sample location, lichens were collected in as small an area as possible. This usually was an area of approximately 25 m radius. Subsequent replicates were collected at intervals of approximately 100 m depending on availability of sufficient quantities at each location.

Samples were collected by removing the lichens from their substrate, and clipping away the bases of the lichens to remove any accumulated detritus. Teflon coated scissors were used to reduce the possibility of contamination from the scissor blades. The samples were immediately placed into labelled polyethylene bags. All samples were air dried overnight to prevent microbial decomposition prior to analysis.

The lichen samples were analyzed for the following parameters: Ag, Al, As, B, Ba, Be, Ca, Cd, Ce, Co, Cr, Cu, Fe, Hg, K, Mg, Mn, Mo, Na, Ni, P, Pb, Pb^{210}, Ra^{226}, Ra^{228}, Se, Ta, Ti, Th^{230}, Th^{232}, U, V, Y, and Zn. Analysis techniques for the various elements were as follows:

1. Acid digestion; inductively coupled plasma - atomic emission spectroscopy - Ag, Al, B, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, No, Na, Ni, P, Pb, Ti, V, and Zn.

2. Acid digestion; inductively coupled plasma - mass spectrometry - Ce, Nb, Ta, and Y.

3. Delayed neutron counting - U.

4. Acid digestion; cold vapour atomic absorption - Hg.

5. Acid digestion; hydride generation atomic absorption - As, and Se.

6. Ashing, acid dilution, solvent extraction, beta counting of Bi daughter - Pb^{210}.

7. Ashing, fusion, $BaSO^4$ precipitation - Ra^{226} counting, Ra^{228} counting Ac daughter.

8. Ashing, fusion, $BaSO^4$ precipitation, $Ce(OH)_2$ coprecipitation - spectroscopy, Th^{230}, and Th^{232}.

4.3.3 Results

4.3.3.1 Introduction

The elements will be considered in three groups: rare earths, trace elements, and radiochemicals. Graphical representations have been made of the mean level of some elements occurring above detection limit levels in the lichens, to illustrate the variability among the sites. Summarized data for all elements occurring above detection limits are given in Table 4.1.

4.3.3.2 Rare Earth Elements

Of all the elements, cerium had the greatest variation among sites (Figure 4.2). The Den Lake samples had cerium concentrations two orders of magnitude greater than the Great Slave Lake samples. Levels of La, Nd, and Sm were also greater at Den Lake than at Great Slave Lake. Concentrations in the Cressy Lake samples were less than an order of magnitude greater than concentrations in the Great Slave Lake samples for all four of these rare earths.

Table 4.1 Summary of Analytical Data of Lichens for All Elements Occurring Above Detection Limits in at Least One Replicate Sample. (Numbers are means with standard deviation in brackets.)

Element	Great Slave Lake	Cressy Lake	Den Lake
Al	84.00 (6.24)*	126.67 (11.55)	81.00 (3.61)
As	0.47 (0.06)	0.47 (0.15)	0.37 (0.12)
Ba	11.33 (1.15)	7.33 (4.16)	5.33 (1.53)
Ca	1316.67 (436.84)	873.33 (378.07)	643.33 (40.41)
Ce	26.33 (22.23)	115.33 (44.50)	996.67 (819.78)
Cu	0.70 (0.01)	0.87 (0.12)	0.60 (0.17)
Fe	95.00 (13.23)	143.33 (5.77)	84.33 (10.21)
Hg	0.04 (0.01)	0.04 (0.01)	0.03 (0.01)
K	870.00 (70.00)	1233.33 (152.75)	993.33 (11.55)
La	15.33 (13.58)	71.00 (11.36)	530.00 (401.12)
Mg	340.00 (40.00)	256.67 (32.15)	243.33 (20.82)
Mn	28.67 (17.79)	81.67 (28.50)	57.00 (25.87)
Nb	0.15 (0.05)	0.07 (0.03)	<0.05 (0.00)**
Nd	16.33 (14.43)	74.00 (8.89)	446.67 (316.28)
Sm	2.67 (2.89)	12.33 (0.58)	47.33 (31.07)
Ti	2.67 (0.58)	3.97 (0.06)	2.97 (0.06)
U	1.90 (1.30)	5.50 (0.89)	3.30 (0.44)
Y	5.33 (3.21)	34.00 (3.46)	22.00 (2.65)
Zn	14.33 (3.06)	21.67 (5.51)	10.67 (0.58)
Pb^{210}	30.00 (5.00)	25.00 (5.00)	26.67 (5.77)
Ra^{226}	0.60 (0.18)	0.52 (0.12)	0.52 (0.03)
Th^{230}	<0.02 (0.00)**	0.07 (0.01)	0.07 (0.02)
Th^{232}	<0.02 (0.00)**	0.24 (0.11)	0.33 (0.08)

*Values are in ug/g dry weight with the exception of Pb^{210}, Ra^{226}, Th^{230}, and Th^{232} which are in Bq/g ash weight, and U in ug/g ash weight.

**< indicates value was below detection level for analytical procedure used.

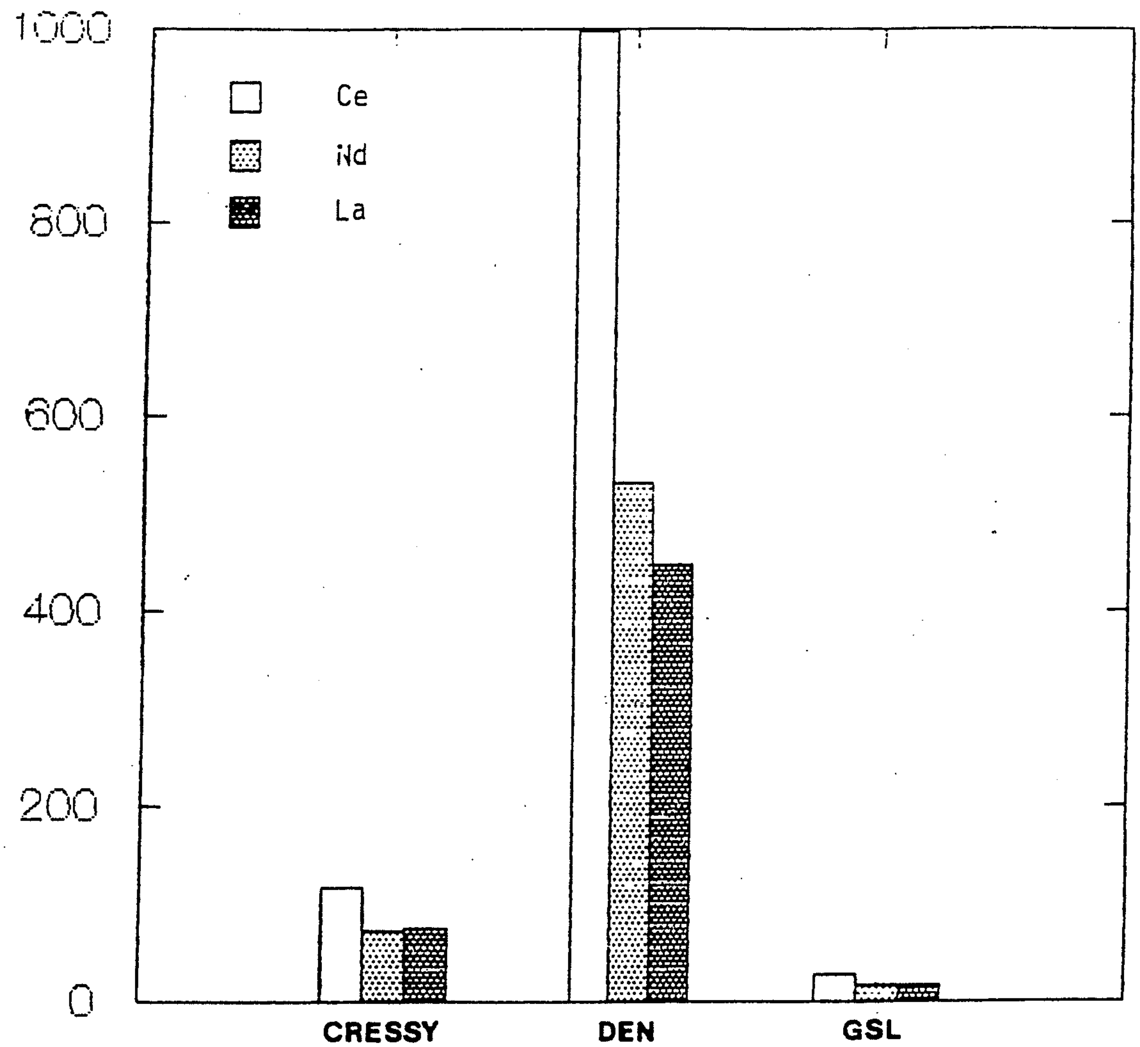

Figure 4.2 Mean Levels of Cerium, Neodymium and Lanthanum (ug/g) in *Cladina mitis* from Three Sites Near Thor Lake.

4.3.3.3 Trace Elements

Many of the trace elements occurred at levels below detection limits in all nine lichen samples collected. Of interest is the fact that both Be and Ta, two of the elements of interest insofar as the mine development is concerned, occurred at undetectable levels in all samples.

Trace elements did not vary in a consistent manner among the three sites, nor was the variability among the sites for the various trace elements as high as for the rare earths and for the Th isotopes. The trace elements with the greatest variability among the three sites were Y (Figure 4.3), Nb (Figure 4.4), and Mn. Y and Nb are of interest concerning mine development. The highest level of Nb occurred in the Great Slave Lake samples. Y and Mn were highest in the collections near the mine site, with the Cressy Lake samples being higher than the Den Lake samples.

The high level of Nb in samples from the Great Slave Lake site is puzzling. The samples were collected near the road between the mine site and Great Slave Lake. If the elevated Nb levels were due to contamination because of road movement or transportation of ore samples along the road, a corresponding increase in other elements associated with the ore body would be expected in the lichen samples as well. Because of this, the elevated Nb levels must be considered a natural anomaly.

Variation of other trace elements (Figure 4.5) was generally less than a factor of two.

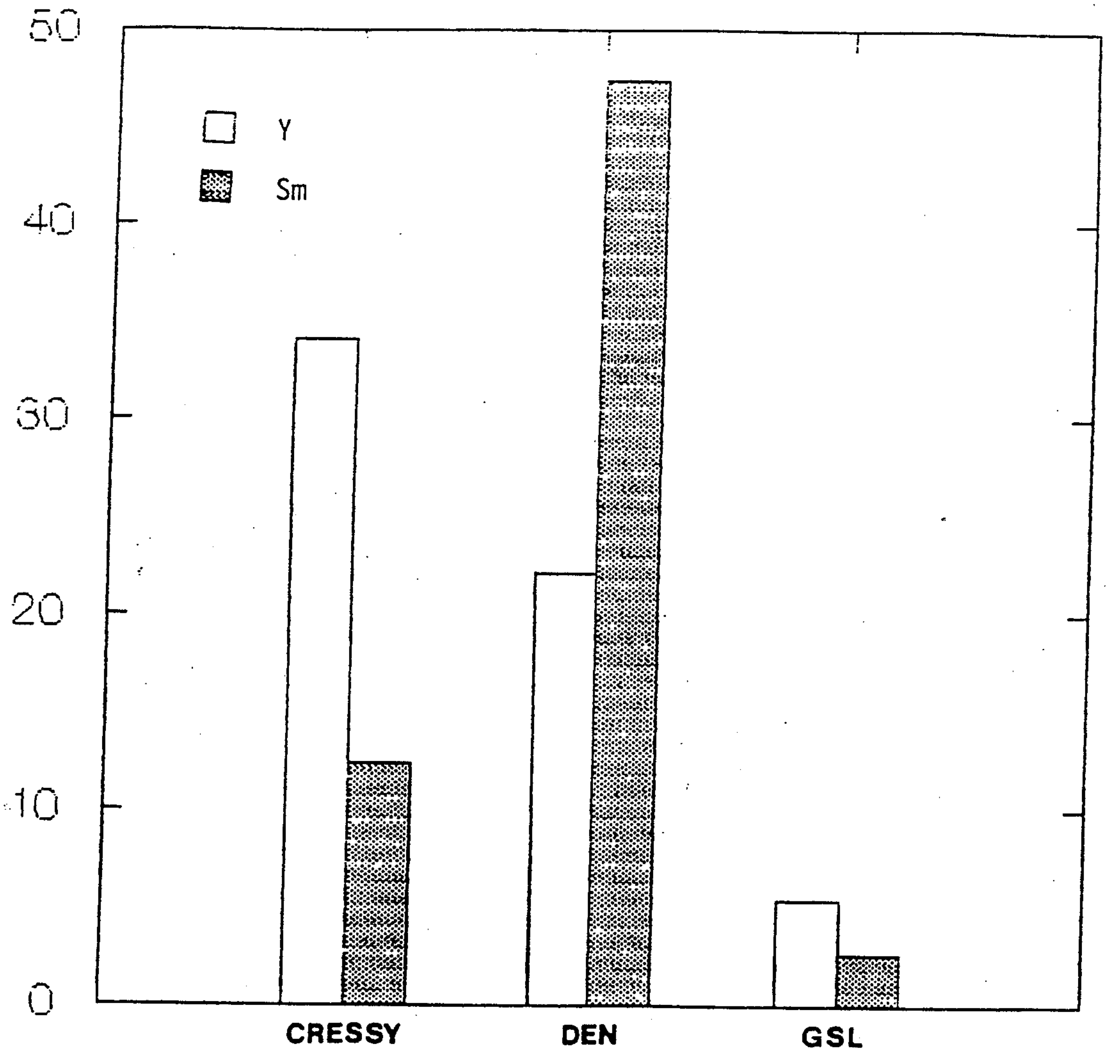

Figure 4.3 Mean Levels of Yttrium and Samarium (ug/g) in Cladina mitis from Three Sites Near Thor Lake.

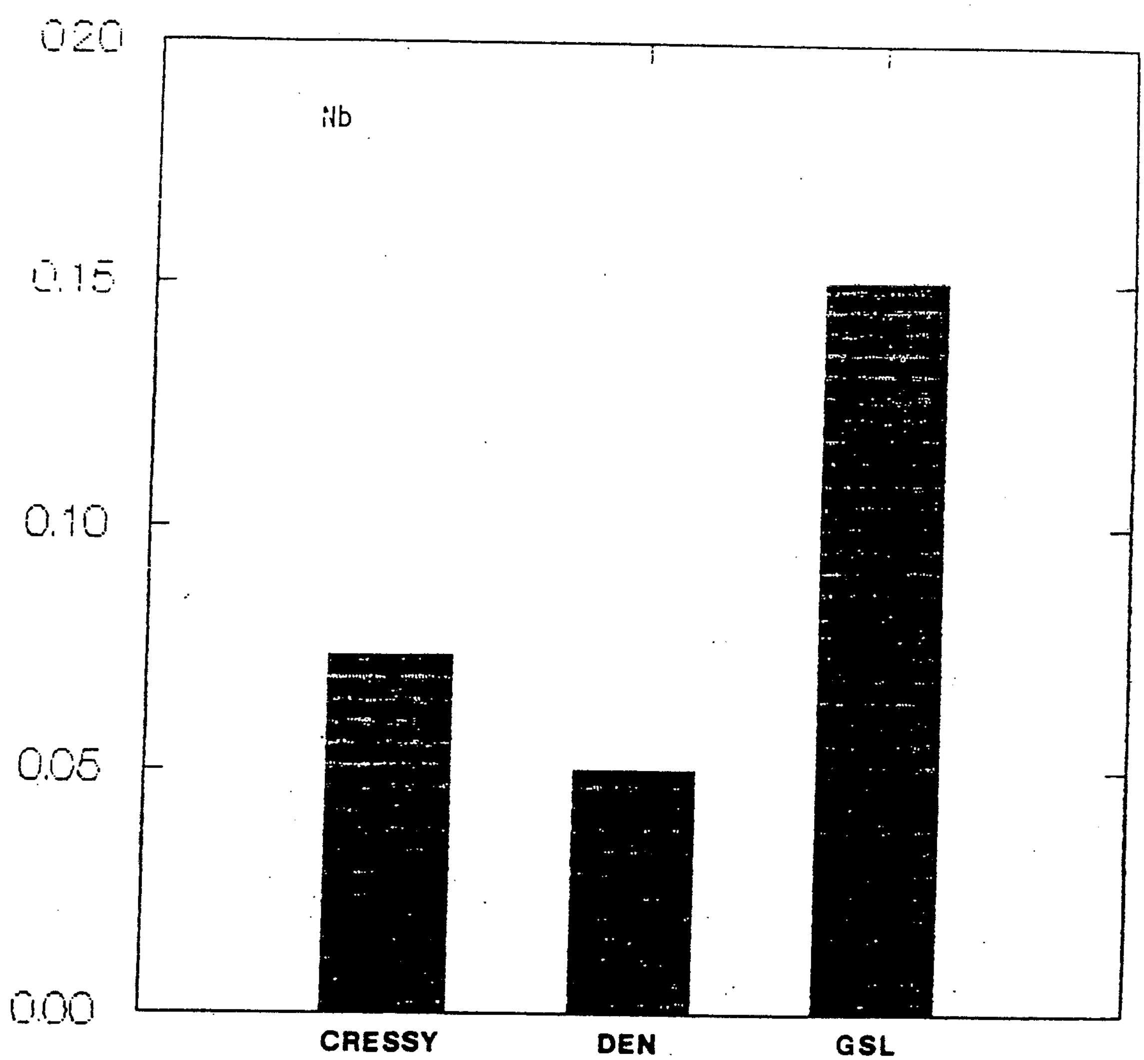

Figure 4.4 Mean Level of Niobium (ug/g) in Cladina mitis at Three Sites Near Thor Lake.

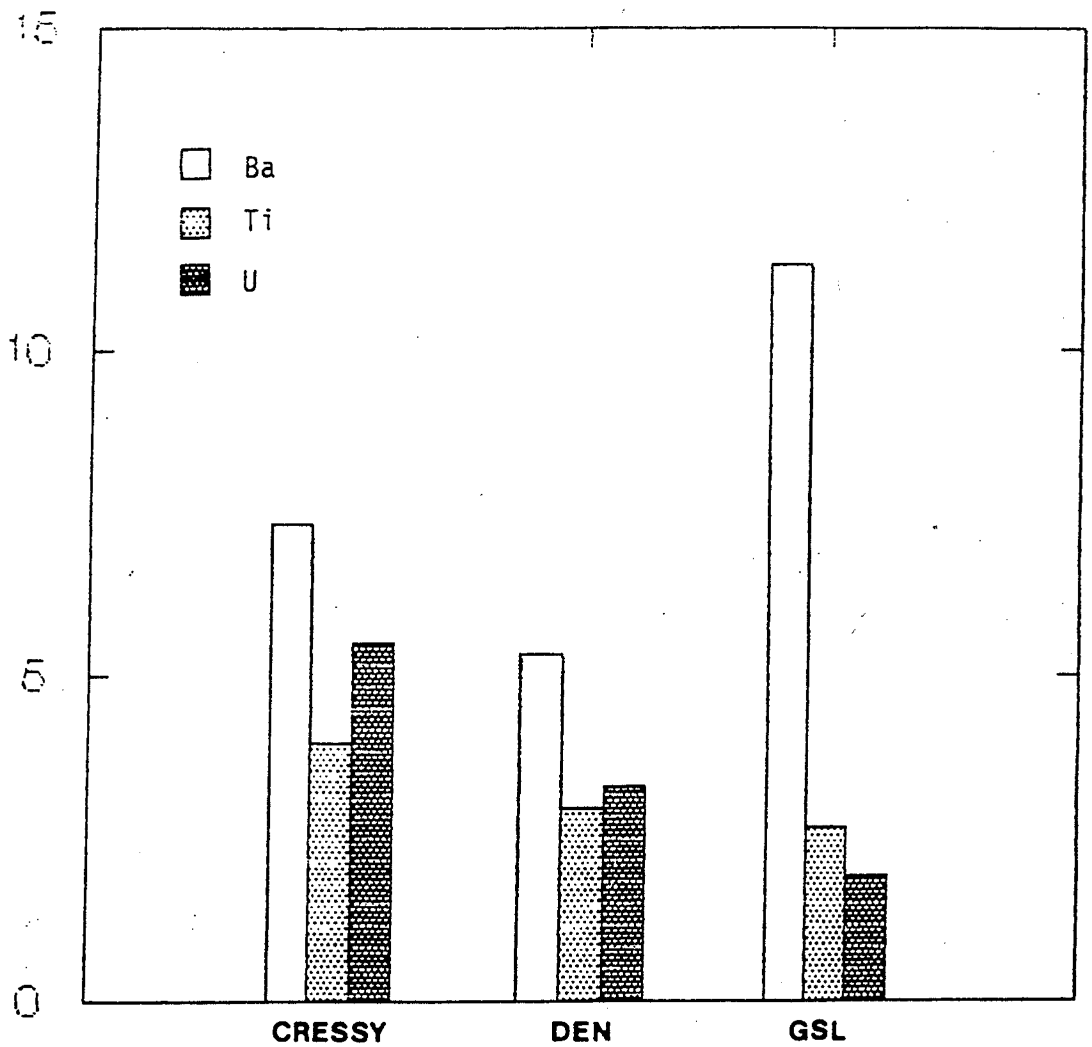

Figure 4.5 Mean Levels of Barium, Titanium and Uranium (ug/g) in Cladina mitis at Three Sites Near Thor Lake.

4.3.3.4 Radiochemicals

Of the radiochemicals examined, Th^{232} (Figure 4.6) showed the greatest range amongst sites. The Great Slave Lake samples had levels of Th^{232} below 0.02 Bq/g while the Den Lake samples averaged 0.33 Bq/g. Th^{230} (Figure 4.7) was also elevated in the samples taken near the proposed mine site. However, Ra^{226} (Figure 4.6) and Pb^{210} were marginally higher at the Great Slave Lake site than at the two sites near the development area. Ra^{228} occurred below the detection limits in all samples collected.

4.3.4 Conclusions

Elevated levels of some of the elements of interest insofar as the mine development is concerned occurred in the Cladina samples collected nearest the ore deposit. Ce showed the greatest range among sites, with levels two orders of magnitude greater at the mine site than at the Great Slave Lake site. These high levels may occur naturally because of proximity to the ore body. La, Nd and Sm were also higher at the Den Lake site. Levels in the Cressy Lake samples were intermediate between the levels in the Den Lake samples and Great Slave Lake samples. Anthropogenic causes of elevated element levels at Den and Cressy Lakes cannot be ruled out because of the exploration activity.

Kabatas-Pendias and Pendias (1984) quote results from two studies that give values for Ce, La, Nd and Sm in lichens and mosses. The results from the Den Lake samples at Thor Lake exceed the maximum values found in these other studies by two orders of magnitude. Even the control site at Great Slave Lake had values exceeding those from other studies by a factor of five.

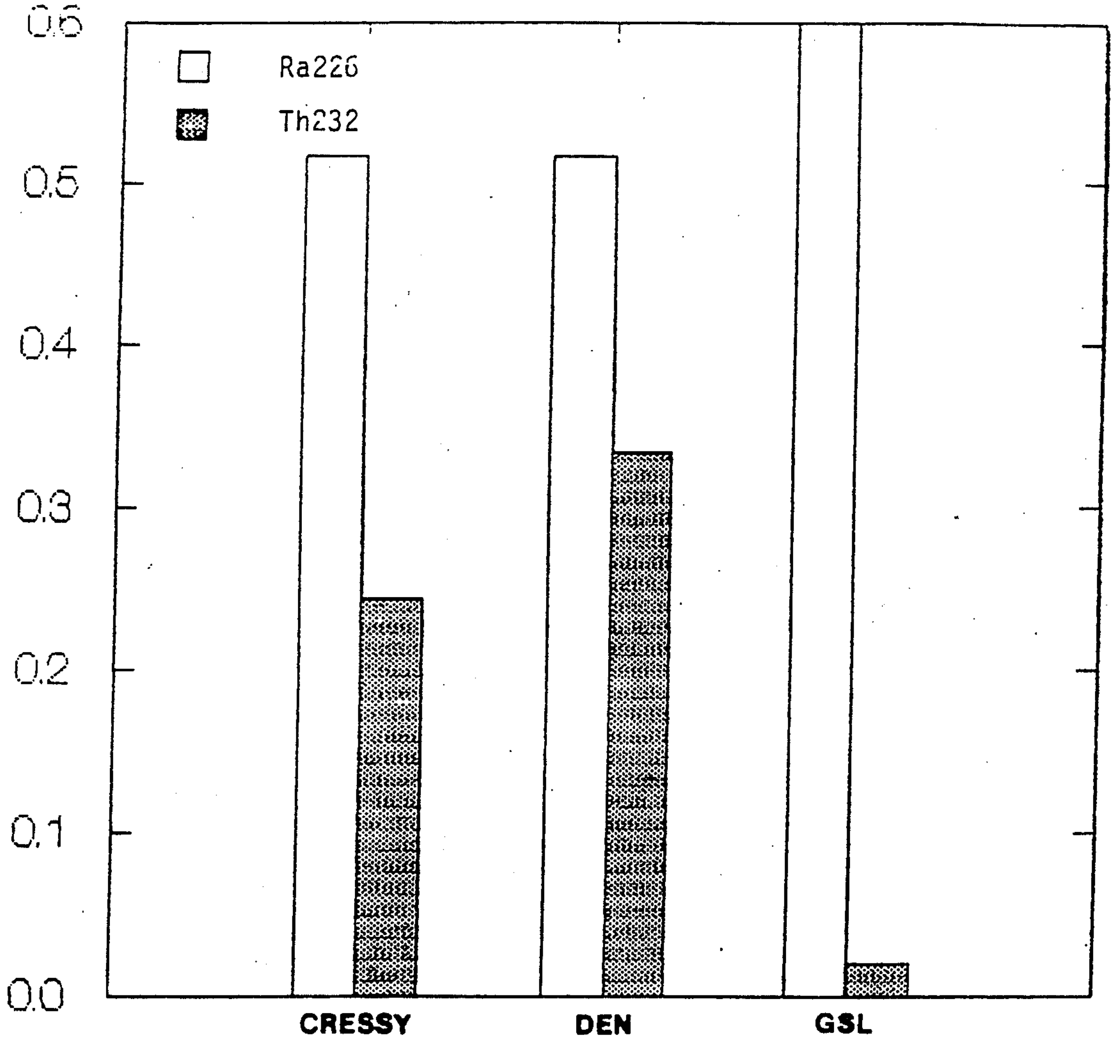

Figure 4.6 Mean Levels of Radium-226 and Thorium-232 (Bq/g) in Cladina mitis at Three Sites Near Thor Lake.

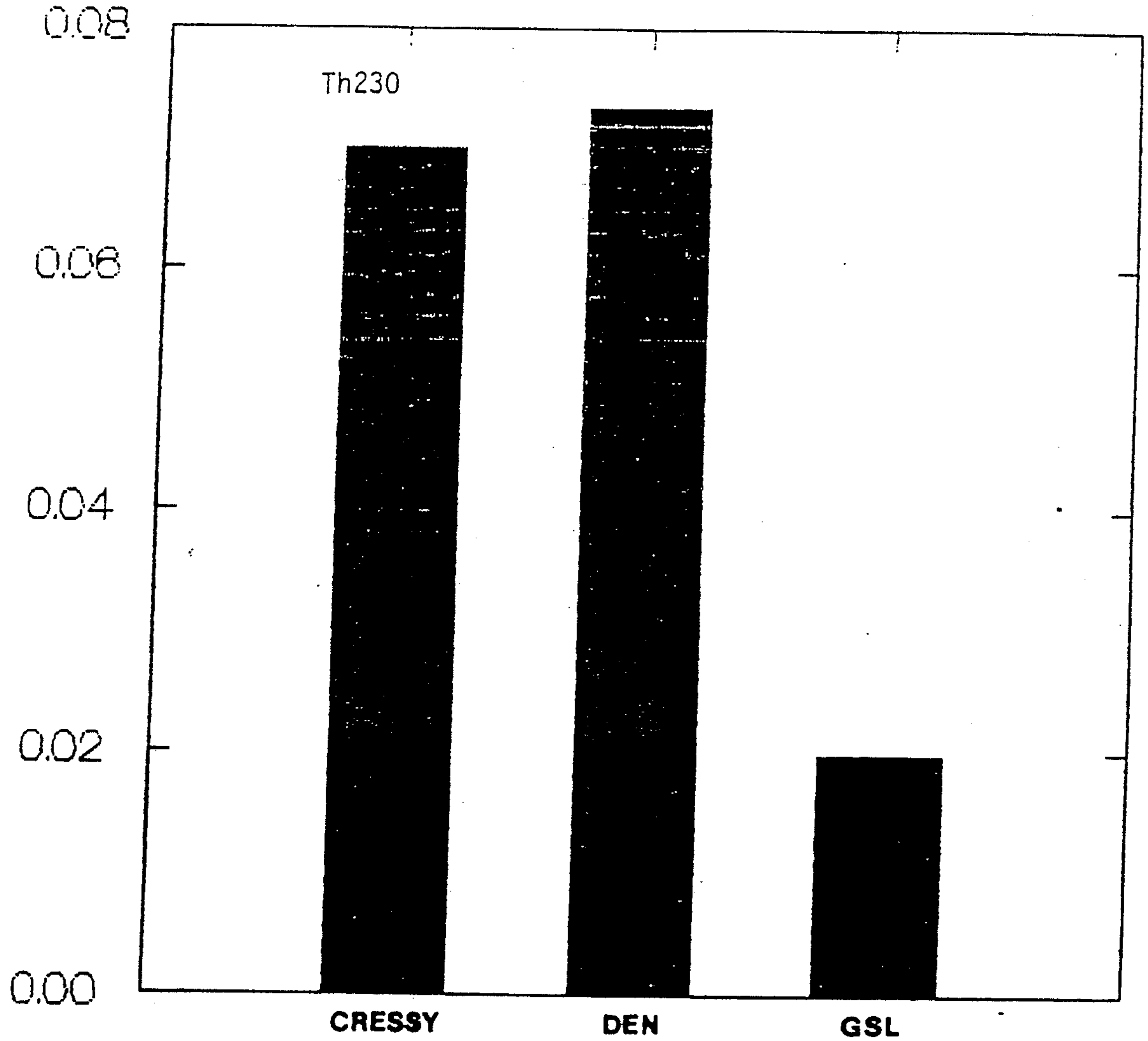

Figure 4.7 Mean Level of Thorium-230 (Bq/g) in Cladina mitis at Three Sites Near Thor Lake.

Elemental concentrations in Cladina mitis are recently available for three areas in northern Saskatchewan (Sheard et al. 1988). Metals common to both Sheard et al. (1988) and the current study are: Al, Ba, Be, Fe, Mg, Mn, Ti, and Zn. Ti and Al levels were approximately 50% lower in the samples from Thor Lake than in the samples from northern Saskatchewan. Concentrations of the other metals fall within the ranges for the Saskatchewan samples.

U levels in the samples from Thor Lake fall at the low end of the spectrum for Cladina mitis from Saskatchewan. However, this is not surprising as the Saskatchewan samples were collected largely in the uranium mining areas of that province. Pb^{210} and Ra^{226} values were similar at Thor Lake to levels in northern Saskatchewan.

While Be levels were below detection levels in Cladina mitis with the analyses technique used, levels in the waste rock from mining (unknown at present) may be of concern during closure of the mine. Be is known to inhibit germination of seeds and the uptake of Ca and Mg by roots (Kabatas-Pendias and Pendias 1984). Be concentrations between 2 and 16 ppm in solution are toxic to plants. For this reason, caution must be taken to prevent mixing of mine rock wastes with the replaced soils upon decommissioning of the mine site, or problems with reestablishing vegetation could occur.

4.4 Biophysical Classification

4.4.1 Introduction

A biophysical classification is based on the biological aspects of an area (vegetation) and the physical aspects (landforms and soils). These components are strongly interrelated, with each having some degree of effect on the expression of the other. Separate discussions of the vegetation communities and the soils and landforms are presented, then the two areas are integrated in a mapped classification system.

The vegetation description is based largely on results of the field survey. The soils are described based largely on available literature, but in combination with observations made in the field and from air photos.

4.4.2 Methods

The species of plants found at each site were recorded and a cover/abundance rating given for each species at a site. The scale used for recording this was a modified Braun-Blanquet scale with the following parameters:

r	solitary individuals with little cover value
+	few individuals, cover <1%
1	numerous individuals, cover 1-5%
2	any number, with cover of 5-25%
3	any number, with cover of 25-50%
4	any number, with cover of 50-75%
5	any number, with cover >75%

Where possible, several replicate sites were visited for each apparent vegetation community type. These were then grouped and the most important species based on cover or abundance or uniqueness to one community type were identified and used for the community characterization. Any physical properties that were characteristically associated with a community type were also identified. Observations made of soil characteristics during these site visits were used to match soil features to existing soil classification information for the area.

Biophysical boundaries were drawn on air photo mosaics of the Thor Lake area. The boundaries were based largely on major changes in physical characteristics. Within each map unit the mix of vegetation units is described in relation to the landforms present in that map unit.

4.4.3 Results and Discussion

4.4.3.1 Vegetation

<u>Ecoregion</u>

The Thor Lake area falls within Rowe's (1972) northwestern transition section of the boreal forest, which is described as open subarctic woodland. However, Bradley et al. (1982) state that through northern Manitoba, Saskatchewan, and the district of MacKenzie as far as Snowdrift, the boundary separating the northwestern transition zone from the boreal closed coniferous forest was placed too far south. They define the low subarctic ecoregion as being characterized by open woodlands of black spruce with a ground cover of reflectant lichens, whereas the boreal ecoregion is characterized by the prevalence of closed crown forests.

In the Thor Lake area, closed forests of black spruce occur on mesic sites of thin till over bedrock, with a ground cover of feathermosses. This forest type falls within the boreal ecoregion classification and indicates that Rowe's (1972) boundary between northwestern transition and boreal closed coniferous forests should occur somewhere to the north of the east arm of Great Slave Lake. However, the paucity of herbaceous species in the forests of the Thor Lake area suggests that this area is near the northern limits of the boreal ecoregion. The boundary for the two mentioned ecoregions, therefore, probably occurs a short distance to the north of Thor Lake with just a narrow band of closed boreal forest occurring along Great Slave Lake. This is what Bradley et al. (1982) showed farther east along Great Slave Lake.

Vegetation Communities

Rock - Lichen Woodland

The southern and eastern portions of the lease area are dominated by rock outcrops of moderate relief. The crests and much of the slopes of these outcrops are bare of soil cover and support a sparse vegetation community. Plant distributions are controlled by presence of small amounts of organic and mineral soil present in rock fractures, and depressional areas.

The dominant tree species on these sites in order of abundance are: jack pine, black spruce, paper birch, and white spruce. The trees are well spaced, generally being in the order of 10 m apart. On some of the highest ridges in the eastern portion of the lease area the crests are nearly barren, with an occasional white spruce in a sheltered hollow.

The shrub and grass-forb community on these sites are diverse; 39 taxa were observed on eight sites that were examined. No single shrub or herbaceous species dominated these sites. *Arctostaphylos uva-ursi* and *Juniperus communis* were the most abundant shrubs. *Amelanchier alnifolia*, and *Rosa acicularis* were also present at most sites. While a high diversity of herbaceous species were encountered, few were consistently present at the different sites examined. The most frequently occurring species were *Saxifraga tricuspidata*, *Cryptograma crispa*, Calamagrostis purpurascens, Festuca saximontana, and Poa glauca. Many of the species encountered on this site are disturbance species. They include Agrostis scabra, Corydalis sempervirens, Epilobium angustifolium, and Achillea millefolium.

Rock - White Spruce - Woodland

The rock slope immediately above Great Slave Lake generally supports a vegetation community similar to rock outcrops away from the lake. However, a few noticeable differences are apparent. White spruce almost totally dominates this rock slope, whereas it is subdominant to black spruce and jack pine on rock outcrops beyond the lake ridge. Dryas integrifolia is common on this slope down to the lake. Summer daytime temperatures probably do not climb as high on the slope as they do inland from the lake. Thus, the change in dominant tree species and the common occurrence of Dryas integrifolia, which is totally absent away from the lake, may be caused by a microclimatic difference on the slope to the lake.

Alder - Heath - Woodland

This community type occurs on deposits of glacial till on rock slopes. They are of shallow depth with loamy sand to sandy loam textured soils. The combination of the light soil texture with the slope position results in these sites being relatively well drained. However, they receive much moisture, including runoff from the surrounding rock.

A closed canopy forest dominated by black spruce, but containing jack pine, exists on most sites. Betula neoalaskana and Picea glauca also contribute to canopy cover on many of these sites. Four species of shrubs are common on these sites while few other species occur. Alnus crispa often exceeds 5% cover value. Vaccinium vitis-idaea, Arctostaphylos rubra and Ledum groenlandicum are common throughout this forest type although they contribute less than 5% cover each. Geocaulon lividum is the only regularly occurring forb.

Feathermosses form extensive ground cover mats with Pleurozium schreberi, Hylocomium splendens, and Tomenthypnum nitens being the most abundant. Openings may have well formed lichen stands of Cladina mitis, C. rangiferina and to a lesser extent C. stellaris.

Deciduous Woodland

Sandy loam glacial deposits of shallow depth support woodland communities of almost pure Populus tremuloides. These deposits occur near the crest of rock outcrops on south slopes. Because of the limited extent of this combination of slope aspect, till depth and slope position, this community type represents a small percentage of the total area in the lease area. This flora is at the northeast extremity of the range of aspen. A depauperate aspen-related flora was associated with these stands. Pyrola secunda was seen at only one location other than in aspen stands in this region. Linnaea boreale was largely limited to this site type, as was Viburnum edule.

Disturbance Vegetation

Disturbance species are largely limited to rock outcrops where natural disturbances, such as wind-throw of trees, has created suitable habitat. However, the added human disturbance of the exploration activities at Thor Lake has opened up comparatively large areas of mineral soil on well drained till slopes and saturated lowlands. This has resulted in an abundance of disturbance species appearing in a relatively confined area. On upland sites the commonest species are *Carex aenea*, *Rubus strigosus*, *Corydalis sempervirens*, *Epilobium angustifolium*, and *Matricaria matricarioides*. On wet sites *Typha latifolia*, *Equisetum* spp. and *Eriophorum* sp. were appearing sporadically. Species of less common occurrence on dry to moist sites were *Achillea millefolium*, *Campanula rotundifolia*, *Corydalis aurea*, *Geranium bicknellii*, *Aquilegia brevistyla*, *Epilobium angustifolium* and *Chenopodium capitatum*.

Moist to Wet Bog Forest

In the northeastern portion of the lease area extensive areas of relatively flat till cover and possibly lacustrine deposits occur. The Gleysolic soils of these sites support moist to wet black spruce woodlands with generally shallow peat accumulations. The ground cover is largely feathermosses consisting mainly of *Pleurozium schreberi*, and *Dicranum* spp. with *Hylocomium splendens* being locally abundant. As sites become wetter, *Sphagnum* (mainly *Sphagnum fuscum*) becomes more pronounced as a component of the ground cover. Vascular plant species on these sites are relatively limited. *Arctostaphylos rubra*, *Ledum groenlandicum*, *Vaccinium uliginosum* and *Vaccinium vitis-idaea* are the dominant shrub species in this type. Other species of regular occurrence are *Salix myrtillifolia*, *Rubus chamaemorus* and *Equisetum scripoides*. On the more open, drier locations *Empetrum nigrum* and lichens (*Cladina mitis*, *C. rangiferina*) become a visible part of the community.

Peat Plateau Woodlands

Peat plateaus are not extensive in the area but do occur at margins of fens around some lakes. These sites are treed with black spruce and have an abundant lichen cover composed mainly of Cladina mitis and Cetraria nivalis. The ericoid cover is mainly of Ledums, with Ledum decumbens apparently restricted to these sites in this area. Other abundant species are Vaccinium uliginosum, Vaccinium vitis-idaea, and Rubus chamaemorus. Andromeda polifolia also occurred sparingly on these sites. At the margins of the peat plateaus, where they degrade to fen (evidence of thermal collapse), Arctostaphylos rubra, Myrica gale and Alnus tenuifolia occurred.

Sedge Fen

Floating organic mats border several small lakes in the study area. These are formed from the vegetative remains of grass-like plants (largely sedges and some cottongrass) and are consolidated by the rhizomes of such species as Carex limosa and C. magellanica. These mats may also support Larix laricina, Myrica gale and Betula glandulosa near shore, where they are in contact with the substrate.

4.4.3.2 Soils

Soil Development Factors

Soil development is dependant on several factors, the main ones being surficial geology, climate, vegetation, and time. Surficial geology is important in that it dictates the texture of the soil over the short term. Since deglaciation has happened relatively recently, weathering has had little affect on the grain size distribution of mineral soil particulates in the Thor Lake area. The soils of the Thor Lake area appear to have developed on two major types of deposits. These are glacial till and lacustrine deposits. Craig (1965) showed the maximum extent of glacial Lake McConnell to exclude the area around Thor Lake. However, he gives examples of lacustrine deposits up to elevations of 900 feet, higher than Thor Lake. Presumably this area was ice covered at the time glacial Lake McConnell was extent. Others (Jacobson 1980; Douglas 1967; Bradley et al. 1982) suggest this area was influenced by glacial Lake McConnell and therefore lacustrine deposits may occur.

Disturbance caused by exploration activity at Thor Lake at elevations of 800 feet expose glacial till deposits of sandy loam to loamy sand texture. This does not exclude the possibility of the area being affected by a glacial lake, since if water levels were shallow or inundation was of short duration, lacustrine deposition may not have taken place. The land to the northwest of Thor Lake continues to decline in elevation to below 750 feet, and general relief diminishes with relatively large areas of bog forest occurring. This suggests the possibility that Thor Lake may lie at the edge of glacial Lake McConnell. Indeed, with elevations in the lease area ranging from in excess of 900 feet to below 750 feet, this area could well have been at the maximum shoreline height of glacial Lake McConnell in the area.

The climate of the area is continental subhumid with long cold winters and short cool summers. The soil climate (Clayton et al. 1977) is described as subarctic humid. Mean annual soil temperatures are between -7°C and 2°C with summer soil temperatures 5°C to 8°C. The growing season is less than 120 days. There is widespread discontinuous permafrost in this region. Soils are not dry at any site for long, hence only slight deficits in soil moisture occur during the year. These deficits are less than 6.4 cm.

Organic deposits are common and extensive in the northwestern corner of the lease area. In this climatic region, decomposition of the organic remains of the vegetation is slow. Under certain conditions the plant remains may accumulate and form the soil.

Soil Classification

The map in Clayton et al. (1977) indicates this region is predominantly rock with Orthic Gleysols being subdominant. Associated with the rock are areas of Brunisols where glacial till is deep enough to allow soil formation. The Orthic Gleysols are associated with lacustrine and glaciofluvial deposits.

More detailed soil classification has been carried out for the Lockhart River map area adjoining the Thor Lake area to the east. On shallow till (of the same texture as at Thor Lake) over bedrock, in the boreal ecoregion, soils are classified as being in the Nonacho Lake 2 soil association. This association includes Eluviated Dystric Brunisols in well drained positions, Gleyed Dystric Brunisols in imperfectly drained locations and peaty phase Rego Gleysols on poorly drained sites.

On lacustrine deposits along the east arm of Great Slave Lake, soils are put in the Redcliff Island soil association. This consists of Orthic Turbic Cryosols and Gleysolic Turbic Cryosols. The Orthic Turbic Cryosols are well drained while the Gleysolic Cryosols are poorly drained.

Because of the similar soil texture found at Thor Lake to that described for the Nonacho Lake association, in combination with similar forest types and climatic zones, this soil classification should apply to the Thor Lake area as well. Low areas in the northwest of the lease site which appear to have been under the influence of glacial Lake McConnell correspond to the Redcliff Island association.

4.4.3.3 Biophysical Classification Units

Seven biophysical units were mapped in the Thor Lake study region (Figure 4.8). Each unit consists of one or more vegetation communities; proportions vary within the unit (Table 4.2). Two units may have the same two vegetation communities in them but at different percentages of occurrence.

The first map unit is an extensive rock slope between the upland north of Great Slave Lake down to the shore of the lake. This is occupied by the rock-white spruce woodland type. Large depressions parallel to the lake shore along the slope are occupied by alder-heath woodland.

Map unit number two is an ice-scoured rock upland with mineral soil restricted to fracture zones in the rock. Rock-lichen woodland dominates this map unit with alder-heath woodland and bog forest contributing to the vegetation communities only in the rock fractures.

The third map unit is a mosaic with rock outcrops and with rock-lichen woodland vegetation occurring as evenly spaced islands in a matrix of alder-heath woodland and bog forest. The latter vegetation types occur on extensive glacial till deposits which occupy all areas surrounding the crests of the rock knobs. Exposed rock outcrops are in

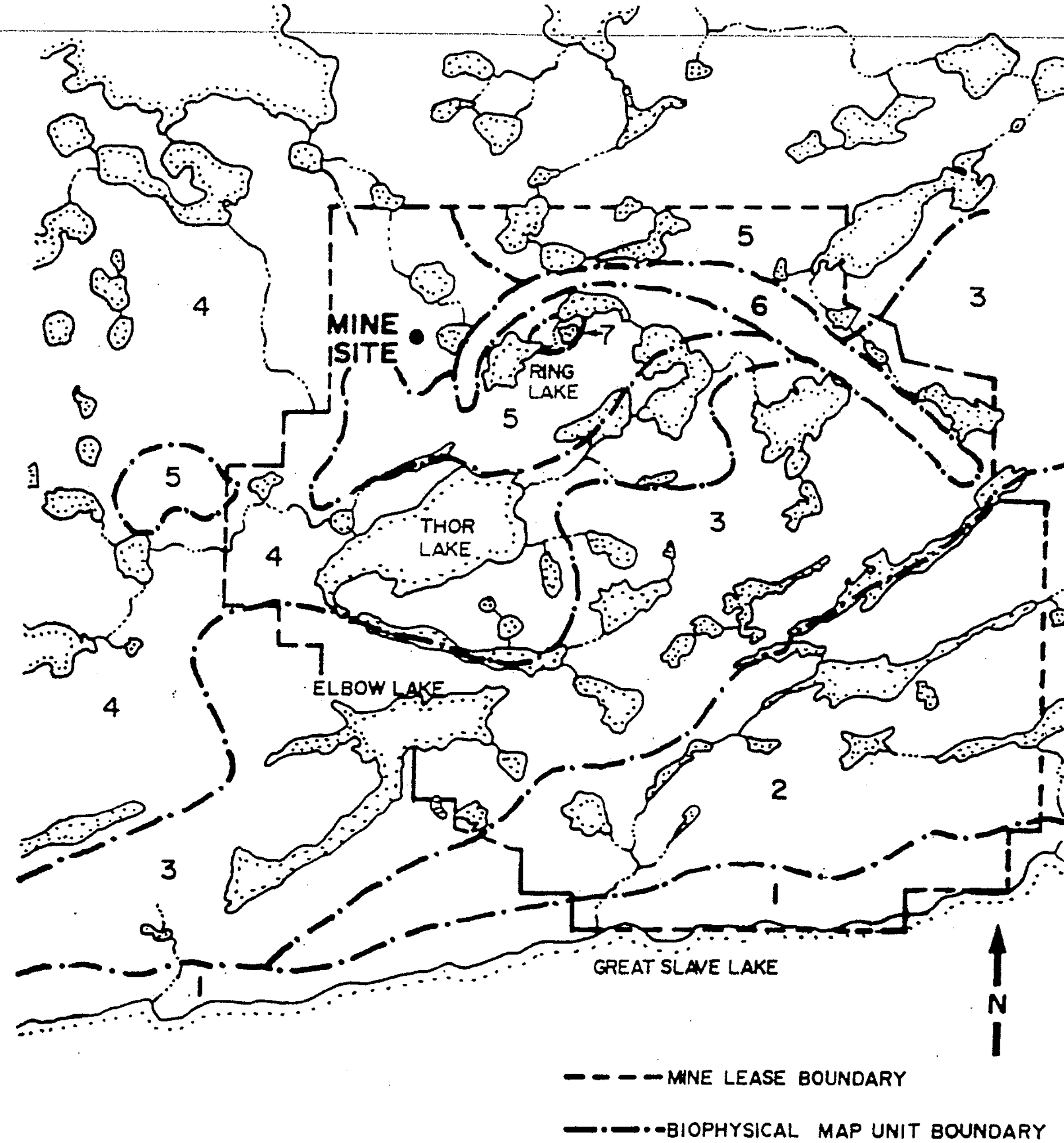

Figure 4.8 Biophysical Map of the Thor Lake Area.
(Map units are described in Table 4.1)

Table 4.2 Percentage of Areal Coverage of Vegetation Community Types Within Each Biophysical Map Unit.

Biophysical Map Unit	Vegetation Communities	Percentage Areal Coverage
1	Rock-white spruce woodland	65
	Alder-heath woodland	35
2	Rock-lichen woodland	80
	Alder-heath woodland	15
	Bog forest and sedge fen	5
3	Rock-lichen woodland	30
	Alder-heath woodland and bog forest	70
	Sedge fen and peat plateau	<1
4	Bog forest	70
	Rock-lichen woodland and alder-heath woodland	25
	Sedge fen and peat plateau	5
5	Rock-lichen woodland	40
	Alder-heath woodland	55
	Bog forest	5
6	Rock-lichen woodland	75
	Deciduous woodland	15
	Alder-heath woodland	10
7	Sedge fen and peat plateau	100

the order of 100 m diameter. Small areas of sedge fen and peat plateau are associated with a few of the smaller lakes in this map unit.

The northwest corner of the lease area (map unit 4) and extensive land areas beyond this are dominated by bog forest. Scattered islands of rock-lichen woodland surrounded by a ring of alder-heath woodland occur throughout this map unit. The topographical relief in this area is less than areas to the east and south and the mean elevation is lower as well. This region may have occurred at the edge of glacial Lake McConnell. Lakes in this area are frequently ringed by sedge fen and many have extensive beds of aquatic vegetation.

A transition region (map unit 5) occurs between the lowlands of map unit 4 and the upland rock of map unit 3. This area has approximately equal areas of rock-lichen woodland and alder-heath woodland. No visible pattern to the vegetation is apparent in this area.

Map unit 6 is a large crescent shaped rock ridge of high relief. It is dominated by rock-lichen woodland. Thin till veneer occurs in hollows on the slopes. On favourable till sites with southwest exposures the only deciduous communities of the region are found. The remaining till sites have alder-heath woodland. Map unit 7 is a large sedge fen bordering three small lakes. Peat plateau is peripheral to this in some areas.

4.5 References

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5 WILDLIFE STUDIES

5.1 Introduction

The purpose of this study is to characterize the wildlife potential of the Thor Lake mine lease and the area immediately to the west of it. Investigations completed to date include aerial surveys for active beaver lodges and fall waterfowl. Studies to be completed include winter ungulate and spring raptor aerial surveys.

5.2 Methods

An aerial reconnaissance and surveys of the study region (Figure 5.1) were made on August 31 and September 1, 1988. The waterfowl and beaver lodge surveys coincided spatially, covering an area of 134 km^2 (Figures 5.1, 5.2).

The expansion of the survey block to the west of the mine lease site was done in response to the initial look at the area. This allowed me to compare the frequencies of waterfowl and beaver between the mine lease region and the area to the west, which appeared to represent more suitable habitat.

Surveys were flown using a Cessna 182 fixed-wing aircraft with the pilot and a navigator-recorder in the front of the aircraft, and two observers in the rear of the plane. Flight elevations ranged from 75 to 100 m and the speed, 75 to 80 km/hr. The combined waterfowl and aquatic furbearer surveys were flown in a pattern which included all wetland habitat in the survey block. Wildlife observations were recorded on 1:50,000 scale NTS maps for future analysis.

A beaver lodge was considered active if a freshly constructed food cache was visible. Wherever possible, waterfowl were identified to

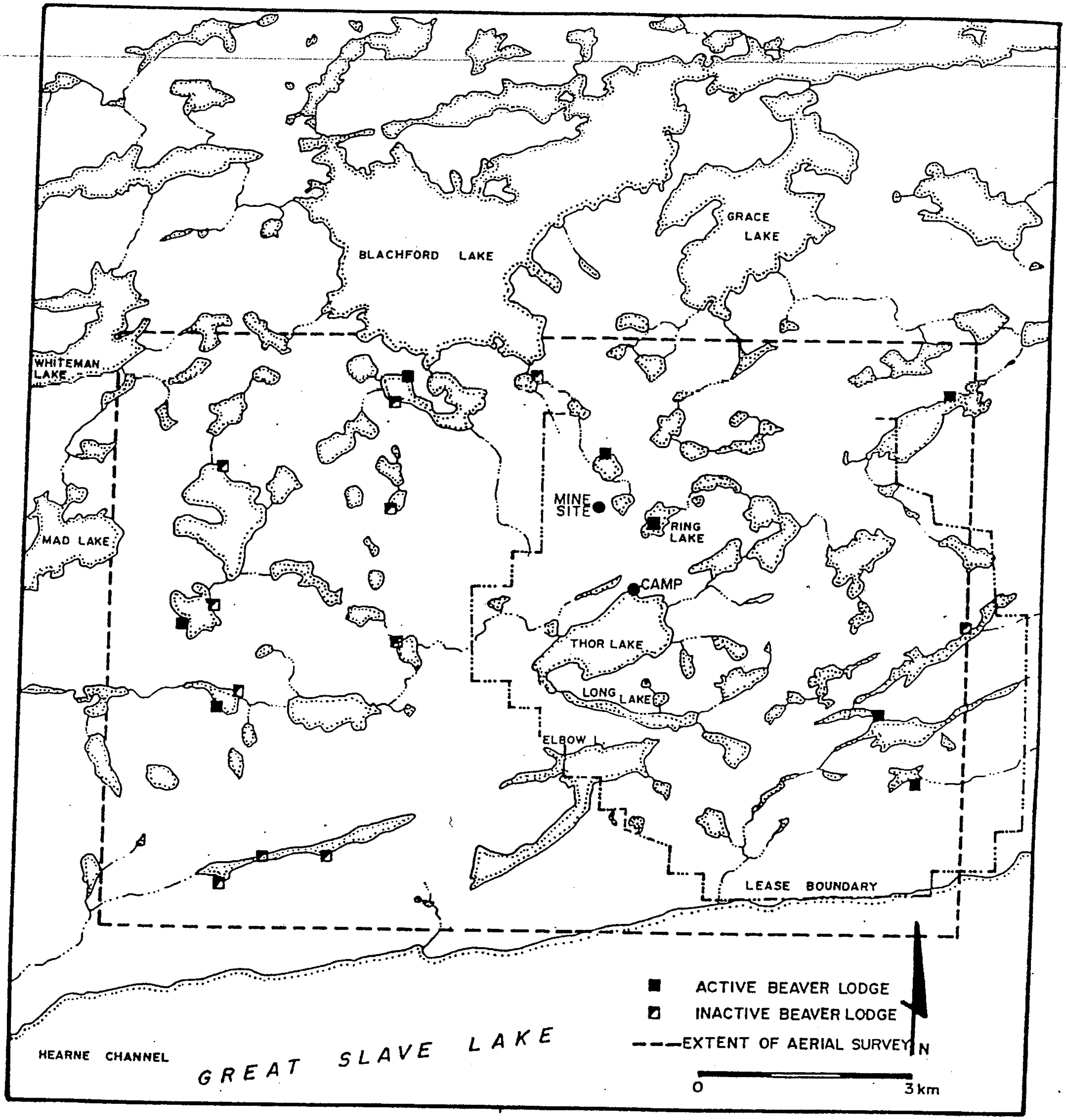


Figure 5.1 Locations of Beaver Lodges in the Thor Lake Area, Fall, 1988.

Legend for Figure 5.2

1. 4 Common Mergansers
2. 1 Common Loon
3. 10 Mallards
4. 35 Ring-necked Ducks
5. 4 Mergansers Species
6. 1 Common Loon
7. 1 Ring-necked Duck
8. 5 Mallards
9. 2 Arctic Loons
10. 4 Mallards
11. 1 American Coot
12. 40 Ring-necked Ducks
13. 8 Mallards
14. 25 Diving Ducks
15. 35 Ring-necked Ducks
16. 1 Diving Duck
17. 4 Ring-necked Ducks
18. 1 Loon Species
19. 2 Common Loons
20. 2 Common Loons

A. Adult Bald Eagle Flying

B. Raven Flying

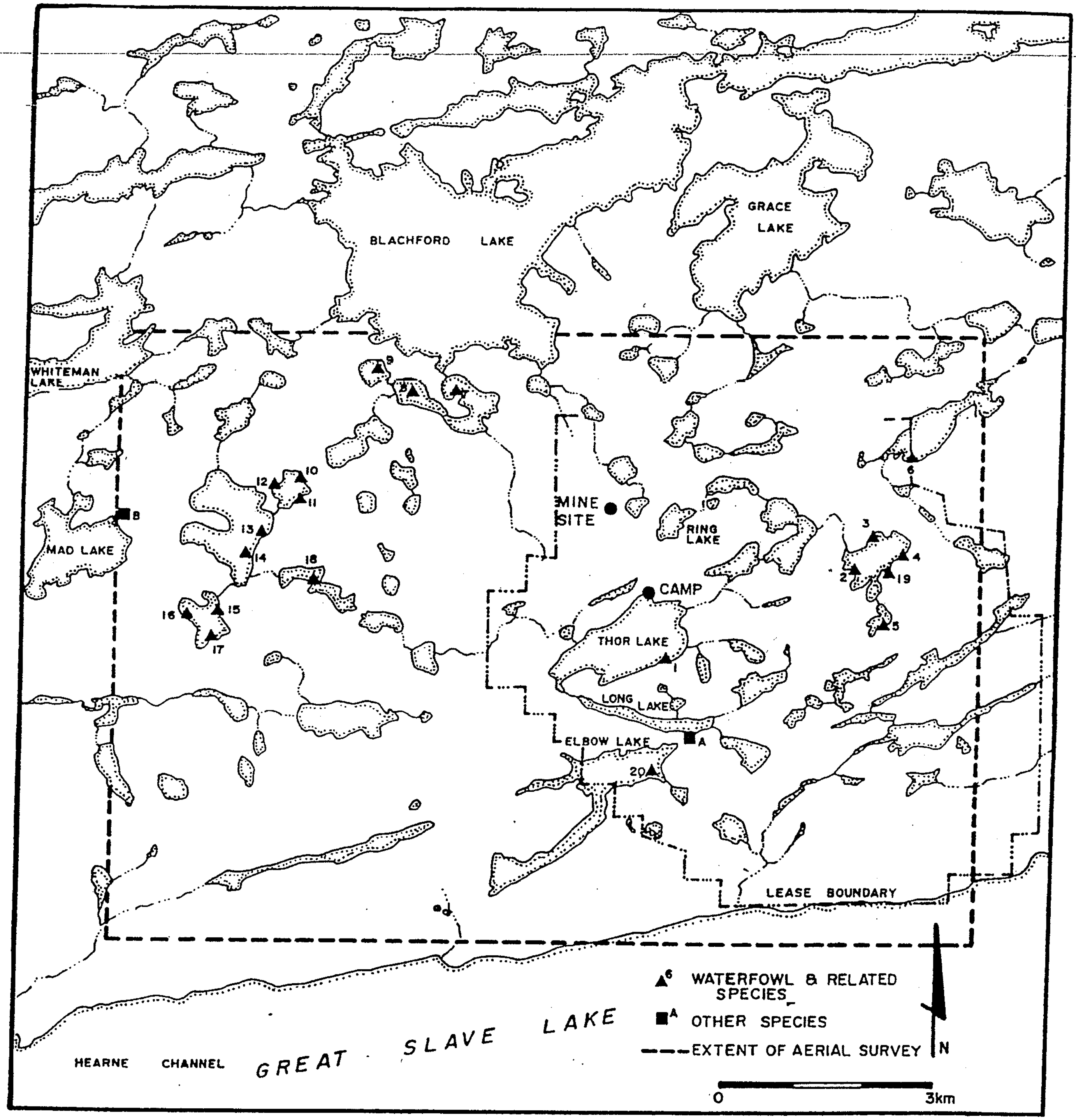


Figure 5.2 Aerial Observations of Avian Species in the Thor Lake Area, Fall, 1988.

species or groups. Incidental wildlife observations made by crew members were also recorded on the maps.

5.3 Results and Discussion

5.3.1 Beaver Lodge Survey

A total of eight active lodges, or one active lodge per 17 km, were recorded (Table 5.1). The portion of the survey block lying west of the mine lease area supported a higher density of beaver lodges, although more active lodges were located within the lease area (Figure 5.1).

The region west of the mine lease appears more attractive to beaver, with over 200% more lodges observed. The large number of inactive lodges there compared to the mine lease area (Figure 5.1) also suggests that the habitat supports a more dynamic population with greater population fluctuations.

No suitable shallow water bodies or other features (i.e., houses or "push-ups") were observed during the surveys which would indicate muskrat activity.

5.3.2 Waterfowl Survey

Results of the waterfowl survey are shown in Figure 5.2 and tabulated in Table 5.2. A total of 196 waterfowl were observed during the flight. The ring-necked duck (_Aythya collaris_) was the most common diver, and the mallard (_Anas platyrhynchos_) was the only dabbling species identified. The other species observed included several Arctic loons (_Gavia arctica_).

The distribution of waterfowl was not uniform, as twice as many birds were observed outside the mine lease area. The northwest corner

Table 5.1 Beaver Lodges in the Thor Lake Area, Fall, 1988.

Status	Number of Lodges	Lodges/km^2*
Active	8	17.1
Inactive	11	12.2

*Based on aerial survey of 134 km^2.

Table 5.2 Waterfowl Observed During A Fall Aerial Survey of the Thor Lake Area, 1988.

Species/Groups	Numbers
Common loon	8
Arctic loon	2
Ring-necked duck	125
Common merganser	4
American coot	1
Mallard	27
Unidentified divers	25
Unidentified ducks	4
Total waterfowl	196

of the survey block, in particular, appears to contain some relatively good waterfowl habitat. Several shallow lakes with extensive emergent vegetation occur there.

5.4 Conclusions

The habitats within the mine lease could support diverse resident wildlife. However, a more detailed assessment must wait until the surveys for ungulates and raptors have been completed. The survey for ungulates, specifically moose (Alces alces) and barren ground caribou (Rangifer tarandus), will probably take place in February, 1989. The final survey will be conducted in early summer to coincide with the raptor breeding cycle. This survey will extend some distance along the north shore of Hearne Channel, in order to identify any cliff nesting species such as the peregrine falcon (Falco peregrinus). This species could be affected by increases in water traffic associated with the development and operation of the mine.

6 ARCHAEOLOGY STUDIES

6.1 Introduction

The objectives of the Thor Lake archaeological survey were to:

a) review the relevant literature,

b) examine, on foot, areas which might have been used as campsites, whether in the historic period or in precontact times,

c) record the locations of archaeological sites discovered,

d) record the characteristics (e.g., size and nature of terrain) of sites found, and

e) recover samples of exposed artifacts.

The study location consisted of, primarily, areas to be affected by construction as outlined in the general introduction. Areas where disturbances had already occurred were examined, in case any artifacts remained which might indicate site locations and the need for further testing. As well, selected areas neighbouring the mine site were looked at to determine the importance of the area in prehistoric times.

The north shore of Great Slave Lake immediately south of Thor Lake is of special archaeological interest. There are few protected locations conducive to camping along the shore because it is marked by sudden relief, rising as much as 70 m within 0.5 km of the shoreline. Topographical maps and local information indicate that the most desirable sheltered locations occur at the mouths of the Francois and Beaulieu Rivers, some 15 and 28 km to the west, respectively, or at McKinley Point, 10.5 km east. According to topographic maps, the beach and point of land marking the start of the road from Great Slave Lake to Thor Lake would have provided one of the few accessible camp spots between these locations.

All artifacts collected as well as field notes, a site report and photographs are deposited with the Prince of Wales Museum, Yellowknife. A copy of the site report is deposited with the Canadian Museum of Civilization, Ottawa.

6.1.1 Areas Examined

Six areas were examined:

a) The docking area on Great Slave Lake (Figure 6.1). This includes the beach, the point of land to the southeast, between the water and the road, and the first 100 m of road. This stretch of road was surveyed as far as the base of the steep rock hill bordering the north shore of the lake.

b) The first 2 km of the road to Great Slave Lake (Figure 6.2). This section occurs between the mine site and Fred Creek, draining Thor and Fred Lakes.

c) The mine site proper (Figure 6.2). This site covers an area from the southwest shore of Den Lake to 0.5 km west of the lake, and from the north end of the open pit area 0.75 km south to the future monitoring ponds. The proposed waste dump area, 0.25 km north of the mine, was not examined in detail as it consisted of low-lying boggy ground.

d) The area between Thor and Cressy Lakes (Figure 6.2), especially the shoreline of Thor Lake, from the present construction camp west to the outlet of Thor Lake.

e) The high rock ridges adjacent to the mine site (Figure 6.2). To the south, this ridge includes the north shore of Cressy Lake, and the

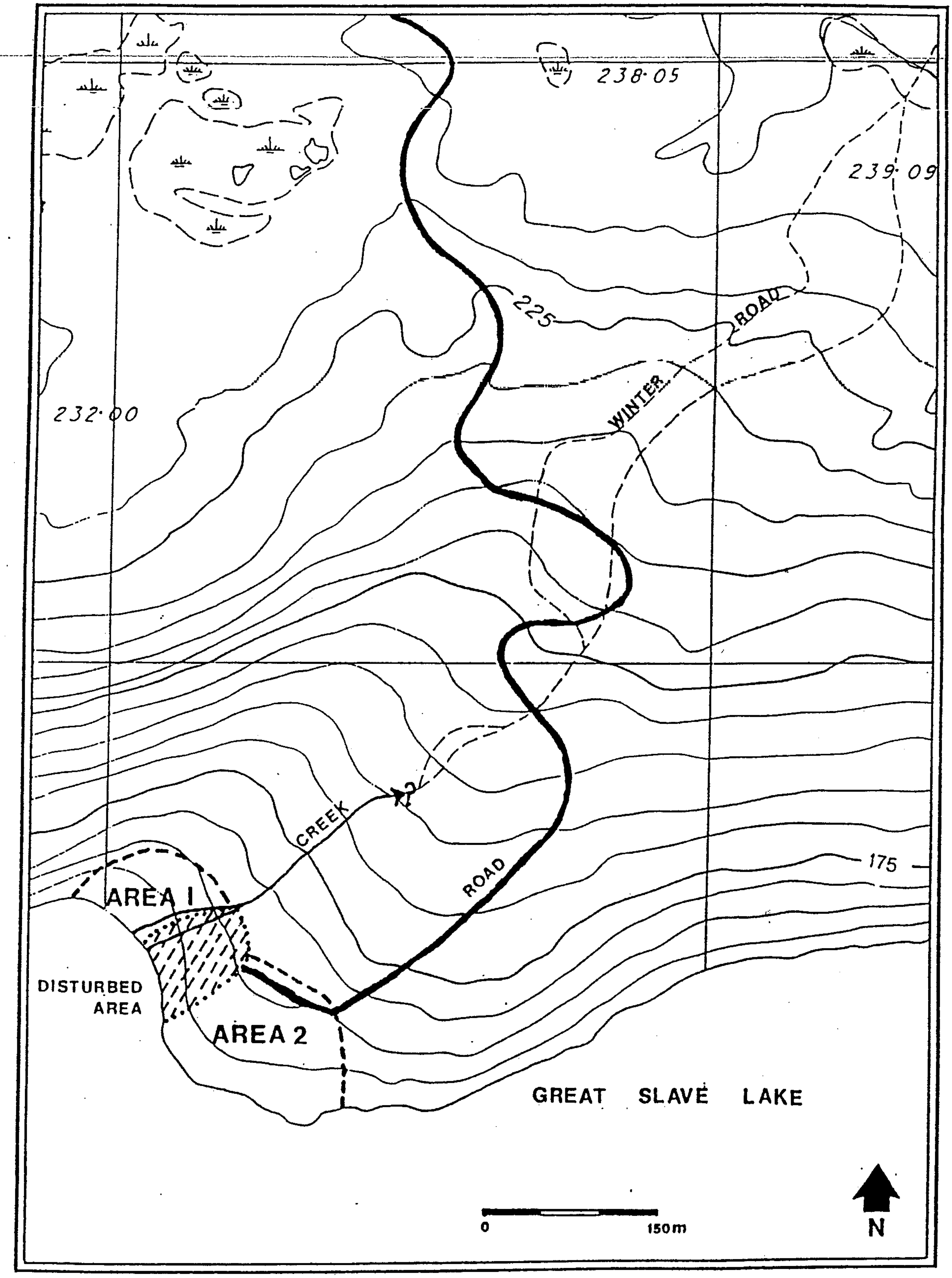


Figure 6.1 Map of the Reg Site (KaPb-4) on the North Shore of the Hearne Channel, Great Slave Lake.

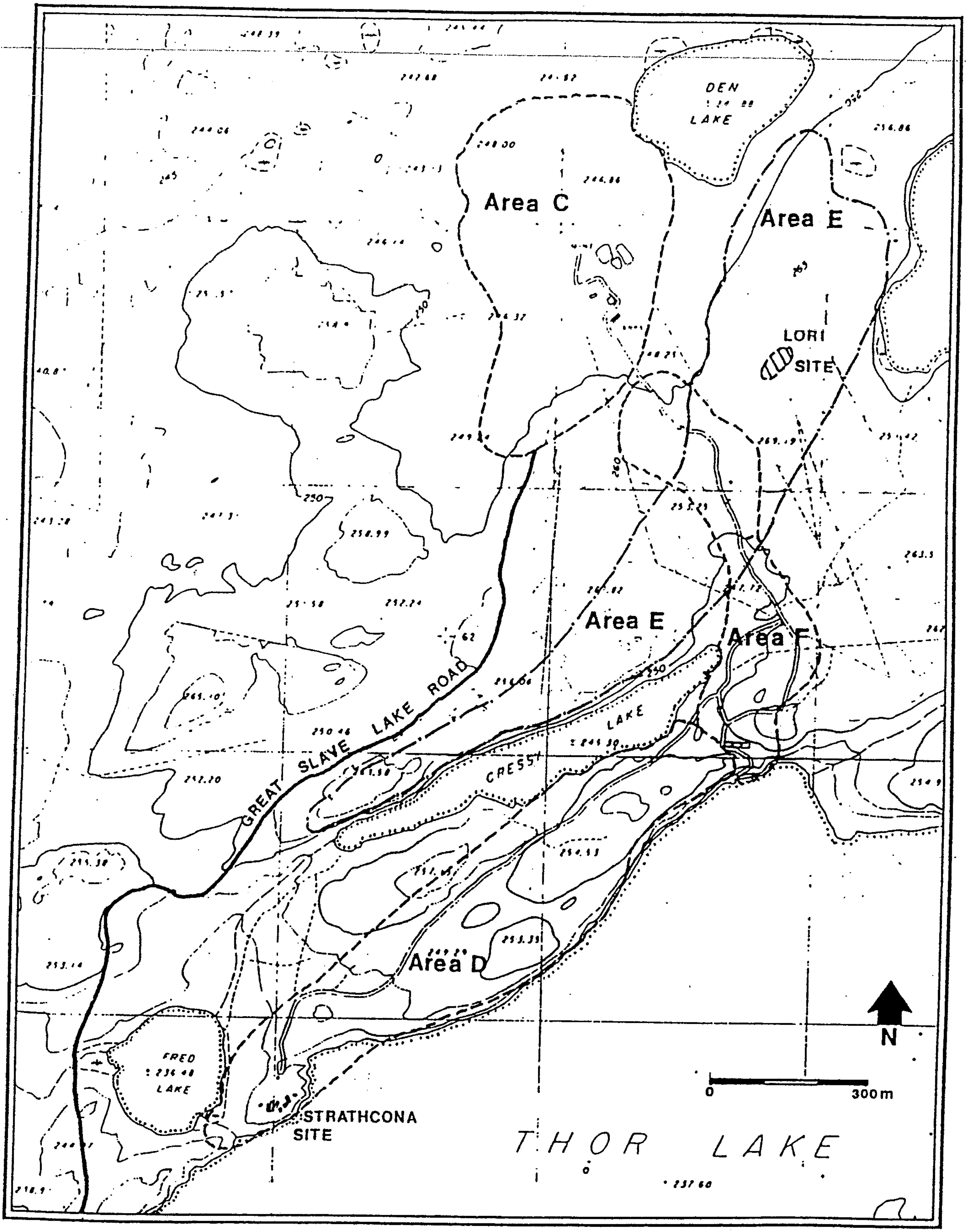


Figure 6.2 Map of Five Archaeological Survey Areas, in the Thor Lake Area.

proposed tailings and reclaim water pipelines. To the east the area includes the south shore of Den Lake.

f) The present construction camp, including the road leading to the mine and the clearing presently used for garbage disposal (Figure 6.2).

6.1.2 Methods

Surface surveys were the most common method used. Surface examinations were made of flat exposures of bedrock and soil, although the latter occurred rarely. Occasionally, sections of lichen were lifted in order to examine the underlying bedrock. Bulldozed material along roads and at the edges of clearings was also examined, in case there were undisturbed portions of sites.

Four widely-spaced pedestrian transects were made across the disturbed portions of the mine site, two north-south and two east-west. Areas between the transects which were potential heritage sites were also examined. Bulldozed material on the periphery of the mine site was examined, as were low-lying rock outcrops beyond the north and southwest edges of the site.

Limited subsurface testing was carried out, adjacent to places where artifacts were recovered at the docking site on Great Slave Lake. Two 30 x 30 cm test pits were excavated by trowel to determine if artifact concentrations were present. Three 20 x 20 cm shovel holes were made to determine the underlying soil structure. These were dug from 13 to 26 cm below the surface. The material was not screened.

Elevations above Great Slave Lake were estimated from 5 m contour lines on 1:5000 maps. Site measurements were determined by pacing (one pace approximately 1 m).

6.2 Archaeological Background

In 1949, MacNeish carried out pioneering surveys in the Great Slave Lake area and established the initial prehistoric sequences in the MacKenzie region (Cinq-Mars and Martijn 1981:32). His work was continued by Noble, who surveyed the Great Slave Lake area, especially to the north and east, over four summers from 1966 to 1969. In August 1968, Noble (1971:103) canoed west along the north shore "to the upper end of Hearne Channel," where he recorded the McKinley Point site (KaPb-1), 10.5 km east of Thor Lake. It is not known if he examined the proposed dock area of the Thor Lake project.

The McKinley Point site, the closest recorded site to Thor Lake, is on a narrow isthmus and consists of the remains of two hearths as well as a projectile point base and a scraper. The site was assigned to the Waldron River Complex and dated to A.D. 500 to 900 (Noble 1971; Archaeological Survey of Canada: Archaeological Site Form, KaPb-1).

Noble (1971, 1981) has outlined the general cultural history of central MacKenzie region on the basis of his work, as well as that carried out by other archaeologists. The central MacKenzie was occupied by northern Paleo-Indians shortly after deglaciation 7000 years ago. Several complexes from the Northern Plains appeared between 3000 B.C. and A.D. 200 although they are poorly represented. Between 1300 to 600 B.C., the Canadian Tundra Tradition, derived from Arctic Paleo-Eskimos, reached as far south as northern Saskatchewan and Manitoba.

Finally, about 500 B.C., the Taltheilei Shale Tradition appeared, which Noble (1981:102) considers to be the major ancestral Athapaskan tradition. It is characterized by "the prolific use of gray silicious shales ... while elsewhere to the east, quartzite provides the most readily accessible material" (Noble 1981:103). White quartz, basalt, red jasper and various cherts were also utilized although their frequency of use varied through time (Noble 1971:110-115). The tradition consists of ten successive complexes extending into the historic period, circa A.D. 1840 (Noble 1971).

Noble was able to correlate the various Taltheilei Shale complexes, partially on the basis of their positions on the raised beach lines of eastern Great Slave Lake. These features are the result of isostatic rebound. The ten successive complexes are found from 1.5 to 19 m above present lake level. This uplift, however, is much reduced at the western end of the lake, where sites dating to 900 B.C. are only 3.4 m above shoreline, instead of well over 19 m as found in the east. The difference led Noble to suggest the presence of one or more geomorphological "hinges" west of the major site at Taltheilei Narrows, 80 km east of Thor Lake.

6.3 Ethnohistoric Background

The Taltheilei Shale Tradition lies "across much of the historic Yellowknife-Chipewyan homeland" (Noble 1981:102). The Yellowknifes were a Chipewyan regional group who lived in an area from the Coppermine River south to modern Yellowknife, and east to the upper Thelon and Back Rivers (Gillespie 1981b:285, Figure 1). On the basis of the appearance of regional variations, Noble (1977:68) suggests the Chipewyan and Yellowknife separated after A.D. 200.

The Yellowknifes were first recorded at Fort Churchill as early as 1721 (Gillespie 1981b:286). Conflicts with their western neighbours, the Dogribs, led to their gradual decline after the establishment of local trading posts in the early 1800s. They were further depleted by epidemics and began to amalgamate and intermarry with the Dogribs to the west and the Chipewyan to the east. Today, they no longer have "an identifiable dialectal or ethnic identity" (Gillespie 1981b:285) and are known only from the historic record.

6.4 Site Results

Three sites were recorded. The Reg site (KaPb-4) consists of prehistoric and recent material found at the docking area and adjacent road at Great Slave Lake. The Lori site (KaPb-3) is a prehistoric lithic debitage scatter on the crest of the high ridge south of Den Lake and east of the mine site. The Strathcona site (KaPb-2) is the disused diamond-drilling exploration camp at the west end of Thor Lake. It was recorded for future archaeological reference.

Four artifacts were collected, all from the Reg site: three white quartz biface fragments and one bone hide flesher.

6.4.1 The Reg Site (KaPb-4)

The Reg site (Figure 6.1) is located on a small point on the north shore of Hearne Channel, Great Slave Lake, 10.5 km west of McKinley Point. The site extends from the northwest end of a small beach, along the point of land (south), and east to the beginning of a short section of flat bedrock shore. It stretches from the shore up a moderate slope to the road, which parallels the shore at about 10 m elevation above the shoreline.

Artifacts were found at two separate localities. The first, area one, consists of the undisturbed northern half of beach and extends inland for 90 paces. The area was not examined further inland since it was expected that development would not occur this far from shore.

Area two consists of the point of land immediately south of the beach. It is about 100 paces across and extends 100 paces inland to the road.

6.4.1.1 The Reg Site (Area One)

The south half of the beach (Figure 6.3) has been bulldozed; nothing remains of the surface for 100 paces inland. However, the north half of the beach is undisturbed. The active beach is eight paces wide and is bordered by a recent storm line of debris. Behind it are occasional small shrubs. Scattered trees occur below an exposed gravel beach ridge 22 paces inland. Beyond this ridge are dense trees, bushes and heavy lichen growth. Several of the trees have been blown over by the wind, raising large root mats up to 1.5 m across and 30 to 40 cm thick, exposing the underlying soil.

A small streamlet has eroded a shallow channel through the south edge of the undisturbed area. This has exposed the underlying soil.

Several recent camp fires were found on and below the exposed gravel beach ridge where the first scattered trees appear. However, there was no sign of recent intensive use.

A white quartz biface fragment (KaPb-4.1) (Figure 6.4) was found 19 paces inland, on the surface of the gravel on the shore side of the old beach ridge. Although visibility was good along the bare ridge, no other lithic materials were found.

Another white quartz biface fragment (KaPb-4.2) (Figure 6.4) was found in the root mat of a tree-throw 48 paces from shore and 4 paces

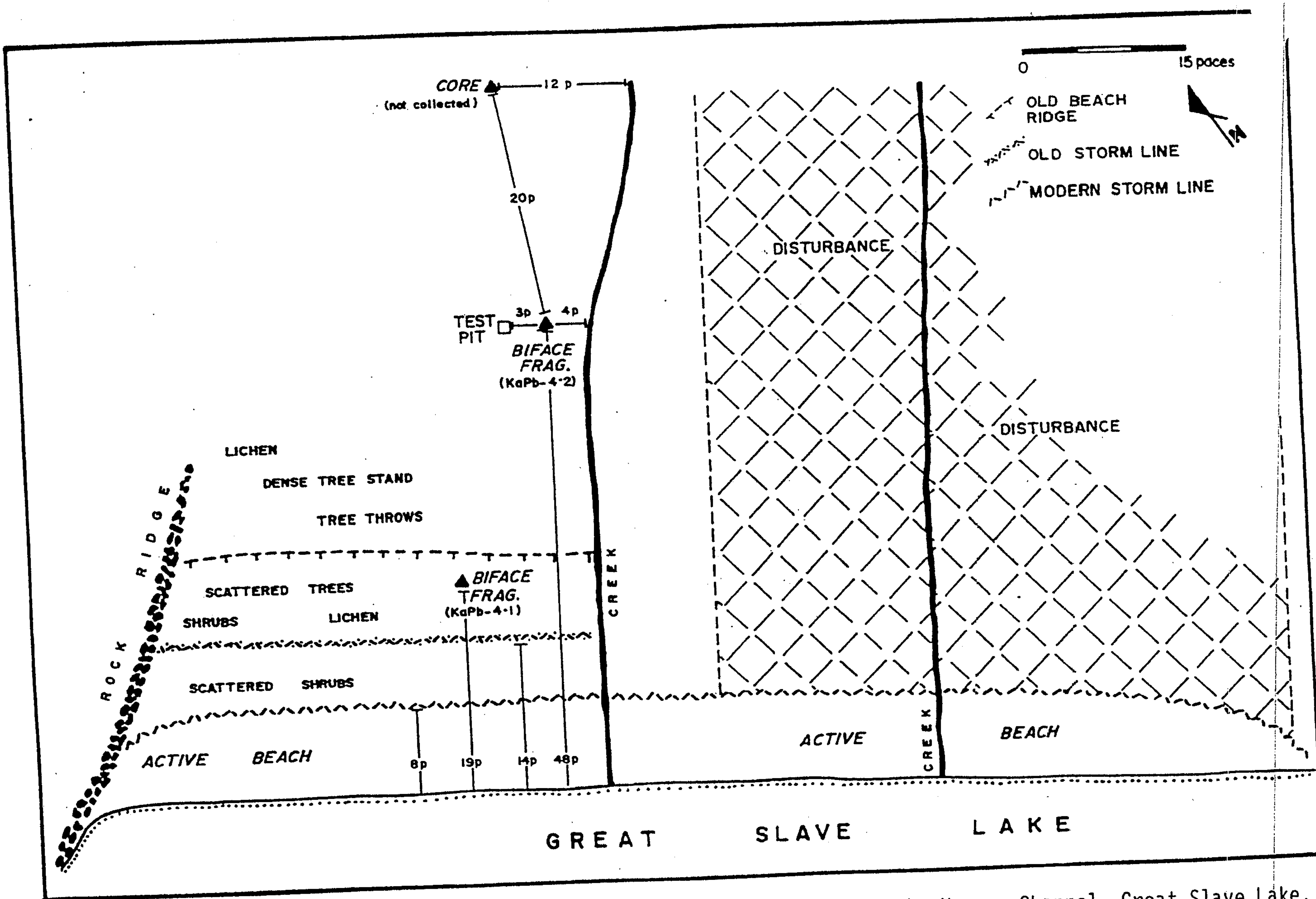
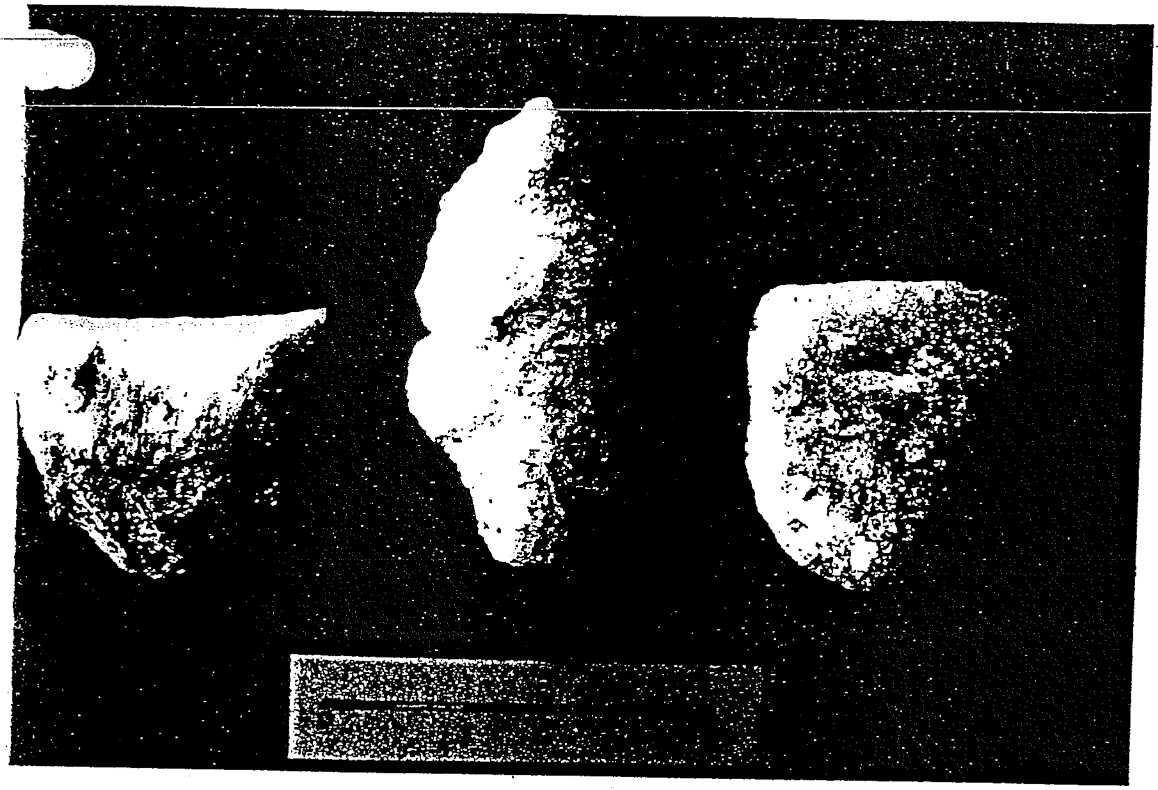
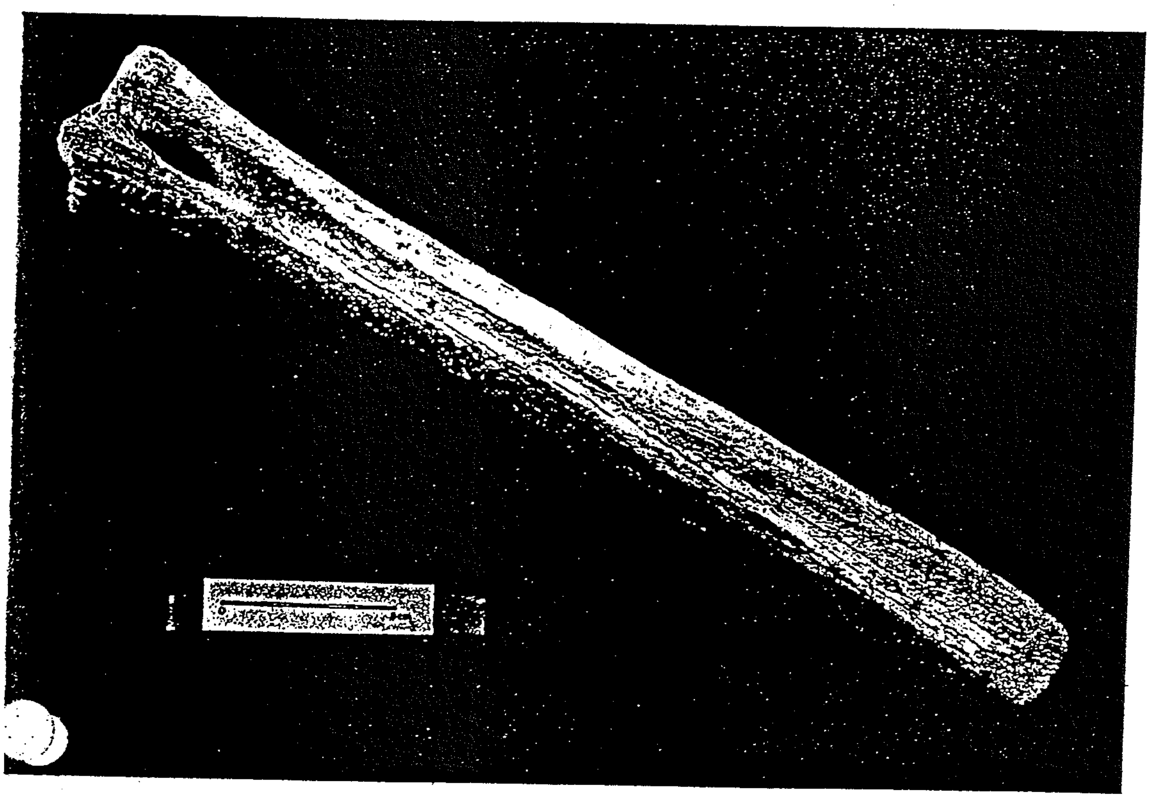


Figure 6.3 Map of Area One of the Reg Site (KaPb-4) on the North Shore of the Hearne Channel, Great Slave Lake.



gure 6.4 Biface Fragments from the Reg Site (KaPb-4). Left to Right: KaPb-4.4; KaPb-4.2; KaPb-4.1.



ure 6.5 Bone Flesher from the Reg Site (KaPb-4.3).

north of the stream. A test pit, 30 x 30 cm and 13 cm deep, was dug three paces west but did not produce any artifacts. A white quartz core fragment was found in the roots of another tree-throw, 68 paces from shore and 12 paces north of the stream. Fourteen other tree-throws were examined, but none produced any further artifacts.

6.4.1.2 The Reg Site (Area Two)

Area two is the point of land south of the beach (Figure 6.1). It is covered by dense lichen, thick bushes and scattered trees, only a few of which are windblown. Above the 10 m elevation, the ground rises steeply and consists mostly of bare bedrock. The road from the beach cuts across the point, parallel to the shore at about 10 m elevation then swings northeast to ascend the hill.

Five or six small scattered bone fragments were found along the north edge of the road. These had been damaged by the road-building equipment and it was not clear if they were originally there as a result of human or natural activities. Near the bone fragments, but on the south edge of the road, was a biface fragment (KaPb-4.4) (Figure 6.4), and a piece of shatter, both of white quartz. Although there was extensive subsurface exposure along both sides of the road, no other material was found.

A 30 x 30 cm test pit was excavated 15 paces southwest of the biface fragment. The first 15 cm consisted of lichen, root mat and peat. The next 10 cm were of loose beach cobbles 10 to 15 cm in size. Three shovel holes were dug in an attempt to locate gravel beach lines. Neither these, nor the several tree-throws on the point, revealed any cultural material.

The point is bordered on the east by a short stretch of flat bedrock shore, which is used for recreational fishing by people from the mine. A bone hide flesher (KaPb-4.3) (Figure 6.5), partially sunk into the lichen, was found adjacent to this shore. No evidence of recent campsites was found on the point, perhaps because of the thick lichen cover.

6.4.2 The Lori Site (KaPb-3)

The Lori site (KaPb-3) consists of a scatter of white quartz debitage, on the highest crest of a rock ridge, 0.5 km southeast of the mine site (Figure 6.2). Seven flakes and pieces of shatter were found scattered over an area 20 paces in diameter. A modern cairn had been built on the southwest corner of the scatter. Thus any rocks which might have been a part of a cultural feature, such as a tent ring or fireplace, were displaced. However, the surrounding lichen patches were broken up, increasing the visibility of the substrate. Thus the seven pieces of debitage were probably all or nearly all of the artifacts that were in the area.

A piece of white quartz resembling a core was found at the base of the ridge 150 paces west of the Lori site. It was lying on the surface of a lichen patch, so it was not possible to determine if it was a core carried in from elsewhere, or if it was the result of prospecting activities. Although the substrate visibility was good in the area, no other material was found.

6.4.3 The Strathcona Site (KaPb-2)

The Strathcona site (KaPb-2) is the modern diamond-drilling exploration camp on the west end of Thor Lake, 100 paces east of its outlet to Fred Lake (Figure 6.2). A pace map was made of the site to indicate the locations and functions of specific features (e.g., hearths, refrigerator pit). This information might be of interest to future archaeological work in the area.

6.5 Discussion

Sites on the shore of Great Slave Lake near Thor Lake are assumed to follow Noble's (1981) beach line chronology. The discussion of dates must be regarded as tentative, because elevations were estimated in this study.

6.5.1 The Reg Site

The three biface fragments, core fragment and shatter found at the Reg site are all of white quartz. None were water worn. The biface fragment (KaPb-4.1) was about 2 m above water line which, according to Noble's chronology, would make it no older than 200 years. It is 42 mm long, 38.6 mm wide and 12.4 mm thick. The base is missing. Crushing on the lateral edges suggests bipolar working.

The biface fragment (KaPb-4.2) was from 5 to 8 m above the water line, making it 480 to 680 years old. It is 63.5 mm long, 41.1 mm wide and 11.5 mm thick. Although it is the most nearly complete of the three bifaces, both corners of the base appear to be missing.

The third biface fragment (KaPb-4.4) was found on the road side about 10 m elevation above the lake. This would make it no more than about 1500 years old. It is 38.7 mm long, 41.1 mm wide and 11.5 mm thick. The fragment has split cleanly across its midsection. Its rather irregular outline suggests that it had not been completely finished.

The bone hide flesher (KaPb-4.3) was made from the metatarsal of a large ungulate, probably a moose. The outer surface is somewhat weathered, so that it cannot be determined if the working edge was serrated, similar to hide fleshers found in central Saskatchewan (e.g., Kehoe 1978:101). The flesher is 62.5 cm long and has been worked 84.5 mm from the cutting edge, at an angle of 20'. The extent of working on the obverse side cannot be determined due to weathering. The cutting edge is 25.7 mm wide. It is probably of recent date because it was found on the surface, and the rate of bone preservation is poor in the boreal forest.

6.5.2 The Lori Site

The seven pieces of quartz debitage from the Lori site were all relatively small, no more than 2 cm in length, and appeared to be from the same core material. They are probably the result of a single lithic reducing activity. It is surprising that these and all other lithic artifacts were of white quartz only. Noble (1971, 1981) stresses the use of shales and quartzites in the Taltheilei Tradition; quartz seemed to have played a minor role. Either the absence of shale and quartzite in the study area is a sampling error, because of the scarcity of sites, or there is a difference in the tradition between this portion of Great Slave Lake and its eastern arm.

6.5.3 The Study Area

I expected that more prehistoric materials would be found in the study area. The docking area provides a suitable camping spot for canoe travel, and the high ridges bordering the mine site are also suitable travel routes. Despite the dense vegetation cover, especially lichen, there were ample exposed areas which indicated, by the absence of artifacts, that the area has seen little use.

The Reg site on Great Slave Lake seems to have been seldom used, perhaps because it lies halfway between McKinley Point and the mouth of the Francois River, within a day's travel of each other. As well, lengthy occupation of the site may not have occurred because access to the interior is limited over the steep hilly shore. Regardless of cause, the site seems to have been little used either in the prehistoric past or recently.

It was not expected that material would be found at the mine site, since it is situated on low-lying ground with nothing to attract people to it. Although the area had been extensively disturbed, the amount of soil removed was often small and there were ample opportunities for investigation. Nothing was found at the mine site proper or on adjoining outcrops of flat bedrock.

A check was made to see if people had been using the general area. High ridges which provided escape from insects, ease of travel and observation points were examined. Similarly, lake shores and creeks which might have provided camp spots or, to some degree, fisheries, were also examined. The only material was at the Lori site which, as mentioned, was probably the result of a single lithic reducing activity, marking a brief stop at one of the best observation spots in the area.

People probably made little use of the area because there were excellent access routes into the interior by means of the nearby Francois and Beaulieu Rivers. The former leads to Blachford Lake and others immediately to the north, and the latter leads to the MacKay Lake system some 250 km northeast. This was the route taken by Hearne and his Chipewyan party on their return south from the Arctic Ocean in 1771 (Figure 6.6).

Hearne (1955:144, 160) wrote that his group stopped at, or near, the mouth of the Beaulieu River on December 24, 1781 and spent "some days in hunting beaver." Today, people from Yellowknife visit the area to hunt moose.

Hearne then crossed the lake to the south through the Simpson Islands, where they, "lost much time in hunting deer and beaver, which were very plentiful on some of the islands. ... The lake is stored with great quantities of very fine fish; particularly between the islands..." As well, Taltheilei Narrows, 80 km east, "was and continues to be a major fishery" (Noble 1977:71).

Thus, desirable sources of resources, as well as transportation routes to the interior, lay outside the mine site area. Since there are no specific attractions, and the expanse of land is so great, it is not surprising that few sites were found in the study.

6.6 Conclusions

No further work is recommended at the mine site proper. In light of the sparsity of cultural materials at the Reg site, Great Slave Lake, further investigation is not warranted. However, since cultural materials were found under the lichen cover on the north half of the beach,

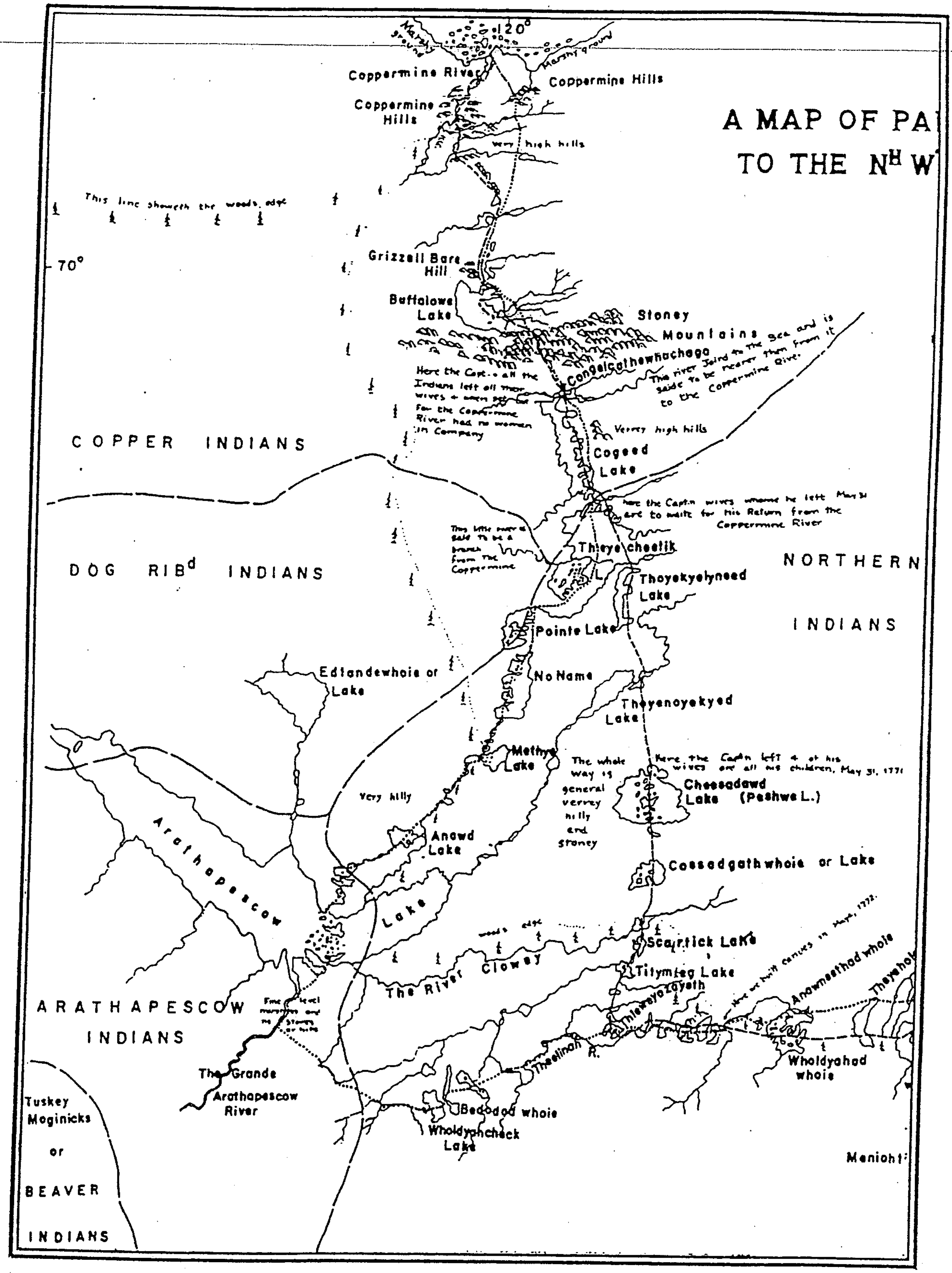


Figure 6.6 Portion of Samuel Hearne's 1772 Map Showing Route Across Great Slave Lake (Arathapescow Lake). From Warkentin and Ruggles 1970:93.

this area should be avoided by future development. Any further development should be placed in the south half of the beach and the adjacent point. This is the area where development has already taken place.

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APPENDIX A

Table A.1 Analytical Water Quality Data for Thor and Elbow Lakes, September 1988.

	Thor Surface	Thor Bottom	Elbow Surface	Elbow Bottom
Major ions (mg/L)				
CO_3	2.0	2.0	7.0	NIL
Ca	30.0	30.0	33.0	33.0
Cl	5.4	5.4	1.7	1.7
HCO_3	181.0	180.0	183.0	197.0
K	2.1	2.1	2.3	2.3
Mg	18.0	18.0	19.0	19.0
Na	6.5	6.6	4.1	4.1
SO_4	0.4	0.4	0.8	0.7
Micronutrients (mg/L)				
C, tot. inorg.	36.0	35.0	36.0	39.0
C, tot. org.	16.0	16.0	12.0	12.0
N, ammonia	0.07	0.09	0.09	0.07
N, NO_2+NO_3	0.04	0.04	0.05	0.04
N, total Kjeld.	1.1	0.73	0.64	0.66
P, total as P	0.03	0.06	0.13	0.25
PO_4, ortho as P	<0.01	<0.01	<0.01	<0.01
Trace elements (mg/L, except * ug/L)				
Ag	<0.001	<0.001	<0.001	<0.001
Al	0.014	<0.005	<0.005	<0.005
As*	<0.5	<0.5	<0.5	0.6
B	0.05	<0.05	0.09	<0.05
Ba	0.072	0.080	0.085	0.084
Be	<0.001	<0.001	<0.001	<0.001
Cd	<0.001	<0.001	<0.001	<0.001
Ce	<0.001	<0.001	<0.001	<0.001
Co	<0.001	<0.001	<0.001	<0.001
Cr	0.007	0.009	0.015	0.008
Cu	<0.001	0.002	<0.001	0.003
Fe	0.078	0.084	0.027	0.047
Hg*	<0.05	<0.05	<0.05	<0.05
Mn	0.035	0.039	0.050	0.076
Mo	<0.005	<0.005	<0.005	<0.005
Nb	<0.001	<0.001	<0.001	<0.001
Ni	<0.001	<0.001	0.001	0.002
Pb	<0.005	<0.005	<0.005	<0.005
Ta	<0.001	<0.001	<0.001	<0.001
Tl	<0.001	<0.001	<0.001	<0.001
V	<0.01	<0.01	<0.01	<0.01
W	<0.005	<0.005	<0.005	<0.005
Y	<0.001	<0.001	<0.001	<0.001
Zn	0.003	0.002	<0.001	<0.001

Table A.1 (Continued).

	Thor Surface	Thor Bottom	Elbow Surface	Elbow Bottom
Radionuclides (Bq/L, except * ug/L)				
Pb^{210}, total	<0.02	<0.02	<0.02	<0.02
Ra^{226}, total	<0.005	<0.005	<0.005	<0.005
Ra^{228}, total	<0.04	<0.04	<0.04	<0.04
Th^{230}, total	<0.01	0.04	<0.01	0.04
Th^{232}, total	<0.01	<0.01	<0.01	<0.01
U^{*}, total TOPO	<0.5	<0.05	<0.05	<0.5

Table A.2 Analytical Water Quality Data for the Cressy Lake-Lake A Drainage Route, September 1988.

	Cressy Lake Surface	Cressy Lake Bottom	Fred Stream	Lake A Surface
Major ions (mg/L)				
CO_3	NIL	NIL	NIL	NIL
Ca	24.0	24.0	30.0	29.0
Cl	0.9	0.9	5.4	4.8
HCO_3	122.0	122.0	182.0	167.0
K	2.0	2.0	2.0	1.6
Mg	11.0	11.0	18.0	17.0
Na	2.5	2.5	6.3	5.7
SO_4	3.8	3.8	0.6	1.0
Micronutrients (mg/L)				
C, tot. inorg.	24.0	24.0	36.0	33.0
C, tot. org.	19.0	19.0	16.0	18.0
N, ammonia	0.09	0.11	0.09	0.08
N, NO_2+NO_3	0.05	0.04	0.04	0.04
N, total Kjeld.	0.79	0.93	0.69	0.66
P, total as P	0.04	0.09	0.04	0.23
PO_4, ortho as P	<0.01	<0.01	<0.01	<0.01
Trace elements (mg/L, except * ug/L)				
Ag	<0.001	<0.001	<0.001	<0.001
Al	<0.005	<0.005	<0.005	<0.005
As*	1.9	2.0	<0.05	<0.05
B	<0.05	<0.05	<0.05	<0.05
Ba	0.015	0.020	0.059	0.041
Be	<0.001	<0.001	<0.001	<0.001
Cd	<0.001	<0.001	<0.001	<0.001
Ce	<0.001	<0.001	<0.001	<0.001
Co	<0.001	<0.001	<0.001	<0.001
Cr	0.005	0.002	0.004	0.004
Cu	<0.001	0.002	<0.001	<0.001
Fe	0.30	0.31	0.056	0.042
Hg*	<0.05	<0.05	<0.05	<0.05
Mn	0.054	0.056	0.025	0.003
Mo	<0.005	<0.005	<0.005	<0.005
Nb	<0.001	<0.001	<0.001	<0.001
Ni	0.001	<0.001	<0.001	<0.001
Pb	<0.005	<0.005	<0.005	<0.005
Ta	<0.001	<0.001	<0.001	<0.001
Tl	<0.001	<0.001	<0.001	<0.001
V	<0.01	<0.01	<0.01	<0.01
W	<0.005	<0.005	<0.005	<0.005
Y	<0.001	<0.001	<0.001	<0.001
Zn	0.002	0.002	0.001	0.002

Table A.2 (Continued).

	Cressy Lake Surface	Cressy Lake Bottom	Fred Stream	Lake A Surface
Radionuclides (Bq/L, except * ug/L)				
Pb^{210}, total	<0.02	<0.02	<0.02	<0.02
Ra^{226}, total	<0.005	<0.005	<0.005	<0.005
Ra^{228}, total	<0.04	<0.04	<0.04	<0.04
Th^{230}, total	<0.01	<0.01	<0.01	<0.01
Th^{232}, total	<0.01	<0.01	<0.01	<0.01
U^*, total TOPO	1.0±0.8	1.1±0.8	<0.05	<0.05

Table A.3 Analytical Water Quality Data for the Surface Waters of Ring and B Lakes, September 1988.

	Ring	B
Major ions (mg/L)		
CO_3	NIL	NIL
Ca	30.0	21.0
Cl	1.0	4.4
HCO_3	148.0	94.0
K	2.6	0.7
Mg	14.0	9.0
Na	2.1	3.9
SO_4	0.9	0.8
Micronutrients (mg/L)		
C, tot. inorg.	29.0	18.0
C, tot. org.	33.0	33.0
N, ammonia	0.17	0.27
N, NO_2+NO_3	0.08	0.07
N, total Kjeld.	1.8	1.4
P, total as P	0.19	0.02
PO_4, ortho as P	<0.01	<0.01
Trace elements (mg/L, except * ug/L)		
Ag	<0.001	<0.001
Al	<0.005	0.007
As*	<0.5	2.3
B	<0.05	<0.05
Ba	0.059	0.016
Be	<0.001	<0.001
Cd	<0.001	<0.001
Ce	<0.001	<0.001
Co	<0.001	<0.001
Cr	0.005	0.004
Cu	<0.001	<0.001
Fe	0.058	0.097
Hg*	<0.05	<0.05
Mn	0.017	0.007
Mo	<0.005	<0.005
Nb	<0.001	<0.001
Ni	<0.001	<0.001
Pb	<0.005	<0.005
Ta	<0.001	<0.001
Tl	<0.001	<0.001
V	<0.01	<0.01
W	<0.005	<0.005
Y	<0.001	<0.001
Zn	0.003	0.004

Table A.3 (Continued).

	Ring	B
Radionuclides (Bq/L, except * ug/L)		
Pb^{210}, total	<0.02	<0.02
Ra^{226}, total	<0.005	<0.005
Ra^{228}, total	<0.04	<0.04
Th^{230}, total	<0.01	<0.01
Th^{232}, total	<0.01	<0.01
U^{*}, total TOPO	<0.5	<0.5

APPENDIX B

Table B.1 Elemental Data (ug/g) for Thor Lake Whitefish Flesh, September 1988.

	Sample 1	Sample 2	Sample 3
Trace Elements			
Ag	<1	<1	<1
Al	15	2	<1
As	0.9	0.2	0.3
B	<5	<5	<5
Ba	<1	<1	<1
Be	<1	<1	<1
Ca	15000	37000	4100
Cd	<1	<1	<1
Ce	<0.3	1.2	0.3
Co	<1	<1	<1
Cr	<1	<1	<1
Cu	<1	<1	<1
Fe	33	42	17
Hg*	--	--	--
K	18000	8400	9300
Mg	900	1100	630
Mn	4	5	1
Mo	<4	<4	<4
Na	2000	1900	2000
Nb	<0.1	<0.1	<0.1
Ni	<1	<1	<1
P	20000	25000	7600
Pb	5	<4	<4
Se	0.3	0.5	0.3
Ta	<0.1	<0.1	<0.1
Ti	<1	<1	<1
V	<4	<4	<4
W*	--	--	--
Y	<0.4	0.5	<0.4
Zn	130	110	28
Physical Properties			
Ash (%)	1.99	1.93	1.98
Radionuclides			
Pb^{210}, total**	<0.02	<0.02	0.12
Ra^{226}, total**	0.005	<0.005	<0.005
Ra^{228}, total**	<0.04	<0.04	<0.04
Th^{230}, total**	<0.01	<0.01	<0.01
Th^{232}, total**	<0.01	<0.01	<0.01
U	0.1	0.4	<0.1

*Sample lost in analytical lab
**Bq/g

Table B.2 Elemental Data (ug/g) for Thor Lake Whitefish Bone, September 1988.

	Sample 1	Sample 2	Sample 3
Trace Elements			
Ag	<1	<1	<1
Al	3	9	<1
As	0.1	0.4	0.4
B	<5	<5	<5
Ba	11	6	10
Be	<1	<1	<1
Ca	180000	120000	170000
Cd	<1	<1	<1
Ce	<0.3	<0.3	<0.3
Co	<1	<1	<1
Cr	<1	<1	<1
Cu	<1	<1	<1
Fe	48	42	28
Hg*	--	--	--
K	9600	7700	6700
Mg	3100	1600	2300
Mn	31	22	31
Mo	<4	<4	<4
Na	3400	3400	2600
Nb	<0.1	<0.1	<0.1
Ni	<1	<1	<1
P	92000	20000	85000
Pb	<4	<4	<4
Se	0.2	0.3	0.2
Ta	<0.1	<0.1	<0.1
Ti	<1	<1	<1
V	<4	<4	<4
W*	--	--	--
Y	<0.4	<0.4	<0.4
Zn	150	200	130
Physical Properties			
Ash (%)	17.8	14.4	17.0
Radionuclides			
Pb^{210}, total**	<0.02	<0.02	<0.02
Ra^{226}, total**	0.01	0.01	<0.005
Ra^{228}, total**	<0.04	<0.04	<0.04
Th^{230}, total**	<0.01	<0.01	<0.01
Th^{232}, total**	<0.01	<0.01	<0.01
U	<0.1	<0.1	0.1

*Sample lost in analytical lab
**Bq/g

Table B.3 Elemental Data (ug/g) for Thor Lake Northern Pike Flesh, September 1988.

	Sample 1	2	3
Trace Elements			
Ag	<1	<1	<1
Al	<1	6	<1
As	0.1	0.1	0.1
B	<5	<5	<5
Ba	1	2	<1
Be	<1	<1	<1
Ca	28000	290000	12000
Cd	<1	<1	<1
Ce	0.4	0.4	0.6
Co	<1	<1	<1
Cr	<1	<1	<1
Cu	1	1	<1
Fe	23	57	9
Hg*	--	--	--
K	12000	12000	15000
Mg	1200	990	1000
Mn	12	12	4
Mo	<4	<4	<4
Na	3000	3600	2000
Nb	<0.1	0.2	<0.1
Ni	<1	<1	<1
P	24000	18000	13000
Pb	<4	<4	<4
Se	0.4	0.6	0.3
Ta	<0.1	<0.1	<0.1
Ti	<1	<1	<1
V	<4	<4	<4
W*	--	--	--
Y	<0.4	<0.4	0.5
Zn	130	240	54
Physical Properties			
Ash (%)	1.78	1.56	1.56
Radionuclides			
Pb^{210}, total**	<0.02	<0.02	<0.02
Ra^{226}, total**	<0.005	<0.005	<0.005
Ra^{228}, total**	<0.04	<0.04	<0.04
Th^{230}, total**	<0.01	<0.01	<0.01
Th^{232}, total**	<0.01	<0.01	<0.01
U	0.1	0.1	<0.1

*Sample lost in analytical lab
**Bq/g

Table B.4 Elemental Data (ug/g) for Thor Lake Northern Pike Bone, September 1988.

	Sample 1	Sample 2	Sample 3
Trace Elements			
Ag	<1	<1	<1
Al	<1	<1	<1
As	<0.1	<0.1	<0.1
B	<5	<5	<5
Ba	21	9	13
Be	<1	<1	<1
Ca	220000	160000	160000
Cd	<1	<1	<1
Ce	<0.3	<0.3	0.3
Co	<1	<1	<1
Cr	<1	<1	<1
Cu	<1	<1	<1
Fe	12	15	16
Hg*	--	--	--
K	4500	7700	8600
Mg	3600	2900	3100
Mn	75	44	46
Mo	<4	<4	<4
Na	5100	4800	3400
Nb	<0.1	<0.1	<0.1
Ni	<1	<1	<1
P	100000	81000	81000
Pb	<4	<4	<4
Se	0.1	0.2	0.2
Ta	<0.1	<0.1	<0.1
Ti	<1	<1	<1
V	<4	<4	<4
W*	--	--	--
Y	<0.4	<0.4	<0.4
Zn	170	220	180
Physical Properties			
Ash (%)	18.6	17.6	16.7
Radionuclides			
Pb^{210}, total**	<0.02	<0.02	<0.02
Ra^{226}, total**	<0.005	<0.005	<0.005
Ra^{228}, total**	<0.04	<0.04	<0.04
Th^{230}, total**	<0.01	<0.01	<0.01
Th^{232}, total**	<0.01	<0.01	<0.01
U	<0.1	<0.1	<0.1

*Sample lost in analytical lab
**Bq/g