# Appendix V5-3F

Hope Bay Belt Project:
Environmental Baseline Studies Report 1996

TMAC RESOURCES

# *BHP World Minerals*
# *Hope Bay Belt Project*

# ENVIRONMENTAL BASELINE STUDIES REPORT 1996


Prepared for:
**BHP World Minerals**
San Francisco, CA, USA

Prepared by:
**Rescan Environmental Services Ltd.**
Vancouver, BC, CANADA



**February 1997**


Rescan

# HOPE BAY BELT PROJECT

## 1996 ENVIRONMENTAL BASELINE STUDIES REPORT

**February 18, 1997**

526-1, 526-3

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# Executive Summary

# EXECUTIVE SUMMARY

## Preamble

BHP (World Minerals and Minerals Canada Ltd.) has been collecting environmental baseline data in support of its exploration activities in the Hope Bay Belt region of the Northwest Territories since 1993. The purpose of this report is not to make a formal submission for regulatory approvals, but rather to present the results of environmental and socioeconomic data collection efforts during 1996, which continued and expanded upon the studies undertaken in the area during 1993, 1994 and 1995. It is understood that BHP may wish to provide this report to government agencies for information purposes.

The information contained herein may be used in the future for impact assessment and management should more of the Hope Bay Belt exploration targets ultimately proceed to application for approval for project development. Accordingly, the design of data collection programs has incorporated the assembly of data that can support the assessment of cumulative impacts and the assessment and protection of ecosystem integrity (through the identification and study of valued ecosystem components). Also, in 1996, more intensive effort than in previous years was afforded to the evaluation of socioeconomic conditions to help maximize the welfare of Inuit peoples and northerners more generally, should any of the Hope Bay Belt exploration projects proceed to development. Community consultation programs and the collection and integration of Inuit traditional knowledge also received increased attention during the 1996 data collection programs and this will continue through 1997 and beyond.

## Terrain and Permafrost

In order to characterize local soils and permafrost conditions, a preliminary geotechnical investigation of the Boston Project area was carried out between May 10 and May 24, 1996. Data were generated to assess terrain sensitivity to construction impacts and support a mine plan feasibility study.

Seven geotechnical boreholes were drilled and logged within the dominant terrain units (rock uplands, marine lowlands, till ridges and lake bottom sediments) with automatic data loggers and thermistor cables installed in three of the boreholes. All recovered core was examined and logged. Frozen soil core was photographed and samples were taken for laboratory testing.

Laboratory tests included natural moisture content, Atterberg limits, particle size distribution analysis and porewater salinity determinations. Ground temperature readings from the thermistor cables were taken at the conclusion of the survey and the data loggers will be downloaded in the spring of 1997. Bedrock rock quality designation (RQD) was typically 60% but ranged from 0 to 90%. Marine soils contained a high proportion of ground ice, ranging from 20 to 50% by volume. All marine soils tested for salt within the permafrost had concentrations varying from 3 to 48 ppt.

The active layer appeared to be 0.3 to 0.4 m thick. Till core had a sand matrix with a trace of silt. Till near the surface contained only thin ice lenses while the ground ice content at depth was very low. Cold continuous permafrost was present everywhere except below larger lakes. The ground temperature below the depth of seasonal variation, approximately ten metres, ranges from -8 to -11°C.

The marine lowlands throughout the Boston site are the most sensitive to disturbance by development activity and thicker than normal fills may be required for permanent structures to reduce the risk of thaw. Construction should be restricted to the winter (frozen tundra) season. Any structure foundations requiring piles in the marine soil unit must be designed for a high salinity permafrost environment.

## Meteorology

Results from the climatological monitoring program at Windy Lake camp and Boston Property indicate that the temperatures and rainfall were similar to regional stations operated by Environment Canada Atmospheric Environment Service (AES). As expected for a property within the Arctic Circle, mean monthly temperatures were below freezing for eight months of the year. The mean monthly temperatures for the Boston automated weather station were below freezing for seven of the eight months that were included in the period of record. The minimum and maximum temperatures were -44 and 16°C for the available period of record.

Precipitation during the month of August (79 mm) was greater than half of the mean annual precipitation (120 mm). From historical data it is expected that over half of the mean annual precipitation falls as rain. This is consistent with data collected at the nearest regional AES stations (Cambridge Bay Airport and Contwoyto Lake (Lupin)).

Wind speeds and direction patterns at the Boston automated weather station were similar to previous years, although the predominant wind direction was slightly different. Class A pan evaporation was monitored at Windy Lake camp for a portion of the assumed ice-free period. The evaporation rate was 53 mm for a 75 day period of record. The overall evaporation rate was definitely affected by the heavy rainfall in August. Unfortunately there are no regional AES stations near the Hope Bay Belt area which monitor evaporation. The nearest station to collect evaporation is Yellowknife airport located approximately 730 km south. Future monitoring of evaporation will provide valuable data for comparison to the 1996 data.

## Air Quality

Five days of high volume (HV) air sampling were performed at both Windy Lake and Boston camp. HV air samplers were used to monitor baseline concentrations of total suspended particulates (TSP) and respirable particulates (PM10). The samplers were installed using a helicopter in order to monitor a true baseline which was not affected by the activities at each camp. All of the TSP and PM10 samples were below the ambient air quality objectives. A number of specially targeted HV air samples were collected in the Windy Lake camp and indicated that the personnel at the core splitting facilities should continue to utilize breathing protection (*i.e.,* dust masks). Personnel other than the core splitters do not need to be concerned about inhaling excessive amounts of nuisance dust.

In addition, a number of HV air samples were collected for particle size and metal analyses. The particle size distribution for all of the samples indicated that particles are very fine, with almost all particles less than 0.45 μm in aerodynamic diameter. Analysis of metals in the collected particulates did not show any reason for concern as all concentrations were well below occupational health and safety standards.

## Hydrology

In 1996, the hydrological baseline monitoring program included monitoring of stream flows at four sites, including three in the north part of the study area at the outlets of Ogama, Glenn and Doris lakes, and one station along the Koignuk River in the south. Water levels were also monitored at Tail Lake and Doris Lake.

Data collection began in early June, during the freshet period. Data collected, were consistent and compared favorably between site catchments and with data available from Water Survey of Canada (WSC) hydrometric stations nearby.

A regional precipitation event occurred in late August and this, combined with a higher than normal spring runoff, resulted in higher than normal runoff in the project area in 1996.

No modifications to the 1997 monitoring program are recommended with the exception of more frequent flow measurements and earlier commencement of monitoring to record peak freshet flows.

## Water Quality

*Boston Property*

Water samples from lakes and streams in the Boston Property area were sampled during the winter (April and June), summer (early August), and fall (late August).

The waters of Spyder and Trout lakes were neutral to slightly acidic, and contained low concentrations of particulate material (total suspended solids (TSS) and turbidity) throughout the 1996 season. Trout Lake had very high TSS and turbidity values in the fall; 5 to 40 times higher than concentrations in Spyder Lake. Winter total metal concentrations were all below the CCREM guidelines for freshwater aquatic life, with the exception of copper and lead concentrations. Total metal levels during the summer were all below guideline values. Fall total metal concentrations were elevated, however, with the guidelines for aluminum, cadmium, copper, and iron all being exceeded. The high total metal levels may have been the result of increased precipitation and water flow during late August of 1996, resulting in riverine transport of sediment and terreginous material. The water column of Spyder Lake remained unstratified throughout the 1996 survey period. Streams had elevated particulate matter values relative to lakes, as generally expected, and exceeded aluminum, copper, and iron guidelines in the fall.

*Doris Lake Property*

Water samples from lakes and streams in the Doris Lake Property area were obtained during the winter (April and June), and fall (late August).

The pH of all six lakes ranged from 6.8 to 8.0 throughout the 1996 survey season. Particulate material was low in all lakes, with slight increases occurring in the fall. During the fall, Roberts Lake[1] had the lowest turbidity value. In the winter, all total metal concentrations fell below the CCREM guidelines for the protection of freshwater aquatic life, with the exception of copper and chromium levels. Fall metal levels were elevated relative to winter, with guidelines for aluminum, cadmium, chromium, copper, and iron all being exceeded. Aluminum, copper, and chromium guidelines were exceeded in nearly every lake in the fall. This may have been the result of high precipitation and runoff during late August of 1996, introducing sediment and terrigenous material into the lakes. All lakes with the exception of Patch Lake remained unstratified in the fall. Outflow streams were more turbid than lake waters, and exceeded aluminum, copper, and iron guidelines during the fall and spring freshet.

## Acid Base Accounting

An acid base accounting (ABA) sampling program was conducted on blasted material removed from the Boston Project bulk sample audit and from Doris Lake drill core. Both locations have a relatively high degree of carbonitization which contributes to the high neutralization potential seen in most of the samples. Neutralization potential ratio (NPR) is a measure of a sample's residual acid generating potential. An NPR value less than 1.0 indicates that the sample is potentially acid generating, a value greater than 3.0 indicates the sample is acid

[1] In this report, we have designated a small unnamed lake (UTM coordinates = N 7562900, E 435400) as Roberts Lake and it is identified as such on maps and in the text contained herein.

consuming and a sample with a value between 3.0 and 1.0 is not clearly acid generating or acid consuming. At Boston, none of the 157 samples tested were definitely acid generating and only 33 samples had neutralization potential ratio values between 1.0 and 3.0. These samples were primarily obtained from the ore zones. The Doris Lake sampling program indicates that the majority of rock types are not acid generating. The exception to this are quartz veins with limited neutralization potential. Three samples from the strongly mineralized mafic volcanics had NPR values in the uncertain range. However, these samples had high net neutralization potential (NNP) values greater than 178 tonnes $CaCO_3$/1000 tonnes. This value is significantly greater than the upper +20 tonnes $CaCO_3$/1000 tonnes guideline for acid generating material.

## Primary Producers

*Boston Property*

Primary producers (phytoplankton and periphyton) were collected from lakes and streams in the Boston Property area in the summer (early August) and fall (late August).

Phytoplankton assemblages in the Boston Property lakes (Spyder, Stickleback, Trout) consisted of primarily cyanobacteria (Cyanophyta) in the summer, with shifts towards diatoms (Bacillariophyceae) and green algae (Chlorophyta) in the fall. Trout Lake phytoplankton were strongly dominated by the same genus of cyanobacteria during both seasons. Diversity Indices ranged from 1.36 to 2.53 for all lakes. Trout Lake had the highest phytoplankton biomass levels in the summer.

Periphyton assemblages were also generally dominated by cyanobacteria, with diatoms and green algae making up the rest of the taxonomic composition. The South Inflow of Spyder Lake had the greatest periphyton density of the three stream sites sampled. Diversity Indices ranged from 1.43 to 2.63. Stickleback Lake and Stickleback Outflow were dominated by the same genus of cyanobacteria, *Anacystis*.

*Doris Lake Property*

Primary producers were collected from the Doris Lake Property lakes (phytoplankton) and streams (periphyton) once during the fall sampling campaign.

The phytoplankton assemblages of Ogama, Doris, Roberts, and Windy lakes were strongly dominated (>94%) by cyanobacteria in the fall. Phytoplankton composition in Tail Lake was just as strongly dominated by diatoms (96%). Patch Lake phytoplankton consisted of cyanobacteria, diatoms, and green algae, resulting in the most diverse phytoplankton assemblage. Patch and Windy lakes had low phytoplankton densities compared to the other lakes. Diversity indices ranged from 0.37 to 2.25. As sampling was conducted only in the fall, no seasonal trends could be identified.

The periphyton assemblages of Patch, Doris, Roberts, and Windy outflows were dominated by cyanobacteria in the fall. Ogama Outflow had a periphyton composition consisting of approximately half diatoms and half cyanobacteria. Doris and Windy outflows had the greatest periphyton densities of the streams sampled. Diversity Indices ranged from 1.49 to 2.63. Ogama, Doris, and Roberts lakes and outflows were all dominated by the cyanobacterial genus *Oscillatoria*.

## Secondary Producers

*Boston Property*

Secondary producers (zooplankton and benthic invertebrates ) were collected from lakes in the Boston Property area in the summer (early August) and fall (late August). Samples of benthos (larval drift and stream benthic invertebrates) were also collected from streams during the summer sampling campaign.

Seasonal trends were observed for zooplankton and benthos density and for benthos taxonomic composition. With a few exceptions, densities were usually greater in the summer than in the fall. Zooplankton communities were generally dominated by cyclopoid copepods and lake benthos samples tended to be dominated by Diptera in the summer, and non-dipteran organisms in the fall. With the exception of the fact that shallower benthos samples tended to have larger densities and greater diversity, there were no important site-to-site differences. The larval drift and stream benthos samples, taken in the summer season, showed a general dominance by dipteran organisms. Seasonal trends were not determined because high water in August made it impossible to locate and retrieve the benthic samplers.

*Doris Lake Property*

Secondary producers were collected from the Doris Lake Property lakes (zooplankton and lake benthos) and streams (stream benthos) once during the fall sampling campaign.

The zooplankton communities in the Doris Lake area were either dominated or co-dominated by Rotifera. This differs from the Boston lakes, and other NWT lakes in similar studies (Lac de Gras area; Rescan 1996), which were dominated by cyclopoid copepods. Densities of zooplankton samples were, however, within the range of the Boston Property samples. As with the Boston Property lake benthos samples, shallower lakes in the Doris Lake area tended to have greater densities than deeper lakes. With the exception of Windy Lake, all lake benthic communities were dominated by Diptera, followed by Nematoda. An opposite trend was observed in Windy Lake. Densities in benthic samples from the Doris Lake Property tended to be lower than in those samples from the Boston Property lakes. Stream benthos taxonomic composition, was generally dominated by Diptera, a similar result to Boston Property samples.

## Fisheries

The fish communities of the Hope Bay Belt exploration areas were sampled in 1996 as part of ongoing baseline data collection. Fish habitat and fish biology were examined in Windy, Doris, Patch, Ogama and Tail lakes (Doris Property) and Spyder and Trout lakes (Boston Property). Inflows and outflows for these lakes were also studied.

Baseline data collection included:

- an aerial survey of the Hope Bay Belt area, including the proposed winter trail;

- detailed habitat characterization and species presence/absence survey of Ogama Inflow, Ogama Outflow, Windy Outflow, Doris Outflow, Boulder Creek, NE Spyder Inflow, Spyder River and Koignuk River; and
- fish species survey of the study lakes.

Northeast Spyder Inflow, Boulder Creek, Doris Outflow and the Koignuk River were identified as important fish spawning streams. Ogama Inflow, Ogama Outflow, Windy Outflow and Trout Outflow appear to be suitable for fish rearing and feeding, but are not important spawning habitats. Large catches per unit effort (CPUE), predominantly of lake trout, were obtained. In contrast, Doris Property streams had relatively low CPUE's.

Species composition of lakes in the Doris and Boston properties differed in several ways. Most Doris Property lakes contained populations of lake whitefish and/or cisco. Lake trout was the only piscivorous species found in all lakes, with the exception of Trout Lake, which contained arctic grayling. Young-of-the-year (y-o-y) were present in seine hauls at Boston, but only during the summer sampling period and only coregonids were captured. The lack of coregonid y-o-y in lake shore seine hauls in fall sampling may be the result of their switch from littoral to deepwater benthic feeding.

Statistical comparisons of fish biological characters between the Doris Property lakes and the Boston Property lakes were not possible due to the low sample sizes obtained at Boston Property. Instead, general observations were made on pooled data for each species. Live catch sizes included four arctic grayling, five lake trout, 12 cisco and 35 lake whitefish. The dead catch was comprised of 19 lake trout, 15 cisco and 16 lake whitefish.

Trace metal analysis was conducted using muscle and liver composites for Doris Property fish and several individual fish from Spyder Lake. A total of 12 metals was examined. Concentrations found were low and varied between lakes, tissues and species. Currently, mercury is the only metal for which CCREM consumption guidelines are enforced. The concentration of mercury observed in muscle and liver tissues was less than the upper allowable limit of 0.5 mg/kg wet weight.

## Terrestrial Ecosystem Mapping

Terrestrial ecosystem mapping (TEM) is a method of stratifying the landscape into polygons that delineate ecosystems. Sample plots were located systematically across the study area from Roberts Bay to Spyder Lake (Boston Camp) along the proposed winter trail corridor.

The purpose of the 1996 field sampling was to identify distinct vegetation communities and associated abiotic factors in order to describe and map ecosystems. In total, 173 sample plots were established and 18 preliminary vegetation communities identified. Ecosystems will be described in the spring of 1997 based on sample plot analysis using a data tabulation program.

## Wildlife Studies

A program of wildlife studies was conducted in the Hope Bay Belt area, during 1996. Goals were to describe the community of terrestrial wildlife and birds, and wildlife habitats present in the area. Specific objectives were:

- to identify species which used the area, and assess their relative abundance;
- to access temporal and spatial changes in use of the area; and
- to evaluate relative importance of different habitat types to different species over time.

A separate aerial survey for marine mammals was carried out in Melville Sound, outer Bathurst Inlet and Dease Strait.

*Terrestrial Wildlife*

Survey components included aerial surveys for ungulates, aerial and ground surveys for carnivores, an aerial survey for nesting raptors, a breeding bird census, aerial and ground surveys for waterfowl, and a small mammal trapping program.

Seven ungulate surveys were conducted between 31 May and 28 November. Total survey time was 32.0 hours. The total number of caribou observed on-transect ranged from four to 1198. On-transect caribou density ranged from

<0.01 to 1.78 caribou/km$^2$. Caribou density was typically highest in the southern portion of the survey area. Caribou calved within the survey area in 1996; the highest concentrations, however, were observed in the post-calving period. During the November survey, 24% of all caribou observed on-transect were from the Victoria Island herd; this proportion increased in the northern portion of the survey area.

Total numbers of muskoxen observed on-transect ranged from 11 to 71; on-transect density ranged from 0.02 to 0.14/km$^2$. Calves were observed on all surveys. Muskoxen were also most prevalent in the southern portion of the survey area.

No recent grizzly bear dens were found in the study area in 1996. There were, however, several observations of bears, including at least eight individuals and two family groups. Sixteen grizzly bear feeding sites were visited and habitat descriptions completed for each. One active wolf den was observed in 1996. This den appeared to be abandoned by 21 July, and it may have not produced pups which survived. Two red fox dens were found, both of which produced pups. Arctic foxes were not observed until surveys in October.

During a survey for raptor nests on 18 July, 36 raptor observations were made. Twenty-six of these included active nests. Species recorded were gyrfalcon, peregrine falcon, rough-legged hawk, and golden eagle. The study area provides important nesting habitat for each of these species, particularly in the northern portion near the coast. Additional species recorded within the study area in 1996 included snowy owl, short-eared owl, and common raven.

Eight breeding bird census plots were surveyed. Fifteen species were identified, and 403 birds were counted on-plot. Shrub habitats supported the highest density of birds, and most of the nests that were found. Surveys for waterfowl identified 12 species, plus sandhill cranes. Canada geese were the most commonly observed, and the most common breeders. White-fronted geese and Pacific loons were also widely distributed and common.

Small mammals were sampled by snap-trapping on four lines. A total of 84 small mammals was captured, comprised of five species. Most common were brown lemmings and northern red-backed voles, followed by collared lemmings and tundra voles. A single Arctic shrew was captured, outside of the species' distribution, according to some references.

*Marine Mammals*

The Hope Bay Belt development will require supporting ship and barge traffic which will traverse outer Bathurst Inlet and Melville Sound en route to and from a landing area in Roberts Bay. In order to determine the occurrence and distribution of marine mammals along this route, assess the potential impact of shipping and help to design mitigation measures where required, three aerial surveys were carried out in 1996. Ringed seals are the most numerous and widespread marine mammals in the Arctic and are likely to be the primary species encountered in the study area.

Three surveys were flown, on June 14, 17 and 20, at a time when many seals haul out on the ice during their annual moult and can be best observed.

Surveys were flown at an altitude of 152 m and a speed of 220 km/h along north-south transect lines spaced approximately 10 km apart, with an additional line added in the Hope Bay area. Observations within each 400 m wide transect strip were recorded on tape and later transcribed onto standard data forms and stratified by survey area.

The estimated densities of ringed seals decreased between surveys where ice surface conditions deteriorated in Melville Sound and Bathurst Inlet, making it difficult to spot animals amidst dark pools of water on the ice. Ice conditions changed least in Elu Inlet and the observed seal density there changed least between flights.

The observed density of seals in Melville Sound was 0.71 seals/km$^2$ on June 14, subsequently dropping to <0.30 seals/km$^2$ by June 20.

In outer Bathurst Inlet the highest density of 0.82 seals/km$^2$ was observed on June 14, dropping to < 0.40/km$^2$ by June 20.

In Dease Strait which was surveyed only on June 17 and 20, observed densities were 0.45 and 0.54 seals/km$^2$, respectively.

A review of previous seal surveys in the Canadian Arctic showed that seal densities in this study area are relatively high.

It was noted in discussions with Inuit hunters that polar bears do not frequent the study area despite the abundance of their primary prey species.

## Archaeology

An archaeological inventory east of Bathurst Inlet was carried out in 1996 as part of the Hope Bay Belt baseline study. Selected exploration and potential mine development locations were examined, including the vicinity of possible barge landing or port sites in Roberts Bay and an area extending approximately 60 km south of this bay, along a proposed winter trail route, and the Boston and Doris Lake project areas.

Twenty-nine new archaeological sites were recorded and one previously recorded site was revisited as a result of these investigations. Most of the sites were situated on elevated ridges or knolls adjacent to waterbodies, although some did occur some distance from water or on lower landforms. All were rock feature sites, most with multiple features, including stone circles, hearths/windbreaks, traps, caches, signal rocks and hunting blinds, as well as a number of specialized structures. Although only limited quantities of artifacts were evident on the surface, some sites did contain bone and/or wood artifacts, and most had variable amounts of scattered animal bone consisting largely of caribou and muskox. Historic debris of tin and glass products was also observed at some of the sites. One small biface artifact was found adjacent to a more recent tent ring site, possibly signifying Paleo-Eskimo use of that location beginning as long ago as 3500 yr. B.P. Several of the stone circle sites exhibited structural features suggestive of Thule occupation, perhaps 800 yr. B.P.

The majority of the sites occur in close proximity to possible development areas, but only six occur within planned developments (four on a winter trail route and two within a possible port location). These sites can be avoided by project revisions, and this has reportedly been done for one site on the portion of the trail route at Roberts Bay which was to be used this winter. Ongoing re-evaluations of the potential for site impacts will be required as development plans are finalized, and more detailed assessments will be necessary for sites which could be impacted.

## Traditional Knowledge, Community Consultation and Socioeconomics

The BHP Minerals Hope Bay Belt Project falls within the geographical area of the very large Naonayaotit Tradition Knowledge Study (NTKS) which is being conducted by the Kugluktuk Augoniatit Association on behalf of the Kitikmeot Hunters and Trappers Association. In May 1996, BHP became a partner in this study and has cooperated in collecting and documenting the information on land use and wildlife resources available from the residents of Cambridge Bay, Bathurst Inlet and Omingmaktok.

Interviews and transcription/translation for the NTKS Project are near completion. The industrial partners, including BHP are working on a pilot project with the KHTA to digitize the map overlays from the interviews.

In 1997, traditional knowledge from the KHTA Project will be integrated into the biophysical baseline being generated for the Hope Bay Belt project. Taking into account the concerns of Inuit elders emphasis will be place on wintering by Victoria Island caribou, the calving grounds of the Bathurst and Queen Maud caribou herds and water quality and fisheries in the Koignuk River.

A limited evaluation of socioeconomic conditions in the communities of the Coronation Gulf region was conducted in 1996. It is customary to reserve detailed socioeconomic assessment until a development decision has been made, so that the results reflect current conditions and provide a realistic basis for planning beneficial action and minimize any possible disturbance of the local economy and Inuit social structure.

# Acknowledgments

## ACKNOWLEDGMENTS

The assistance of many individuals who expedited the successful completion of the 1996 field program is gratefully acknowledged.  Among them, the following deserve special mention:

- The staff at BHP’s Windy Lake and Boston camps who, despite heavy in-house demands, cheerfully and competently provided accommodation and support services for several of our consultant field crews throughout the summer.
- The pilots of Great Slave Helicopters, Ptarmigan Air and Adlair who provided safe and skillful flight services for all field crews.
- Residents of Omingmaktok, Bathurst Inlet and Cambridge Bay who provided services and the benefits of their hunting experience and local land use knowledge to several of our survey teams.

None of these field programs in the far north could succeed without the full cooperation of the local population and technical service personnel from supporting firms and agencies.

## BHP WORLD MINERALS

## HOPE BAY BELT PROJECT 1996
## ENVIRONMENTAL BASELINE STUDIES REPORT

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# Introduction

# INTRODUCTION

This report presents the results of baseline environmental and socioeconomic studies carried out during 1996 for BHP Minerals Canada in the vicinity of its claims in the Hope Bay Belt, Northwest Territories (Nunavut). While this report focuses on 1996 results, both historical and recent project related information is cited and discussed where appropriate. This document is intended for internal data management purposes only, it is not intended as a formal submission to any regulatory agencies although it is understood that the company may wish to distribute it to government bodies for general information purposes. The information contained herein may ultimately be used for the purposes of impact assessment and management should the decision be made to proceed with project development.

The purpose of the ongoing sampling program is to provide a basis for measuring the impacts of proposed mineral development activity on the biophysical, socioeconomic and heritage resources of the Hope Bay Belt, and to focus mitigation planning on the vulnerable components of the ecosystems present.

For management purposes, the 1996 Boston and Doris Lake baseline study programs were consolidated into an overall Hope Bay Belt Program. The study areas are shown in Figures 1-1 and 1-2. The 1996 studies continued and amplified the work done at Boston in 1993, 1994 and 1995 and at Doris Lake in 1995. New initiatives were undertaken in the areas of terrain ecosystem mapping (TEM), archaeology, permafrost investigations, and wildlife habitats, populations and migration.

Traditional and contemporary land use mapping was obtained from the Kitikmeot Inuit Association. The acquisition of some wildlife data by GNWT personnel and Inuit organizations was assisted by BHP with grants and field support in kind.

The results of the 1996 survey program are presented in the following report under separate disciplinary headings. Data are referenced to either the two primary project sites, at Boston and Doris Lake, to the barge landing area at Roberts Bay and the winter trail route, or to the overall aerial survey areas for terrestrial wildlife (primarily caribou and muskoxen) and marine mammals (ringed seals).

Owing to the fact that it is at an advanced stage of exploration relative to the targets, emphasis has been placed on the collection of data at the Boston exploration site.

The weather and hydrological data presented are both general, derived from regional records and site specific, collected at an automated weather station, water level gauging installations on several watercourses and readings from manual staff gauges.

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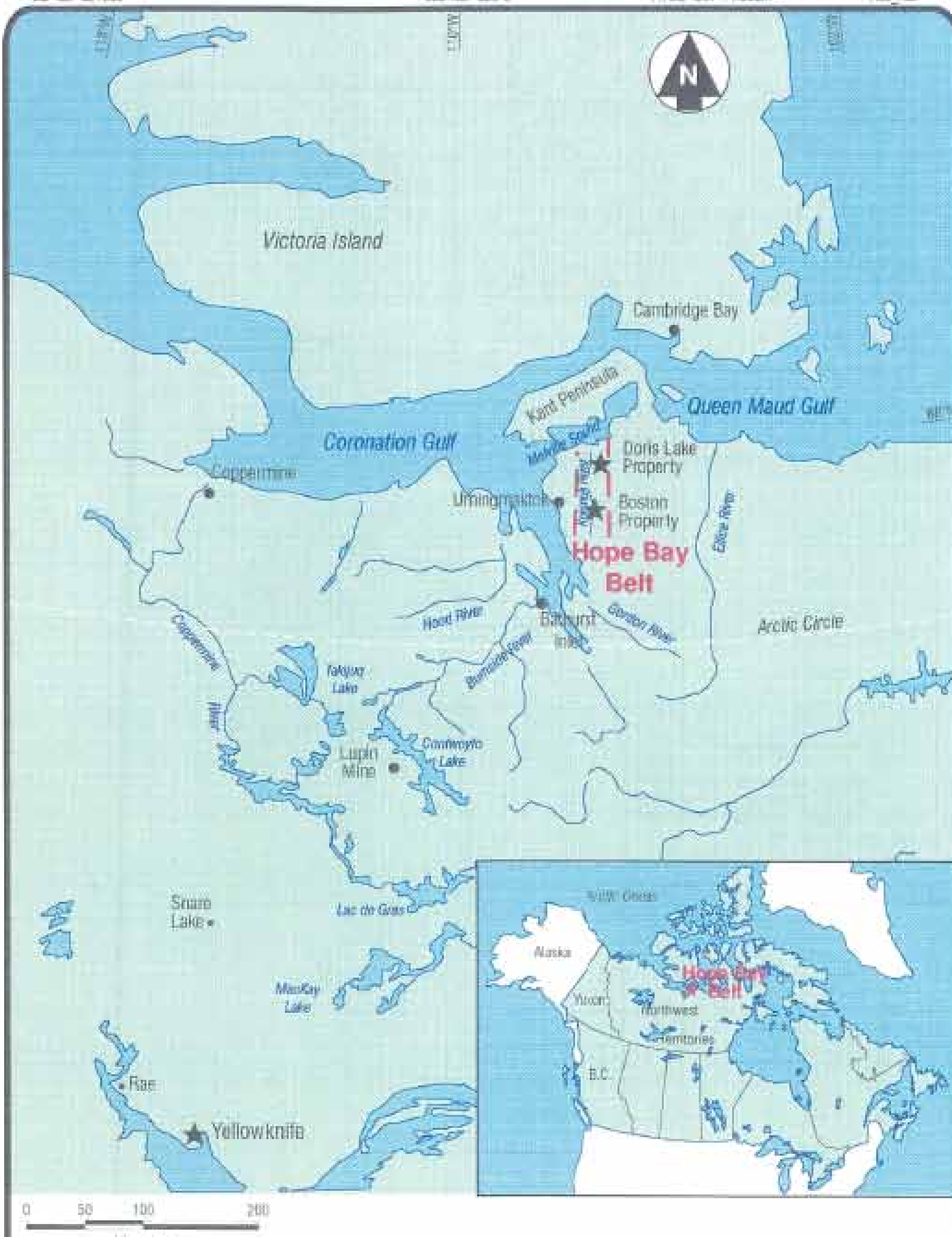


FIGURE 1-1

BHP

**Project Location Map**

Rescan

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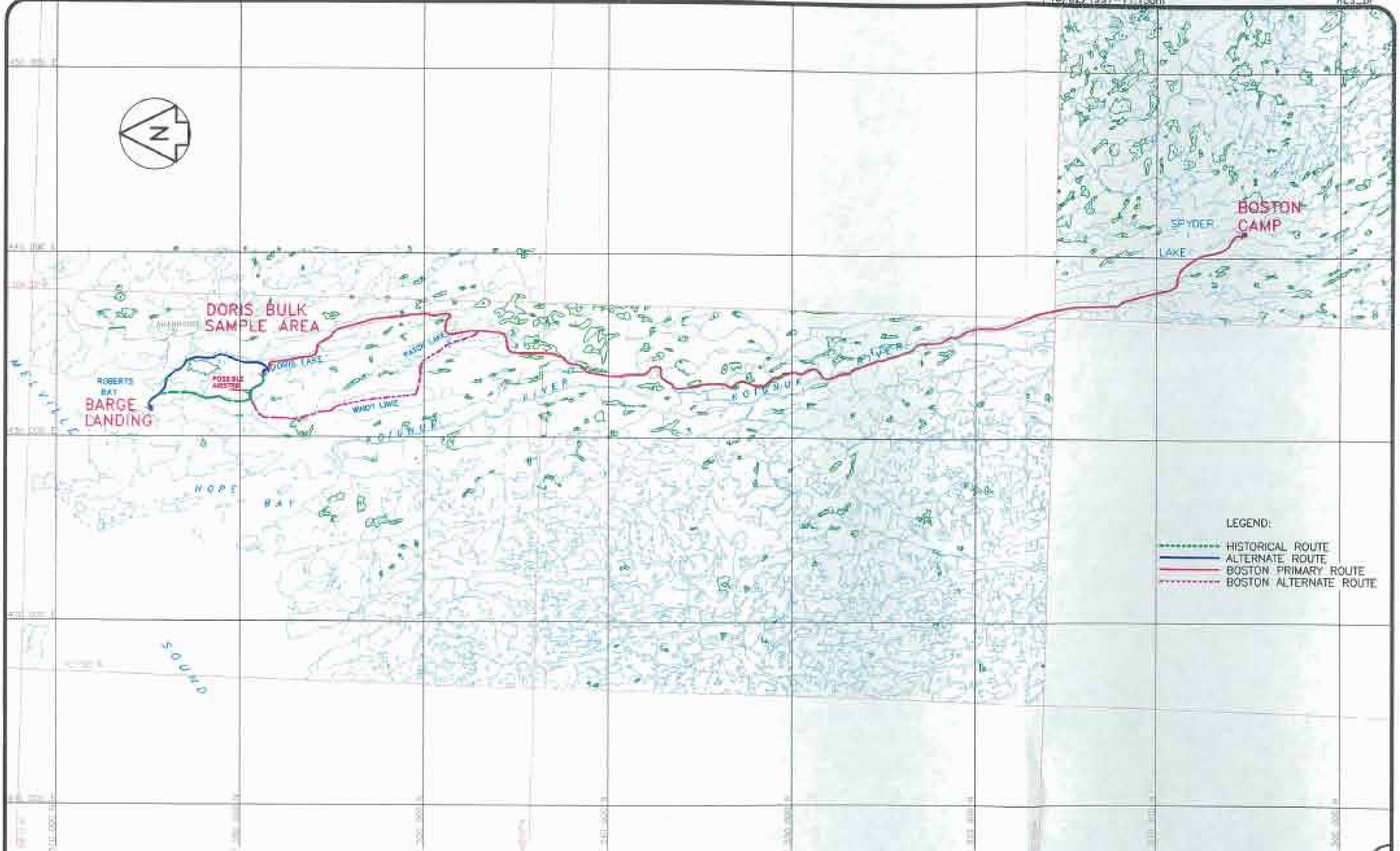



BHP

Winter Trail for Hope Bay Belt Project

Rescan

Fig 1-2

# 1. Terrain and Permafrost

# 1. TERRAIN AND PERMAFROST

## 1.1 Introduction

A preliminary geotechnical investigation of the Boston exploration site area was conducted between May 10 and May 24, 1996. The objective was to collect sufficient geotechnical and permafrost data to characterize the local soils and permafrost conditions. The data were required to assess terrain sensitivity to construction-related impacts for purposes of environmental impact assessment. The secondary purpose was to provide engineering data for a mine plan feasibility study. That study would include preliminary layout and design of support infrastructure.

The project was carried out in two phases, the first phase included drilling and logging seven geotechnical boreholes and installing thermistor cables to measure ground temperature. The second phase included interpretation of terrain and permafrost conditions from low level stereo airphotos that were obtained in July 1996.

## 1.2 General Site Characterization

### 1.2.1 Climate and Permafrost

The closest meteorological weather stations to the Boston site are Contwoyto Lake approximately 280 km to the southwest, and Cambridge Bay, approximately 170 km to the northeast. The mean annual air temperature for Contwoyto Lake, based on Environment Canada weather records maintained until 1981, is -11.8°C. The mean annual air temperature for Cambridge Bay, based on Environment Canada weather records from 1929 to 1990, is -14.9°C. An approximate mean annual air temperature of -13.6°C has been estimated for the Boston site, based on interpolations (proportional to latitude) between the two weather station locations.

The Boston site is situated well within the zone of continuous permafrost. Surficial features typical of permafrost terrain such as frost-mounds, frost-shattered bedrock, sorted circles, mud boils, block fields, and ice wedge polygons are common in the area. Additional details on permafrost conditions are provided in Section 1.4, Geotechnical Conditions.

### 1.2.2 Regional Quaternary Geology

The region has been subjected to multiple glaciations during the Quaternary period. During each glaciation, the area was overridden by the northwestern sector of the vast Laurentide Ice Sheet. Clear evidence of only the most recent (Late Wisconsin) glaciation is preserved in the present-day landscape. Striations, orientation of eskers, grooves and drumlins indicate that the predominant glacial ice movement was north-northwest. Ice movement directions determined by Ryder (1992) range from northwest to north.

The project area became ice-free about 8,800 years ago as the southwest to northeast trending ice sheet melted back toward the southeast (Dyke and Prest 1986) leaving a blanket of basal till as the ice retreated. Immediately following deglaciations, the sea level was about 200 m higher than at present (Dyke and Dredge 1989). The entire project area was submerged and the edge of the ice sheet abutted the open sea. Meltwater streams from the ice carried fine grained sediments toward the sea, resulting in the accumulation of marine sediments on top of the till with the greatest accumulated thickness in the deeper water zones, which now form the valley bottoms.

Following glaciation, isostatic rebound caused a relative decline in sea level. During emergence, all parts of the land surface were washed by waves. Easily erodible surfaces such as marine sediments, till, and glaciofluvial sands and gravels, were reworked and redistributed by waves, currents and sea ice. Some present day rock outcrops were exposed as the thin soil washed off the uplands and accumulated in the valley bottoms.

Since emergence, the effects of natural slope processes, frost action, and permafrost have applied the finishing touches to the present day landscape.

Several lineaments having north-northwest to south-southeast orientations are evident on the air photos south of the proposed mine site (between Spyder Lake and Stickleback Lake, and south of Stickleback Lake). The lineaments include lines of elongated, interconnected depressions infilled mainly with till, and are typically adjacent to bedrock outcrops. These features are probably associated with faults and fracture zones developed within the Hope Bay greenstone belt.

### 1.2.3 Terrain Analysis

The area has a low to moderate surface relief with not more than 50 m of differential elevation between low and high points. The surficial deposits that overlie the bedrock consist of glacial till, marine sediments, glaciofluvial deposits, lacustrine deposits and alluvial deposits.

A map of surficial geology and permafrost features, included as Figure 1.2-1, was prepared by interpretation of stereo airphotos at a scale of 1:10,000. The airphoto coverage was obtained specifically for the project in July, 1996. A mosaic of the airphoto coverage is shown in Figure 1.2-2. Detailed geotechnical data obtained at seven sites, representative of the various terrain units, was used to "ground-truth" the map in Figure 1.2-1.

#### *1.2.3.1 Terrain Map Definitions*

The following surficial geology units have been identified within the area and are shown on the attached terrain map (Figure 1.2-1).

*Alluvial Deposits (A)*

Alluvial deposits are interpreted within floodplains and low river terraces. Generally, they are sands and gravels that may contain lenses and layers of organic material. In some locations, the alluvial deposits are covered by well developed surface vegetation and some peat.

*Lacustrine Deposits (L and Lr)*

Lacustrine (lakebed) deposits are typically silt and sand with a few lenses of organic detritus, and underlie lacustrine plains and gentle slopes. They mainly occur adjacent to the vicinity of present lakes as they are lake bed soils that have become exposed as the lakes in the region shrink in size.

Within the area, the lacustrine deposits can be divided into two types: recent (Holocene age) lacustrine deposits (Lr) and lacustrine deposits of Holocene-

Pleistocene age (L). The former are clearly identified and are composed of fine-grained soils. The latter are not as easily interpreted, therefore, the boundary between L and other types of deposits is less precise.

*Marine Deposits (M)*

Deposits covering marine plains and terraces consist typically of silts and clays with traces of sand. Shells are present in the sediments (Borehole 12259-06; 1996 geotechnical drilling program). The marine deposits are characterized by high ice content. The presence of earth hummocks on the surface is indicative of the marine plains, and it has been used as an indicator when interpreting the airphotos. Large ice-wedge polygons occur in poorly drained areas of the marine plains and are shown on the map (Figure 1.2-1)

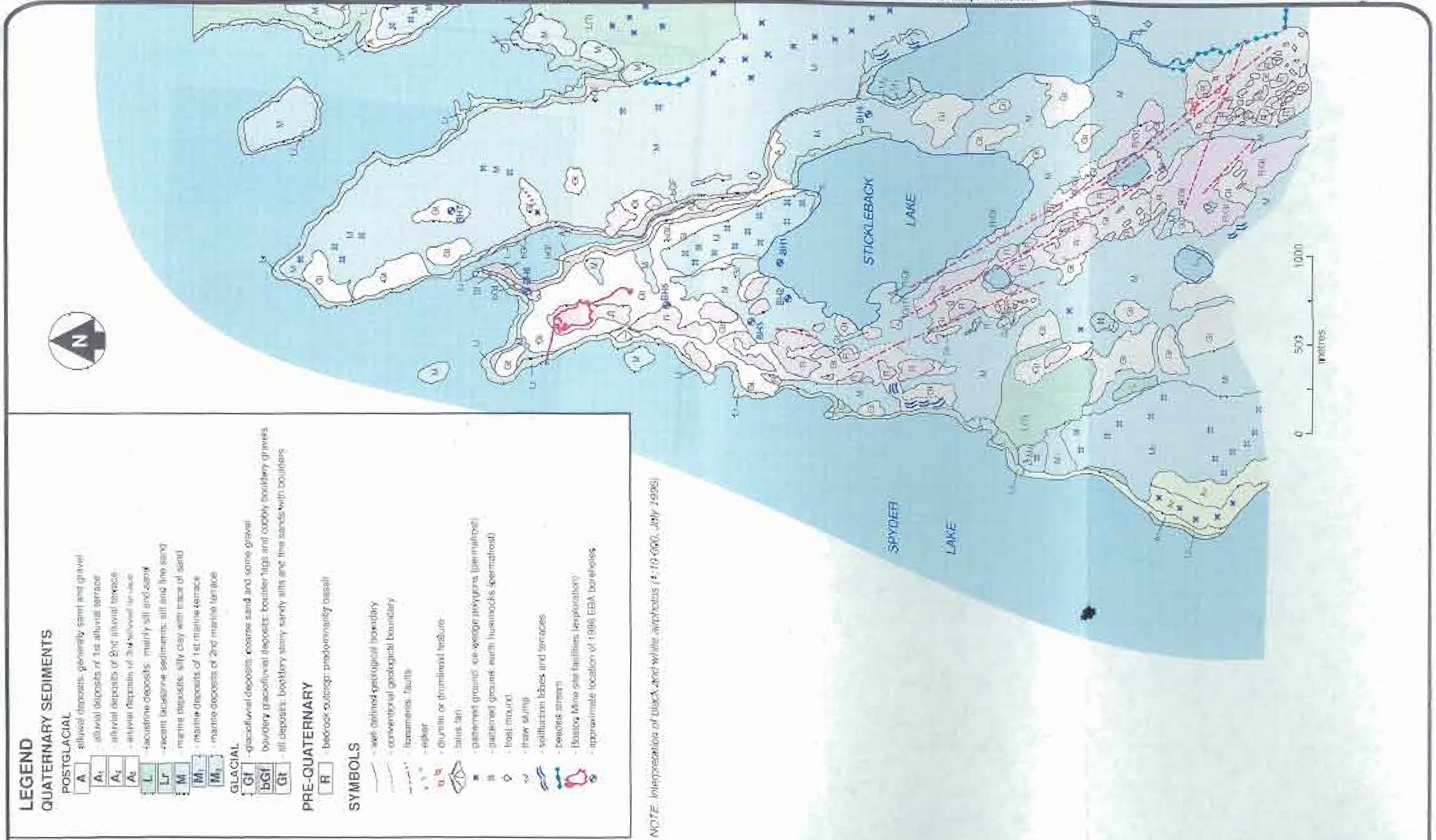
In the southwestern portion of the mapped area, the marine deposits comprise two well-defined terraces: 1st marine terrace ($M_1$) and 2nd marine terrace ($M_2$). The second marine terrace lies at the highest elevation and is believed to be composed of the oldest sediments, with the maximum amount of reworking by erosion and cryogenic geomorphic processes.

Within the rest of the mapped area, the marine sediments have not been separated into terraces due to the lack of geomorphic indicators and insufficient borehole data, and they are shown as “M” symbol on the terrain map (Figure 1.2-1).

*Glaciofluvial Deposits (Gf and bGf)*

Two types of glaciofluvial deposits are interpreted within the site area: glaciofluvial deposits (Gf) and bouldery glaciofluvial deposits (bGf). Gf are identified mainly as eskers and isolated patches of sand and gravel. The eskers are less than three metres high and about 10 to 12 m wide. The glaciofluvial material is typically coarse sand with some gravel.

Areas identified as bGf are boulder lags and cobbly bouldery gravels. They occur in areas where significant thickness of the finer grained till matrix soils have been removed by meltwater, leaving behind the larger cobbles and boulders on the surface.




BHP

FIGURE 1.2-1

# Surficial Geology and Permafrost Features Boston Project Area, Spyder Lake, NWT

Rescan

Source: EBA Engineering Consultants Limited 1996 101-12659L02C

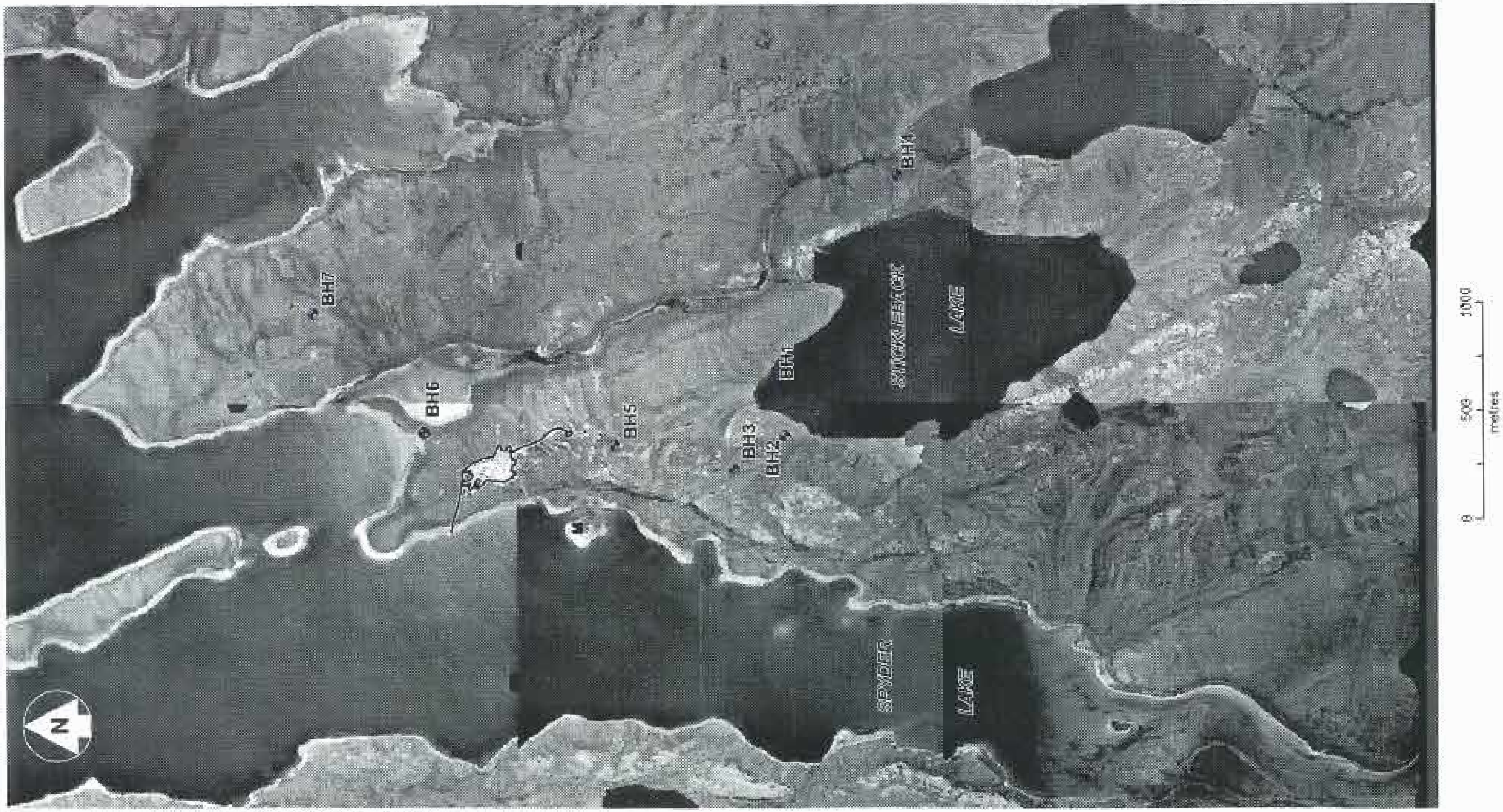



FIGURE 1.2-2

BHP

**Air Photo and Borehole Locations**
**Boston Gold Project, Spyder Lake, NWT**

Rescan

Source: EBA Engineering Consultants Limited, 1996    101-1225BL03A

*Till Deposits (Gt)*

Till is wide-spread in the Spyder Lake area and typically consists of a sand matrix with variable amounts of silt, gravel, cobbles and boulders, and occasionally some clay. It was noted in a preliminary study report (EBA 1993), that surface exposures of till appear to be related to elevation. Interpretation of the recent airphotos support that observation. Below about 80 m elevation, there are few till deposits. Between 80 and 110 m, the till exposed at surface is commonly observed on the flanks of bedrock outcrops where it is relatively thin (about 1.0 m thick) and infills depressions in the rock.

The thickest till deposit (seven metres) was encountered at Borehole 12259-06. The till consists of some gravel, silt and isolated cobbles. The matrix is very fine sand, clasts are coarse sand and fine gravel with some coarse gravel, cobbles and boulders up to 250 mm in diameter. The till is overlain by a five metre thick marine deposit, which in turn is covered by a glaciofluvial deposit (esker).

In locations where till is thin, frost jacked bedrock blocks are common. Scattered boulders resulting from frost jacking and erratics are observed at the surface of the till cover within most of the area.

*Bedrock (R)*

Glacial meltwater has completely stripped bedrock of its till cover over large areas. The bedrock outcrops are easily interpreted and are shown on the map, Figure 1.2-1. Bedrock typically consists of highly altered and foliated grey basalts, that are fractured and frost-shattered at the surface.

## 1.3 Investigation Program

The geotechnical investigation program was carried out between May 10 and May 24, 1996 and consisted of drilling seven boreholes to various depths. The borehole locations were chosen to ensure reasonable coverage of the dominant terrain units (rock uplands, marine lowlands, till ridges, and lake bottom sediments). A thermistor cable and automatic data logger was installed in three of the seven boreholes.

### 1.3.1 Borehole Locations

Six of the boreholes were drilled on land and one borehole was advanced from the ice surface of Stickleback Lake. Borehole locations, surface elevations and completion depths of each borehole are included in Table 1.3-1.

**Table 1.3-1**
**Borehole Location Summary**

| Borehole Number | UTM Coordinates | | Surface Elevation | Completion Depth |
|---|---|---|---|---|
| | Northing (m) | Easting (m) | (m) | (m) |
| 12259-01 | North Bay of Stickleback Lake | | | 10.9 (below lake bottom) |
| 12259-02 | 7504141 | 441213 | 71.7 | 4.1 |
| 12259-03 | 7504380 | 441113 | 77.6 | 16.1 |
| 12259-04 | 7504916 | 442236 | 73.9 | 13.9 |
| 12259-05 | 7504778 | 441172 | 80.5 | 15.6 |
| 12259-06 | 7505683 | 441327 | 69.7 | 15.8 |
| 12259-07 | Not located | - | | 8.4 |

**Note: Borehole coordinates determined by BHP survey crew relative to "mine grid" and converted to North American 1983 datum (NAD83) by Sub-Arctic Surveys Ltd., Yellowknife. Boreholes No. 1 and 7 were not accurately located.**

### 1.3.2 Drilling and Sampling

The boreholes were drilled using a Boyles Brothers BBS-25A diamond drill. Five of the boreholes were accessed using a skid-mounted set up and the remaining two holes required helicopter moves.

All six land-based holes were drilled using cold brine as the circulating fluid to preserve permafrost core. The brine was prepared by mixing a predetermined volume of calcium chloride pellets with fresh lakewater and snow. The snow was used to lower the temperature of the drill fluid to -2°C or colder to provide good quality frozen soil cores. Frozen core and bedrock samples were recovered with either an NQ (47 mm diameter) or HQ (63 mm diameter) wireline core barrel using conventional diamond drilling techniques. Core recovery in the permafrost was excellent at over 95%. Soft (unfrozen) sediments from the lake bottom of Stickleback Lake were recovered using a conventional split spoon. The split spoon was advanced hydraulically using the head of the diamond drill.

All recovered core was examined and logged in the field. Soil and ground ice classification and rock index parameters were determined immediately after the core was retrieved. Rock core samples were placed in wooden core boxes and photographed. Rock core index properties measured in the field included recovery, fracture frequency, and rock quality designation (RQD). Frozen soil core was photographed and selected samples were placed in plastic bags for subsequent testing.

All laboratory testing was conducted in accordance with CSA procedures and specifications. Laboratory tests included the following:

- natural moisture content;
- Atterberg Limits;
- particle size distribution analysis; and
- porewater salinity determinations.

Borehole logs are included in Appendix 1-1. The borehole logs contain geotechnical soil and rock description, including structural characteristics of the recovered rock core, descriptions of the ground ice, and laboratory test results. Appendix 1-2 provides a tabulated summary of all laboratory test data and the results of grain size analysis on selected overburden samples.

### 1.3.3 Ground Temperature Instrumentation

Thermistor cables were installed at three separate locations in order to monitor ground temperatures. The thermistor cables are of standard EBA design with ten sensing beads spaced over a total length of 15 m. One cable was installed in Borehole 12259-03 (May 17, 1996), which is located just west of the north bay of Stickleback Lake. A second cable was installed in Borehole 12259-05 (May 19, 1996) which is located on the rock upland between Stickleback Lake and the exploration camp site. The third thermistor cable was installed in Borehole 12259-06 (May 23, 1996) which is located immediately northwest of the camp on a low lying sand and gravel bar that protrudes into Spyder Lake. All three thermistor cables were connected to automated dataloggers which are programmed to record ground temperature information twice daily.

Ground temperature readings from all three cables were taken upon completion of the field program. The data loggers were accessed again in June and the data retrieved. Continuous data will be available throughout the winter 1996 to 1997 to supplement data included in this report. Ground temperature data collected to date are included in Appendix 1-3.

## 1.4 Geotechnical Conditions

The following provides a general description of the engineering characteristics of the rock/soils identified at the borehole locations. As described above detailed log of each borehole is included in Appendix 1-1 and a summary of laboratory test data is included in Appendix 1-2. Ground temperature data obtained from the dataloggers for the period May to June, 1996 is included in Appendix 1-3. Selected data have been plotted to show ground temperature with depth in the upper 15 m of the soil/rock profile.

### 1.4.1 Bedrock

The bedrock encountered by the site investigation is a highly altered basalt that is medium grey in color with variable greenish tints and highlights. Quartz stringers are common. The basalt is highly foliated in a near vertical to vertical direction and is relatively weak igneous rock. Core recovery was generally 100%. The RQD and fracture frequency were often difficult to ascertain due to the nature of the rock. Recovered core was typically fractured, but most fractures were observed to be along its natural foliations and appear to be drill induced. An occasional horizontal fracture with iron oxide staining was encountered. Notwithstanding the highly fractured core recovery, the RQD was typically around 60%, but ranged from 0 to 90%. The fracture frequency varied from 1 to greater than 15/m.

### 1.4.2 Overburden Soils

The boreholes were positioned to provide geotechnical data for the two principal soil landforms at the site: marine silt and clay and morainal till. These have been related to the interpreted surficial geology in Figure 1.2-1. A brief summary of the engineering characteristics of the major soil types is provided below.

*Marine Soils*

Marine soils that cover the bedrock in all lowlying areas are silt and clay of low plasticity. They have a well developed cover of surface vegetation. The thickness of marine silt and clay is highly variable, reflecting significant undulations in the underlying bedrock (or till) surface. The thickness varied from 1.5 to 8 m at the three boreholes drilled in this unit.

The boreholes were drilled at a time when the entire soil profile was frozen, however, accumulations of ground ice at a depth of 0.3 to 0.4 m indicate that this is the probable range in the thickness of the active layer (depth of seasonal thaw). The active layer will be somewhat deeper in upland regions where bedrock is exposed. Ground ice within the permafrost soil of marine origin is high, typically ranging from 20 to greater than 50% by volume of the soil.

All marine soils that were tested for salt within the pore ice had significant concentration. The salinities within the permafrost vary from 3 to 48 ppt, which is slightly greater than seawater (32 ppt). The salinity of the marine soils is less near the ground surface where salts have been leached out by moisture migration within the active layer and upper permafrost.

*Till*

Till core was obtained in the upper two metres at Borehole No. 5 and below marine soils at Borehole No. 6. The till has a sand matrix with a trace of silt and clay. Cobbles and boulders are disseminated throughout. Till near the surface has a low to moderate ice content as ice inclusions Vx/Vr rather than the thick lenses common in the marine soils. Till at depth has low ground ice content and is quite dense.

### 1.4.3 Ground Temperature

The ground temperature data collected for late May and June, 1996 are included in Appendix 1-3. Cold continuous permafrost is present everywhere except below lakes of substantial size and depth. Large lakes, such as Spyder Lake, are expected to be windows through the permafrost whereas smaller lakes and ponds may have permafrost at depth below an unfrozen lakebed. The permafrost boundary at the lake shore will characteristically be near a water depth of two metres, where lake ice no longer freezes to the bottom. The temperature of the lakebed measured at Stickleback Lake was to 0.7°C. The lakebed soils at that location (BH No. 1) are unfrozen beyond the maximum depth of borehole penetration, 11 m.

The ground temperature below the depth of seasonal variations ranges from -8 to -11°C. The depth to which seasonal temperatures vary is approximately ten metres. There are insufficient ground temperature data to judge the precise thickness of the active layer but it is anticipated to be about 0.4 m. A full year of ground temperature data will be available from the dataloggers when they are retrieved in the spring, 1997.

## 1.5 Terrain Sensitivity To Construction

The marine lowlands that are widespread at the site are the most sensitive to disturbance by site development. The well developed surficial organic layer, high ground ice contents and permafrost features such as ice wedges make this terrain unit particularly sensitive to disturbance. Where the site development such as roads and/or an airstrip encroaches on this unit, thicker than normal fills may be required to reduce the risk of thaw and construction should be restricted to the winter (frozen tundra) season.

The construction plans should be developed to ensure that there is no disturbance to the surface vegetation before fill is placed and there is no traffic on the unfrozen surface. Where structure foundations, such as piles are required within the marine soil unit, they must be designed for a high salinity permafrost environment. This will reduce their normal capacity to about 50% of the values used for adfreeze piles in non-saline conditions.

Facilities that are located within the bedrock and till terrain units will be much less susceptible to construction-related disturbance of the permafrost. The basalt bedrock will make an acceptable foundation unit for footings or rock socketed piles. Additional site-specific data will be required to develop foundation design parameters for final design purposes.

# 2. Meteorology

# 2. METEOROLOGY

The 1996 climatological monitoring program for the Hope Bay Belt area (Boston Property, Doris Lake Property, Roberts Bay and the trail corridor connecting Boston and Doris Lake Properties to Roberts Bay) consisted of an automated weather station at the Boston Property and an evaporation pan and semi-automatic datalogger at the Windy Lake camp. Following is a description of the monitoring methods, setting, results and discussion.

## 2.1 Methods and Setting

An automated weather station has been in operation at the Boston Property since July 1993. The weather station utilizes a Campbell Scientific CR10 datalogger and includes a tipping bucket rain gauge, temperature and relative humidity sensor, ultrasonic snow depth gauge and wind monitor (direction and speed). The sensors are read every five seconds. Hourly and daily averages and maximum wind speed are logged to a data storage module. The station is powered by two 12 V deep cycle marine batteries which are recharged by a 30 W solar panel.

Data collection continued in 1996 at the weather station and the data storage module was downloaded in mid June and reinstalled. The sensors were maintained and recalibrated, as necessary. An on-site geologist was trained to download data from the data storage module. The data were added to the existing database and augmented by regional data (see below). During early June 1996 a manual rain gauge and maximum-minimum thermometer were installed near the Boston camp. Data collected daily from these instruments were used to verify data collected at the automated station.

Due to the consistency of the regional topography, data collected at the Boston weather station are considered representative of the climatological conditions for the Doris Lake Project, trail corridor and Roberts Bay areas.

The climatological monitoring program initiated in 1996 at the Doris Lake Project was continued in 1997. The site-specific data collected for Doris Lake in 1996 consisted of manual data and semi-automatic data collection. The semi-automatic datalogger has a temporary memory module which must be downloaded on a daily basis. The climatological parameters measured include temperature, wind speed, wind direction and cloud cover. Climatological data were monitored with the semi-automatic datalogger throughout the 1996 exploration season. Data from the semi-automated weather station at Doris Lake were used to supplement the data collected at the Boston automated weather station.

A manual evaporation pan was installed at the Doris Lake site (48 km north of the Boston Property) during the ice-free period of 1996. The hook gauge for the evaporation pan was read daily along with precipitation from a manual rain gauge.

In addition to the above parameters an instrument for measuring snowfall was installed in early June 1996 near the Windy Lake exploration camp. The standard system for measuring snowfall precipitation in Canada is a manually operated Nipher shielded snow gauge. The gauge consists of an inverted bell-shaped cone which is designed to maximize snowfall catch efficiency. A copper cylinder is located in the centre of the shield and collects the snowfall. The copper cylinder is recovered on a daily basis to the laboratory where the snow is melted and the resulting volume of water is measured in units of millimetres of water equivalent. The snow gauge was read once a day when there was snow.

To obtain the requisite verification of the on-site data for an environmental impact statement, the climatological databases for the Boston and Doris Lake projects are augmented with government data collected by Environment Canada Atmospheric Environment Service (AES). The locations of the AES and BHP Hope Bay Belt weather stations are indicated on Figure 2.1-1.

## 2.2 Results

Results of the baseline studies for air temperature, precipitation, wind speed and direction, and evaporation are presented below.

### 2.2.1 Air Temperature

The nearest regional AES climatological stations are Cambridge Bay Airport, Contwoyto Lake (Lupin), and Lady Franklin Point Airport. The Boston autostation had similar monthly mean temperatures for the period of record

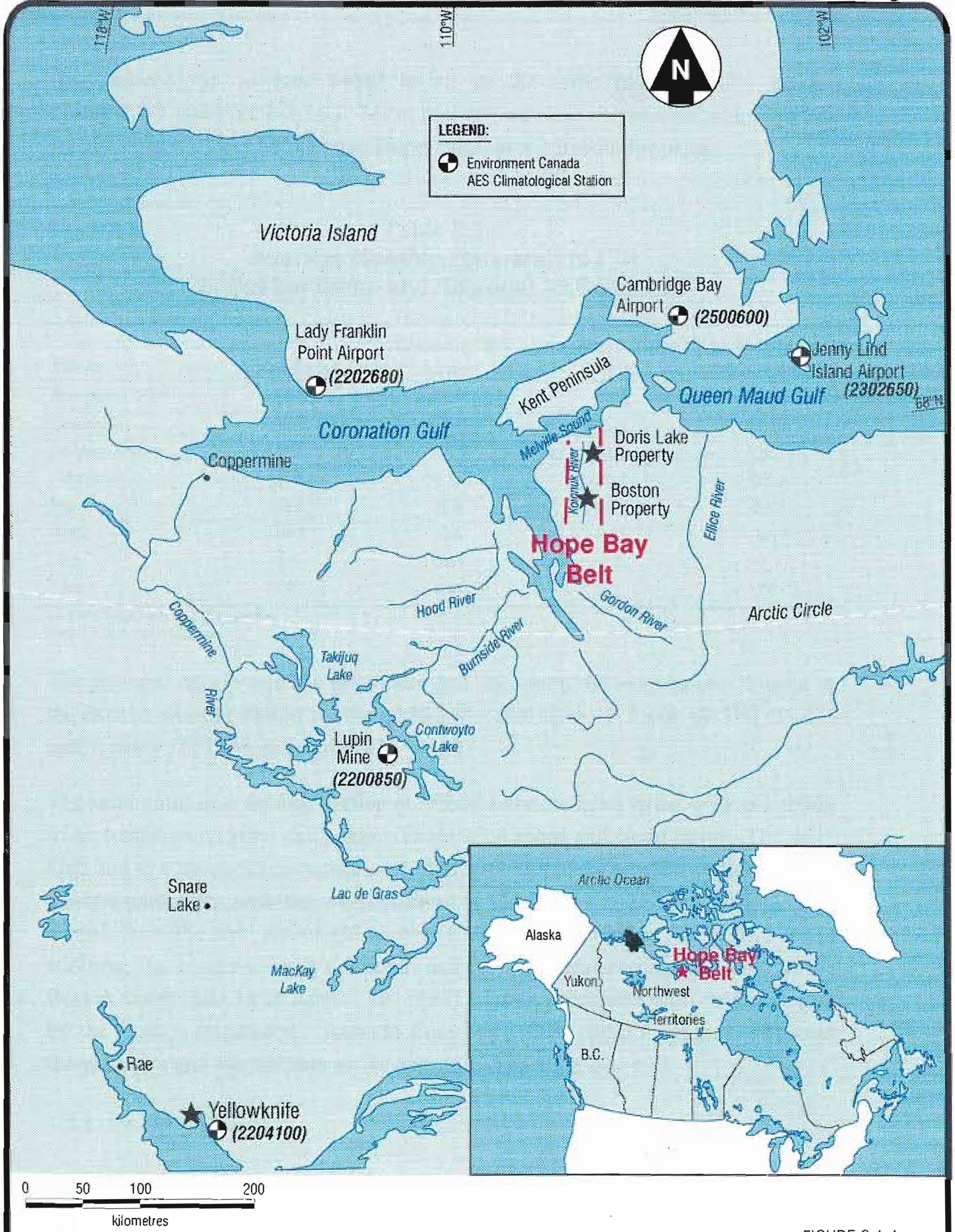



FIGURE 2.1-1

**Location of Regional Climate Stations**

BHP

Rescan

(November 1995 to June 1996) to all of the three regional AES stations (Table 2.2-1 and Figure 2.2-1). Mean monthly air temperatures at Cambridge Bay were consistently colder than the temperatures at the Boston Property.

**Table 2.2-1**
**Average Monthly Temperature (ºC)**
**at Boston Camp and Regional AES Stations**

| Month | Boston Camp | Cambridge Bay Airport | Contwoyto Lake (Lupin) | Lady Franklin Point Airport |
|---|---|---|---|---|
| November 1995 | -21.8 | -23.7 | -20.6 | -17.6 |
| December | -30.8 | -33.9 | -29.9 | -30.0 |
| January 1996 | -31.9 | -33.9 | -31.7 | -29.3 |
| February | -28.8 | -31.3 | -26.7 | -26.8 |
| March | -25.8 | N/A | -25.9 | -25.6 |
| April | -19.2 | N/A | -16.3 | -17.7 |
| May | -7.0 | N/A | -5.8 | -7.4 |
| June | 4.9[1] | N/A | 9.7 | 5.6 |

**1: Only June 1 to June 13 available.**
**Note: N/A = Not Available.**

The extreme hourly average maximum and minimum air temperatures logged at the Boston weather station for the period of record were 16.3 and -44.1°C (June 5 and January 15, 1996, respectively).

The semi-automatic weather station at Windy Lake included twice daily collection of air temperature, wind chill, approximate wind speed and cloud cover. The daily high and low temperatures collected at this semi-automatic weather station were in general agreement with the data collected at the Boston automated station. The records from the semi automated weather station are included as Appendix 2-1. In addition, the maximum and minimum daily air temperature data collected at the Boston camp (July 16 to August 19, 1996) were in agreement with data collected by the Boston autostation. Records from the Boston camp maximum/minimum thermometer and manual rain gauge appear in Appendix 2-1.

### 2.2.2 Precipitation

Precipitation levels are usually higher during the late summer to early winter period although there is precipitation every month of the year. Precipitation was monitored at a total of three different sites. A manual rain gauge and Nipher snow gauge were installed at Windy Lake on June 14, and the monitoring continued until September 4. A manual rain gauge was installed at Boston camp on July 16 and was monitored until August 19. The automated weather station near Boston camp includes a tipping bucket rain gauge which logs one minute rainfall data when it is raining. The period of record for the Boston automated weather station is November 1, 1995 to June 12, 1996. Data from the tipping bucket rain gauge are considered more reliable than those from the manual rain gauges. However, to allow for a continuous period of record from November 1995 to August 1996 data from the Windy Lake manual rain gauge were used for the period from June 12 to the end of August (Table 2.2-2).

Late summer coincided with the highest monthly precipitation rates recorded by the Windy Lake manual rain gauge and regional AES stations. No snowfall precipitation was measured at the Windy Lake Nipher snow gauge for the period of record (June 14 to September 4). Nipher snow gauge data were not collected from November 1995 to mid June 1996 because there were no personnel at the Windy Lake camp to monitor the instrument.

The precipitation data from Boston weather station were compared to those from the regional AES stations at Cambridge Bay Airport and Contwoyto Lake (Lupin). No precipitation data were available from Lady Franklin Point Airport. According to AES the mean annual precipitation for the project site is approximately 120 mm (Environmental Canada 1993). At the Boston site, over one-half of the mean annual precipitation occurred during August, with a total precipitation of 79.2 mm. This is consistent with data collected at the BHP NWT Diamonds project located approximately 300 km south of the Hope Bay Belt projects and the Lupin AES station. At Lupin the month of August experienced approximately 50% of the mean annual precipitation (131.8 and 265 mm, respectively). At the NWT Diamonds project the month of August recorded approximately 35% of the mean annual precipitation (105.7 and 307 mm, respectively) (Rescan 1996). The data indicate that 1996 was a wet year, particularly the month of August.

### 2.2.3 Wind Speed and Direction

Wind speed and direction data were collected at the Boston camp automated weather station and the semi-automatic station at Windy Lake during 1996. The

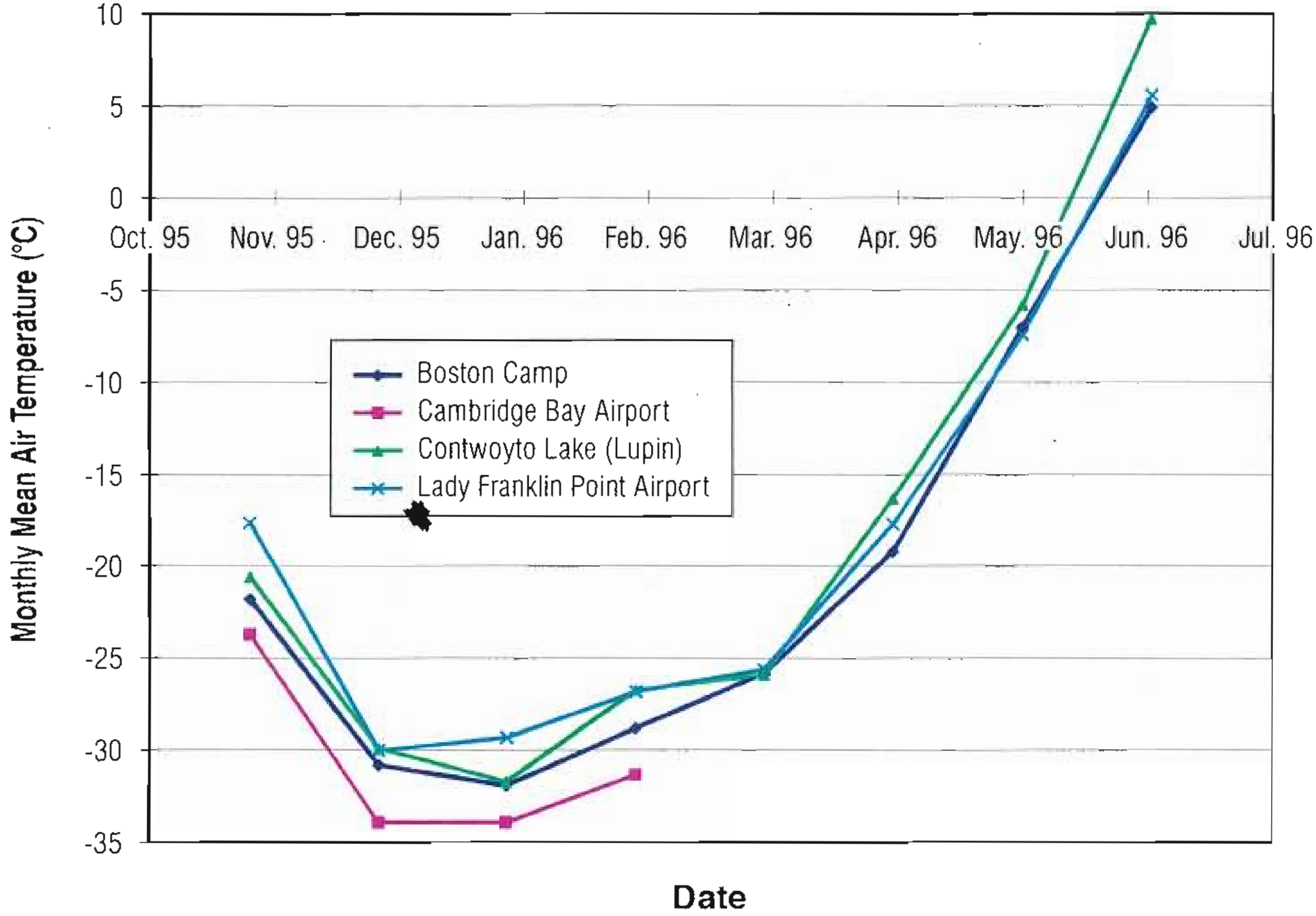



FIGURE 2.2-1

# Mean Monthly Temperatures at Boston Camp and Regional Stations

BHP

Rescan

**Table 2.2-2**
**Total Precipitation (mm) at Boston Camp and Regional AES Stations**

| Month | Boston Camp | Cambridge Bay Airport | Contwoyto Lake (Lupin) |
|---|---|---|---|
| November 1995 | 0 | 4.8 | 7.4 |
| December | 0 | 2.2 | 23.8 |
| January 1996 | 0 | 1.5 | 5.8 |
| February | 0 | 4.3 | 18.4 |
| March | 0 | N/A | 4.4 |
| April | 0.5 | N/A | 8.0 |
| May | 0.3 | N/A | 24.8 |
| June | 6.4[1] | N/A | 54.0 |
| July | 9.9[2] | N/A | 57.7 |
| August | 79.2[2] | N/A | 131.8 |

**1: Only June 1 to June 12 were available from the Boston automated station, June 12 to 30 data was from the Windy Lake manual rain gauge.**
**2: No data was available from Boston automated station, this data was from the manual rain gauge at Windy Lake.**

automated station monitors a wind speed and direction sensor every five seconds. Ten minute and hourly average wind speeds and directions are saved to final storage in the storage module. Standard deviation for wind direction is also logged for the last ten minutes of each hour and for the entire hour. Daily maximum instantaneous wind speeds are logged at the end of the day along with the corresponding wind direction and time of day. The semi-automatic station at Windy Lake collected data for low windchill, and instantaneous wind speed and direction. Wind data from the Boston automated station is considered the most representative of the area since the sensor is monitored every five seconds for 24 hours per day.

Continuous wind data are available for the Boston station from November 1, 1995 to June 12, 1996. The predominant wind direction for the station was from the northwest (26% of the time). The majority of the wind speeds when the wind was blowing from the northwest were in the range of 2.5 to 7.5 m/s. Calm conditions, (*i.e.*, wind speeds below one metre per second) occurred 9.8% of the time. The wind rose for the Boston weather station is summarized in Figure 2.2-2. These wind patterns are slightly different from data collected in 1995 where the predominant wind direction was from the northeast (28% of the time) and calm winds prevailed for 8.7% of the time (Rescan 1995).

### 2.2.4 Evaporation

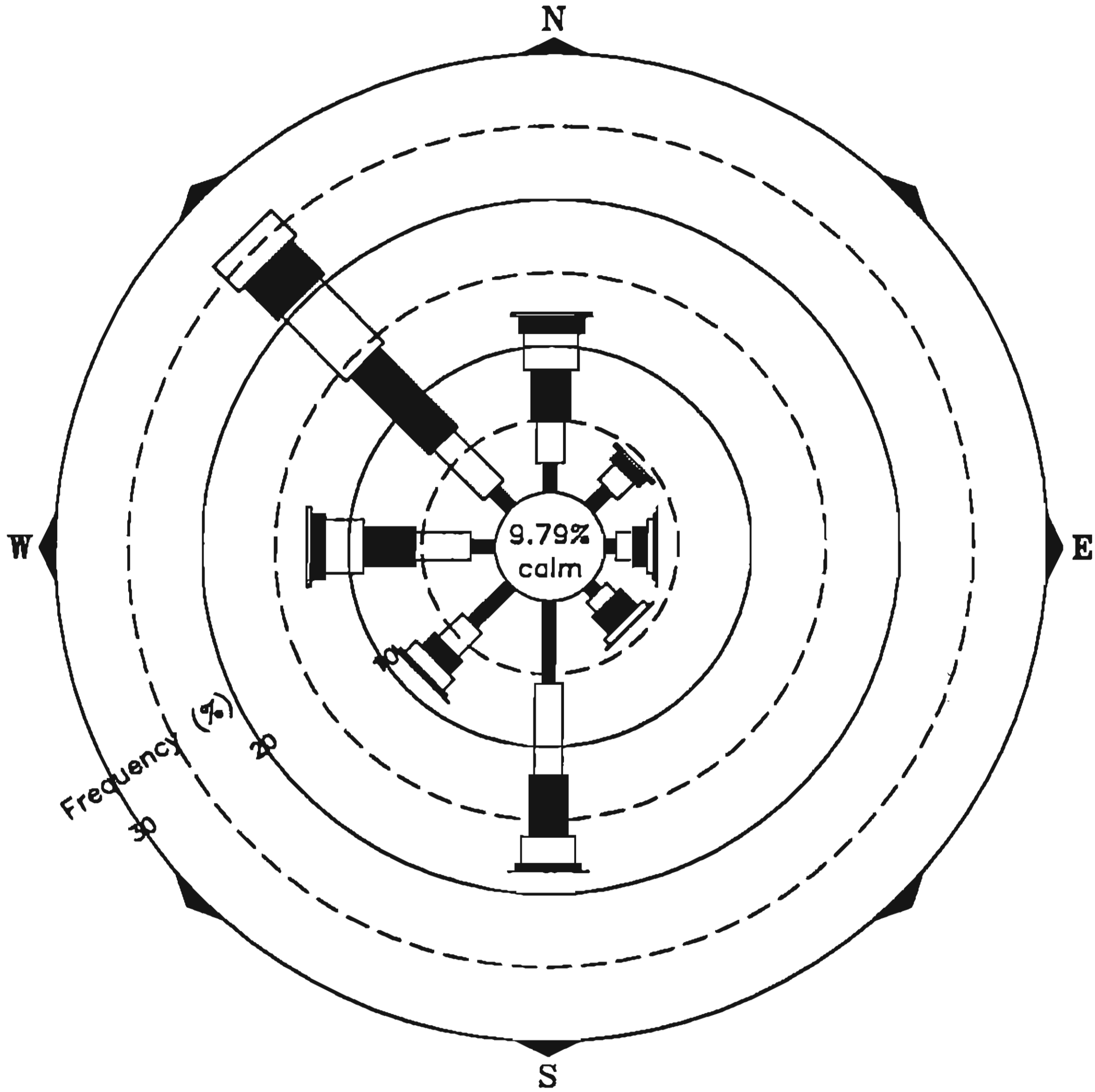
Evaporation data were collected from a Class A evaporation pan located at Windy Lake adjacent to the exploration camp. The on-site staff were trained to collect the hook gauge readings on a daily basis. The evaporation pan was installed June 14 and was monitored daily until September 4. Several of the readings collected between June 14 and July 12 were not valid because the operators failed to collect two hook gauge readings when there was water either added or removed from the pan. Approximately six days of data in this time period were invalid.

Windy Lake evaporation data were compared with data collected at Yellowknife airport (Yellowknife airport is the nearest regional AES with an evaporation pan). Total pan evaporation at Windy Lake between June 14 and September 4 was 53 mm (Table 2.2-3). Mean daily pan evaporation was 0.7 mm, which corresponds to a total pan evaporation rate of 86 mm over the assumed ice-free period of June 19 to October 20 (124 days). The evaporation rate at Windy Lake was relatively low due to heavy rainfall in August.

The total precipitation recorded in August by the manual rain gauge at Windy Lake was approximately 79.2 mm. This is higher than the rainfall recorded for August 1995, 18.7 mm (Klohn-Crippen 1996). Considering the mean annual precipitation for the area is approximately 120 mm, over half of the 1996 yearly total occurred in August. This unusually high rainfall trend was also recorded at the regional AES stations and at the BHP NWT Diamonds weather station located approximately 300 km south of Windy Lake.

The negative evaporation rate for August is unrealistic and is thought to be a result of a problem with the data collection procedures. The rainfall recorded by the manual rain gauge was consistently higher than the rainfall accumulated in the evaporation pan. There could be many causes for this. It is possible that the hook gauge was not being read correctly, the rain gauge was not being read correctly or the stillwell was changing position in the pan from day to day (this would indicate that the pan was not level).

A comparison of evaporation data (Windy Lake *vs* Yellowknife airport) was made for the common period of record for 1996 (June 14 to September 4). The pan evaporation rate at Windy Lake averaged 13% of the pan evaporation rate at the




WIND SPEED SCALE

| m/s | 1.0–2.5 | 2.5–5.0 | 5.0–7.5 | 7.5–10.0 | 10.0–12.5 | >12.5 |
|---|---|---|---|---|---|---|

Data available from November 1, 1995 to June 12, 1996.

# Wind Rose for Boston Weather Station

FIGURE 2.2-2

BHP

Rescan

**Table 2.2-3**
**1996 Class A Pan Evaporation at Windy Lake**

| Month | Windy Lake (mm) | Yellowknife Airport (mm) |
|---|---|---|
| June 15 to 30[1] | 43 | 111 |
| July 1 to 31[2] | 71 | 184 |
| August 1 to 31[3] | -67 | 109 |
| September 1 to 4 | 6 | 10 |
| **Total** | **53** | **414** |

**1: Only 13 days of valid data; the remaining three days were invalid due to operator error.**
**2: Only 28 days of valid data; the remaining three days were invalid due to operator error.**
**3: Thirty days of valid data; the remaining one day was invalid due to operator error. The negative evaporation rate was due to very heavy rainfalls recorded during August 2, 11, and 18 to 24.**

Yellowknife airport (53 mm *vs.* 414 mm). This is not surprising since Windy Lake is approximately 730 km northeast of Yellowknife, and therefore would experience cooler temperatures and less solar radiation. The systematic error in the procedures used to monitor the manual rain gauge and/or hook gauge would also contribute to this difference.

Lake evaporation may be estimated by applying a coefficient to the Class A pan evaporation. Pan evaporation is almost always higher than lake evaporation because of radiation and boundary effects. To be consistent with the BHP NWT Diamonds project an acceptable coefficient is 0.75. If the pan coefficient is applied to the Windy Lake assumed open-water seasonal total of 86 mm, an estimated lake evaporation for 1996 of 64 mm is obtained.

*Recommendations for Future Work*

The instruments for monitoring snow, rain and evaporation should be reinstalled at the Windy Lake camp as soon as it is opened in 1997. The semi-automatic datalogger at Windy Lake camp should also be recommissioned as early as possible. The maximum/minimum thermometer and manual rain gauge should be reinstalled at the Boston site as early as possible in the 1997 exploration season. The on-site personnel should be trained to monitor the equipment on a daily basis. Monitoring should continue daily until each of the camps close at the end of 1997 exploration season. Data should be collected from the Boston automated weather station as early as possible in 1997, and then once every two months by one of the on-site personnel who has been appropriately trained.

# 3. Air Quality

# 3. AIR QUALITY

Air quality is a concern for a variety of reasons. Air quality can affect vegetation and wildlife, visibility, and worker health and safety. From the perspective of long term planning it is important to determine the baseline air quality in order to assess potential future impacts. The 1996 baseline studies for air quality consisted of high volume (HV) air sampling near the Windy Lake camp and the Boston camp.

## 3.1 Methods and Setting

To establish a baseline for air quality an HV air sampling program was implemented. Five days of HV air sampling were performed at each of the sites during August 1996. Air quality near the Boston and Doris Lake properties was expected to be pristine because of the absence of any anthropogenic air pollution sources. The only source of air emissions at the projects were diesel generators used for power generation and a crusher and associated stockpiles of rock removed from the underground exploration program at the Boston site.

A phenomenon known as the arctic thermal inversion often causes air quality problems in the high arctic. The arctic thermal inversion is a major factor for pollution events because of the formation of a stable layer of air near the ground, which prevents mixing and dilution of air contaminants. This phenomenon has been documented in literature and has been closely associated with well documented winter pollution problems at Fairbanks, Alaska.

An HV air sampler draws a known volume of ambient air at a flow rate of $1.13 \pm 0.11\ m^3/min$ through an inlet and through one or more filters which trap particulate matter. The usual configuration collects total suspended particulates (TSP) on the filter paper. The 20 x 25 cm (8" x 10") filter paper is weighed before and after 24 hours of air sampling. The difference in weight of the filter before and after sampling (in micrograms) along with the volume of air sampled (cubic metres) is used to calculate the concentration of particulates in micrograms per normal (or standard) cubic metres of air ($\mu g/Nm^3$). If necessary, the filters may be subsequently analyzed for major ions by ion chromatography (IC).

In addition, a PM10 HV air sampler was used to monitor particulates near the Boston and Doris Lake camps. The PM10 method measures the mass concentration of particulate matter with an aerodynamic diameter less than or equal to a nominal 10 µm in ambient air over a period of 24 hours. These particles are representative of the respirable dust that is of human health concern, and are referred to as PM10. A PM10 sampler is similar to a TSP sampler, however a specialized size selective inlet directs only the <10 µm fraction of the particulate matter to the filter.

To allow for portability, the HV air samplers were powered with gasoline driven generators. The samplers were positioned away from the influence of wind blown dust created by exploration activities (*e.g.*, crusher and stockpiles of rock removed from the underground exploration program at Boston) and the diesel power generation facilities for each camp.

Baseline monitoring for gaseous constituents (carbon dioxide, ozone, sulfur dioxide, nitrogen oxides, *etc*.) was not warranted at this time because of the absence of anthropogenic sources and the high cost of monitoring instrumentation. The baseline TSP and PM10 concentrations are compared with the Canadian *Environmental Protection Act* - Canadian Ambient Air Quality Objectives, and to data previously collected in the region, if any.

## 3.2 Results and Discussion

A total of five days of HV air sampling was performed at each of the sites, Windy Lake and Boston, during August 1996. In addition to monitoring TSP and PM10 concentrations a cascade impactor was used to determine the particle size distribution of the particulate below 10 µm. Several of the HV air samples collected at the Windy Lake camp near a core splitting shack and near the sleeping tents were analyzed for a selected number of metals. The results for each of these studies are presented below.

### 3.2.1 TSP and PM10 Concentrations

The objective of the HV air sampling program was to determine baseline concentrations of TSP and PM10 (particulate matter <10 µm). Hence the samplers were installed far enough away from the exploration camps so that they would not be affected by the camp or exploration activities. The potential sources of interference were exhaust from diesel power generators, dust from air traffic and the crusher (Boston site only), and fugitive dust from wind erosion of the stockpiles of rock from the underground exploration at the Boston site. To avoid interferences the HV air samplers used at Windy Lake were installed within a minimum radius of two kilometres from the camp. At Boston camp the samplers were installed at least 4.4 km away from the camp. The locations of the sample stations with respect to the Windy Lake and Boston camps are summarized in Table 3.2-1.

**Table 3.2-1**
**Location of High Volume Air Samplers near Windy Lake and Boston Camps - August 1996**

| | | UTM Coordinates | | |
|---|---|---|---|---|
| **Location** | **Site** | **East** | **North** | **Comments** |
| Windy Lake Camp | 1 | 430783 | 7549823 | West side of Windy Lake, 2.0 km from camp |
| | 2 | 430754 | 7554987 | North end of Windy Lake, 4.3 km from camp |
| | 3 | 435598 | 7550088 | East side of Patch Lake, 3.3 km from camp |
| | 4 | N/A | N/A | Near core splitting shack at Windy Lake camp |
| | 5 | N/A | N/A | Adjacent to sleeping tent no. 4 at Windy Lake camp |
| Boston Camp | SW | 437511 | 7502194 | 4.6 km southwest of Boston camp |
| | SE | 443325 | 7496203 | 9.3 km southeast of Boston camp |
| | NW | 438374 | 7510939 | 6.2 km northwest of Boston camp |
| | NE | 445090 | 7506554 | 4.4 km northeast of Boston camp |

The TSP and PM10 concentrations for each of the Windy Lake and Boston camp sample sites are summarized in Table 3.2-2. The TSP concentrations at Windy Lake and Boston camp are summarized by Figure 3.2-1 and the PM10 concentrations by Figure 3.2-2.

The TSP concentrations were compared with the Canada *Environmental Protection Act* Ambient Air Quality Objectives (CAAQO). The CAAQO specify three different types of guidelines; desirable, acceptable and tolerable. The most appropriate type of guideline for comparison is acceptable. The CAAQO acceptable objective for TSP monitored over a continuous 24 hour period is less

## Table 3.2-2
## TSP[1] and PM10[2] Concentrations at Windy Lake and Boston Camps - August 1996

| Date | Parameter | Location | Sample Site | Concentration ($\mu g/Nm^3$) |
|---|---|---|---|---|
| August 9 | TSP | Windy Lake | 1 | 29.6 |
| | PM10 | Windy Lake | 2 | 1.9 |
| | TSP | Windy Lake | 3 | 5.3 |
| | TSP | Windy Lake | 4 | 17.2 |
| August 10 | TSP | Windy Lake | 1 | 4.5 |
| | PM10 | Windy Lake | 2 | 1.3 |
| | TSP | Windy Lake | 3 | 6.2 |
| | TSP | Windy Lake | 4 | 360.4 |
| August 11 | TSP | Windy Lake | 1 | 12.3 |
| | PM10 | Windy Lake | 2 | <1.0 |
| | TSP | Windy Lake | 3 | 7.6 |
| | TSP | Windy Lake | 5 | 66.7 |
| August 12 | TSP | Windy Lake | 1 | 35.7 |
| | PM10 | Windy Lake | 2 | 3.8 |
| | TSP | Windy Lake | 3 | 59.3 |
| | TSP | Windy Lake | 5 | 33.6 |
| August 13 | TSP | Windy Lake | 1 | 5.3 |
| | PM10 | Windy Lake | 2 | 9.3 |
| | TSP | Windy Lake | 3 | 47.4 |
| | TSP | Windy Lake | 5 | 5.8 |
| August 14 | TSP | Boston camp | NW | <1.0 |
| | TSP | Boston camp | SW | <1.0 |
| | TSP | Boston camp | SE | 24.8 |
| | PM10 | Boston camp | NE | 18.3 |
| August 15 | TSP | Boston camp | NW | <1.0 |
| | TSP | Boston camp | SW | 13.8 |
| | TSP | Boston camp | SE | 24.5 |
| | PM10 | Boston camp | NE | 1.3 |
| August 16 | TSP | Boston camp | NW | <1.0 |
| | TSP | Boston camp | SW | <1.0 |
| | TSP | Boston camp | SE | <1.0 |
| | PM10 | Boston camp | NE | <1.0 |
| August 17 | TSP | Boston camp | NW | 4.5 |
| | TSP | Boston camp | SW | <1.0 |
| | TSP | Boston camp | SE | <1.0 |
| | PM10 | Boston camp | NE | 19.2 |
| August 18 | TSP | Boston camp | NW | <1.0 |
| | TSP | Boston camp | SW | 4.6 |
| | TSP | Boston camp | SE | <1.0 |
| | PM10 | Boston camp | NE | 4.6 |

**1: Total Suspended Particulates.**
**2: Particulate Matter <10 µm.**
**Note: The criteria for TSP (Canadian Ambient Air Quality Acceptable Objective) is <120 $\mu g/Nm^3$, the criteria for PM10 (United States Environmental Protection Agency) is 150 $\mu g/Nm^3$.**

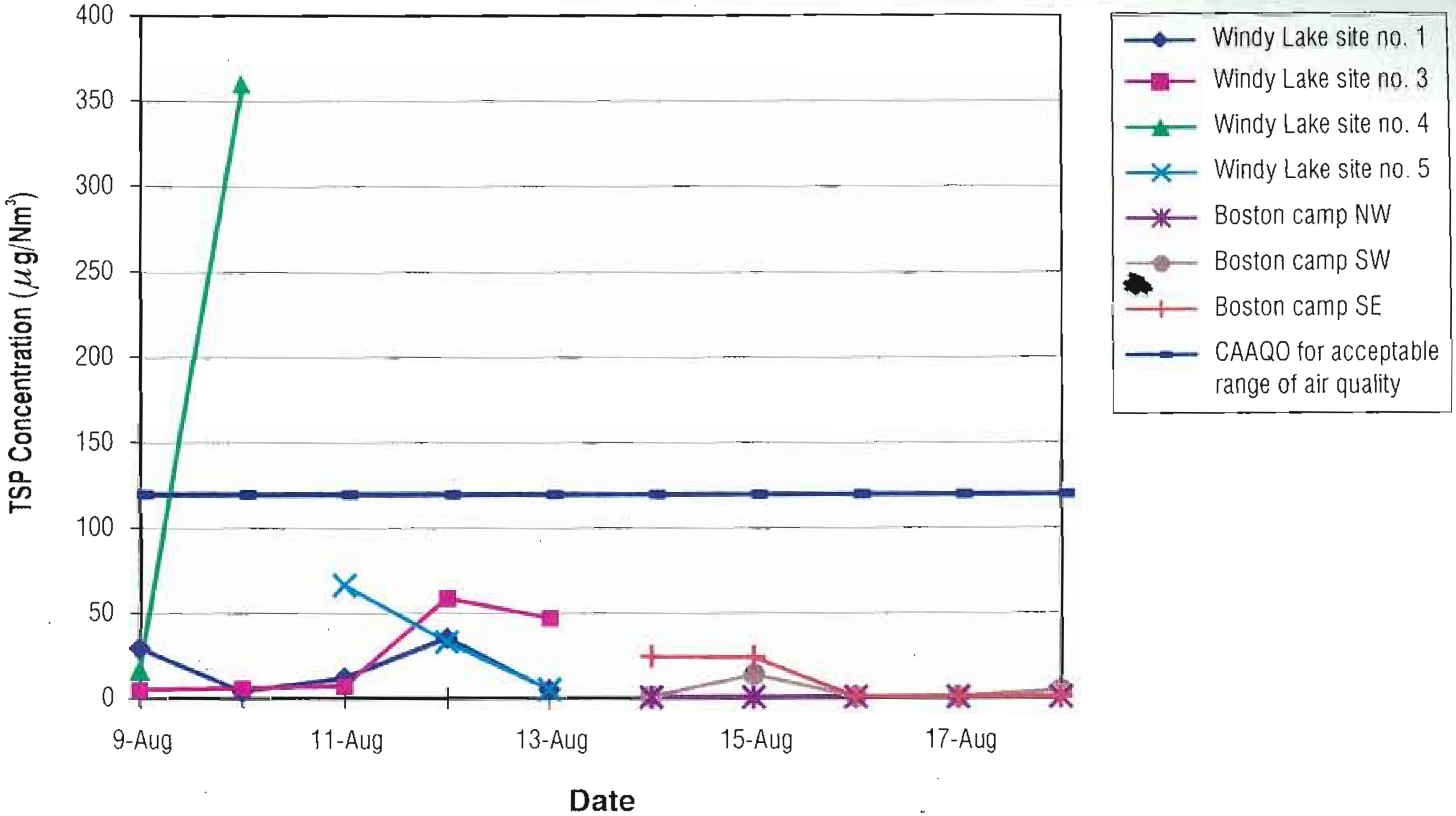



FIGURE 3.2-1

# TSP Concentrations for Windy Lake and Boston High Volume Air Sampling - August 1996

BHP Rescan

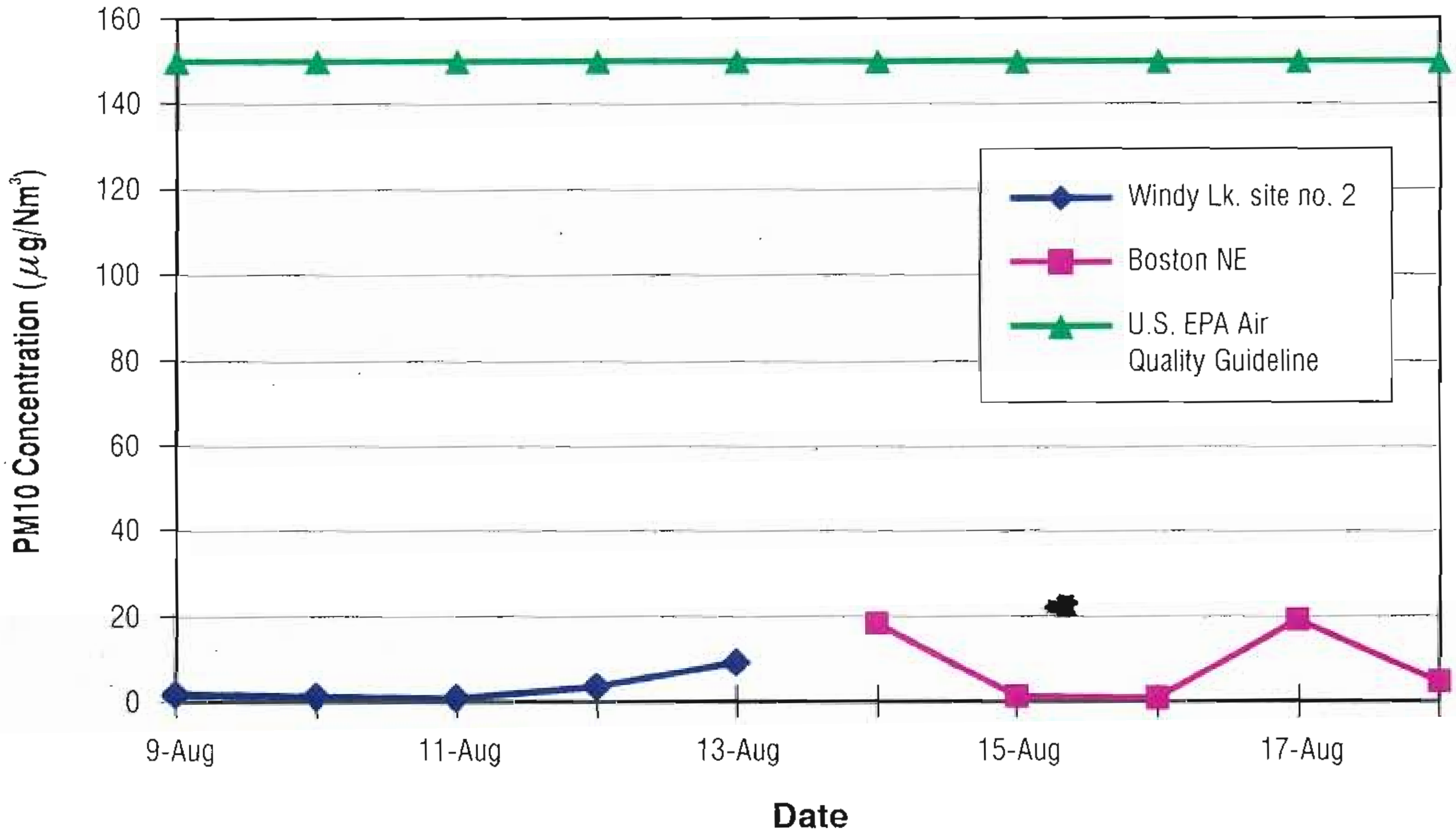



FIGURE 3.2-2

BHP

**PM10 Concentrations for Windy Lake and Boston High Volume Air Sampling - August 1996**

Rescan

than 120 µg/normal cubic metre ($Nm^3$). To date Canada has not adopted guidelines for PM10, however, the United States Environmental Protection Agency (U.S. EPA) guideline is 150 µg/$Nm^3$.

One of the TSP samples exceeded the CAAQO; however, this sample site (near a core splitting shack in the Windy Lake camp) was not representative of baseline conditions. The TSP sampler was installed at this location at the request of one of the BHP Exploration Managers. The high concentration indicated that the workers inside and in the vicinity of the core splitting shack should continue to wear filter masks to avoid inhaling an excessive amount of nuisance dust. The filter masks were consistently being worn by the core splitters and there is no reason for concern.

All other TSP concentrations were below the acceptable CAAQO. The baseline TSP concentrations were expected to be well below the CAAQO because there are no anthropogenic air emission sources in the area. The sample site with the highest TSP concentration at Windy Lake, was located in the camp approximately ten metres from one of the sleeping tents. For two days of monitoring the TSP concentrations were approximately 50 µg/$Nm^3$. These concentrations are higher than the other baseline sites because of foot traffic and the burning of garbage in the camp.

All of the PM10 concentrations monitored at both Windy Lake and Boston camp were well below the U.S. EPA Air Quality Guideline. Again, these results are not surprising because there were no anthropogenic sources of air emissions within a radius of two kilometres from any of the samplers.

### 3.2.2 Particle Size Distributions

The cascade impactor has five cutoff stages (10.0, 7.2, 3.0, 1.5, 0.95 and 0.49 µm) and was installed several times during the sample campaign. There are no government guidelines or objectives for particle size distributions. The objective of the particle distribution size study was to obtain a baseline for future impact assessment.

The particle size distribution for TSP is a function of the emission source. For example, a particle size distribution near a crusher will be much coarser than fugitive dust from a gravel road. A crusher involves mechanical pulverization of whole rocks, thereby producing a coarse type of dust, along with a small portion of finer particulate matter. Fugitive dust from a unpaved road involves continuous pulverization of smaller particles. Hence, the particulates will be finer, gravitational settling will be slower and the wind will be able to carry the particulates further away from the source. The amount of silt (particles with a aerodynamic diameter of 75 µm or less) in the rock being crushed or on the road surface is one of the factors affecting the amount of particulate emissions. There are several other important factors such as the moisture content and size of the original materials. In certain instances a particle size distribution may be used to identify the primary source of particulate emissions when there are several sources in the same area.

A total of five cascade impactor samples were collected and the results were very similar. All of the particulate matter was collected on the base filter which indicates that they had an aerodynamic diameter of less than 0.49 µm. The five samples are summarized by Table 3.2-3.

**Table 3.2-3**
**Particle Size Distributions From Cascade Impactor**

| Date of Sample | Location | Volume of Air Sampled ($Nm^3$) | Comments |
|---|---|---|---|
| August 11 | Windy Lake No. 1 (west side of Windy Lake) | 1547 | All particulates less than 0.49 µm |
| August 13 | Windy Lake No. 2 (east side of Patch Lake) | 1183 | All particulates less than 0.49 µm |
| August 16 | Boston SW (4.6 km SW of camp) | 1169 | All particulates less than 0.49 µm |
| August 17 | Boston SE (9.3 km SE of camp) | 1207 | All particulates less than 0.49 µm |
| August 18 | Boston NW (6.2 km NW of camp) | 1161 | All particulates less than 0.49 µm |

The fine distribution for the particulates is not surprising since there were no anthropogenic sources near the samplers. A very small amount of particulates may have been produced when the helicopter landed twice each day at each sample site to refuel the generators and change the filter. In conclusion, any natural particulate matter caused by wind or the activity of wildlife had a very fine size distribution.

### 3.2.3 Metal Concentrations in Particulates

At the request of BHP a selected number of HV air samples were collected in the Windy Lake camp near the core splitting shack and near the sleeping tents. The particulates collected on these filters were digested in an acid solution and analyzed using atomic adsorption for the follow elements: As, Cd, Cu, Pb, Zn, Hg, Al, Sb and Fe.

Results from the analytical laboratory were expressed in units of total micrograms of metal per filter. In order to convert the weight of metals into a concentration of metals in ambient air, the mass of each metal (µg) was divided by the total volume of air sampled ($Nm^3$) to determine the concentration of metals in units of micrograms per normal cubic metre ($\mu g/Nm^3$). The concentrations of metals in ambient air were compared to the NWT *Mine Safety Act* - Mining Safety Regulations and/or the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs). The calculated concentrations of metals and the occupational standards are summarized in Table 3.2-4.

None of the metals in the particulates exceeded either the NWT or ACGIH criteria. In most cases the concentration of metals on the sample filter was equal to the concentration for the field blank. It should be noted that the amount of particulate matter collected on the filters was very small, in the order of 0.5 g or less. In order to have a more accurate determination of the metals in particulates substantially more sample would be required. The potential for metals in particulates to pose a health risk is minimal unless there is a nearby source such as an exposed concentrate stockpile or a smelter. There are no definite future plans for either of these, therefore, the risk posed by metals in particulates is negligible.

### 3.2.4 Recommendations for Future Work

If it is decided that ore processing facilities are to be installed at Roberts Bay or Melville Sound, further air quality monitoring should be performed. The parameters should include TSP, PM10, settleable particulates (*i.e.*, dustfall) and gaseous constituents such as nitrogen oxides ($NO_x$), sulfur oxides ($SO_x$), carbon monoxide (CO) and hydrogen sulfide ($H_2S$).

## Table 3.2-4
## Concentration of Metals in Ambient Particulate Matter

| Date | Sample Location | Sample Type | Volume of Air Sampled ($m^3$) | Total Metals ($\mu g/Nm^3$) Aluminum | Antimony | Arsenic | Cadmium | Copper | Iron | Lead | Mercury | Zinc |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| August 9 | Windy Lake Camp # 4 | TSP | 1613 | 0.012 | N.D. | $1.3 \times 10^{-5}$ | N.D. | 0.005 | 0.01 | N.D. | N.D. | N.D. |
| August 10 | Windy Lake Camp # 4 | TSP | 1623 | N.D. | N.D. | $6 \times 10^{-7}$ | N.D. | 0.003 | 0.01 | N.D. | N.D. | 0.0006 |
| August 12 | Windy Lake Camp # 5 | TSP | 1505 | N.D. | N.D. | N.D. | N.D. | 0.002 | N.D. | N.D. | N.D. | N.D. |
| | ACGIH TLV/TWA[1] | | | 10,000 | 500 | 10 | 10 | 1,000 | N/A | 150 | 25 | N/A |
| | NWT TLV/RWA[2] | | | 10,000 | 500 | 200 | 50 | 1,000 | N/A | 150 | 100 | N/A |

**1: ACGIH TLV/TWA - American Conference of Governmental Industrial Hygienists - Threshold Limit Value Time Weighted Average 1994 - 1995.**
**2: NWT Mining Safety Act - Mining Safety Regulations, Chapter M-16.**
**Note: N.D. = Not Detectable. The measured concentration of metals was equal to or less than the concentration of metals for a blank filter.**
**N/A = Not Available.**

# 4. Hydrology

# 4. HYDROLOGY

The hydrological portion of the baseline environmental monitoring program for the Hope Bay Belt Project was focused on the potentially affected watersheds within the project area. These included the watersheds of Ogama, Doris and Glenn lakes in the north, and the watershed of the Koignuk River in the south of the project area.

Typical of northern hydrology, the principal processes influencing surface water flows in the project area include snow accumulation and snow melt, surface runoff, lake hydrology with free water evaporation, and stream or river flows. Total precipitation is comprised of rainfall and snowfall, with rainfall occurring in the summer months from June to September and snowfall through the winter months which comprise the remainder of the year. Snow melt and surface runoff occur during the short "freshet" period and the 1996 monitoring program was specifically designed to record flows during this critical time.

## 4.1 Methods and Setting

### 4.1.1 Regional Data Sources

Information was obtained from the Inland Waters Directorate (IWD) of the Water Survey of Canada (WSC) for three regionally gauged hydrometric stations in order to assess the spatial and temporal variability of surface water flows on a regional basis. Six regional stations were proposed for analysis, based on proximity to the project and long-term periods of record. Since data were not available for 1995 and 1996 at three of the stations, they were not used. The stations used included Burnside River at the mouth (10QC001), Ellice River near the mouth (10QD001) and Freshwater Creek near Cambridge Bay (10TF001).

For each of the three regional stations, daily discharge and mean monthly flows were calculated and these values were compared with historical data. The locations of the regional hydrometric stations are shown in Figure 4.1-1 and a summary of particulars for each station is given in Table 4.1-1.

**Table 4.1-1**
**Summary of Regional Hydrology Stations**

| Station Name | Station Number | Latitude | Longitude | Period of Record | Drainage Area ($km^2$) |
|---|---|---|---|---|---|
| Burnside River near the mouth | 10QC001 | 66° 43' 59" N | 107° 06' 04" N | 1968 - 1996 | 16800 |
| Ellice River near the mouth | 10QD001 | 67° 42' 30" N | 104° 08' 25" N | 1971 - 1996 | 16900 |
| Freshwater Creek near Cambridge Bay | 10TF001 | 69° 29' 56" N | 104° 59' 26" N | 1976 - 1996 | 1490 |

### 4.1.2 Site Specific Data

Within the project area four stations were monitored continuously for water levels using a staff gauge, pressure transducer and automated datalogger setup. These stations included the Koignuk River upstream of the entrance to Spyder Lake, and the outlets of Ogama, Doris and Glenn lakes. Water levels in Doris Lake and Tail Lake were also monitored periodically via manual readings on a staff gauge. Monitoring for all water level stations commenced on June 13 in order to record levels during the freshet period and through the summer open water season.

Stream flows were measured occasionally at each automated station to establish a relationship between staff gauge height and discharge. The resulting stage-discharge curves were utilized to calculate flow in each of the catchments and in turn, unit yield runoff.

Table 4.1-2 presents a summary of the hydrometric monitoring stations in the project area for 1996. The locations of the monitoring sites are shown in Figure 4.1-2. Plots of mean daily water levels for each station are shown in Figures 4.1-3 through 4.1-6 respectively.

## 4.2 Results

The analysis of available daily discharge data for Burnside River, Ellice River and Freshwater Creek indicates that mean monthly regional flows were higher in 1996

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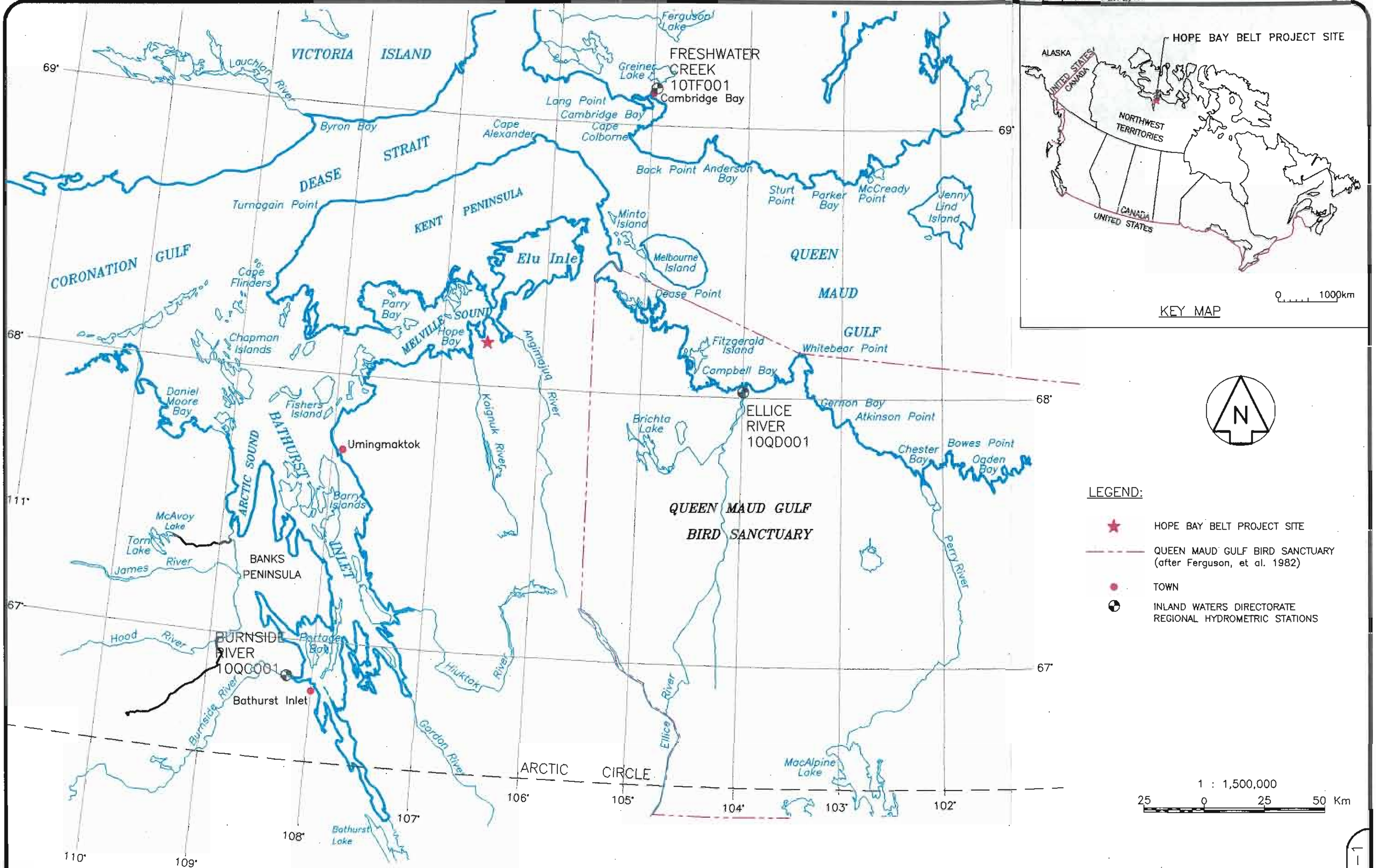



LEGEND:

- ★ HOPE BAY BELT PROJECT SITE
- QUEEN MAUD GULF BIRD SANCTUARY (after Ferguson, et al. 1982)
- ● TOWN
- INLAND WATERS DIRECTORATE REGIONAL HYDROMETRIC STATIONS

1 : 1,500,000

25 0 25 50 Km

BHP

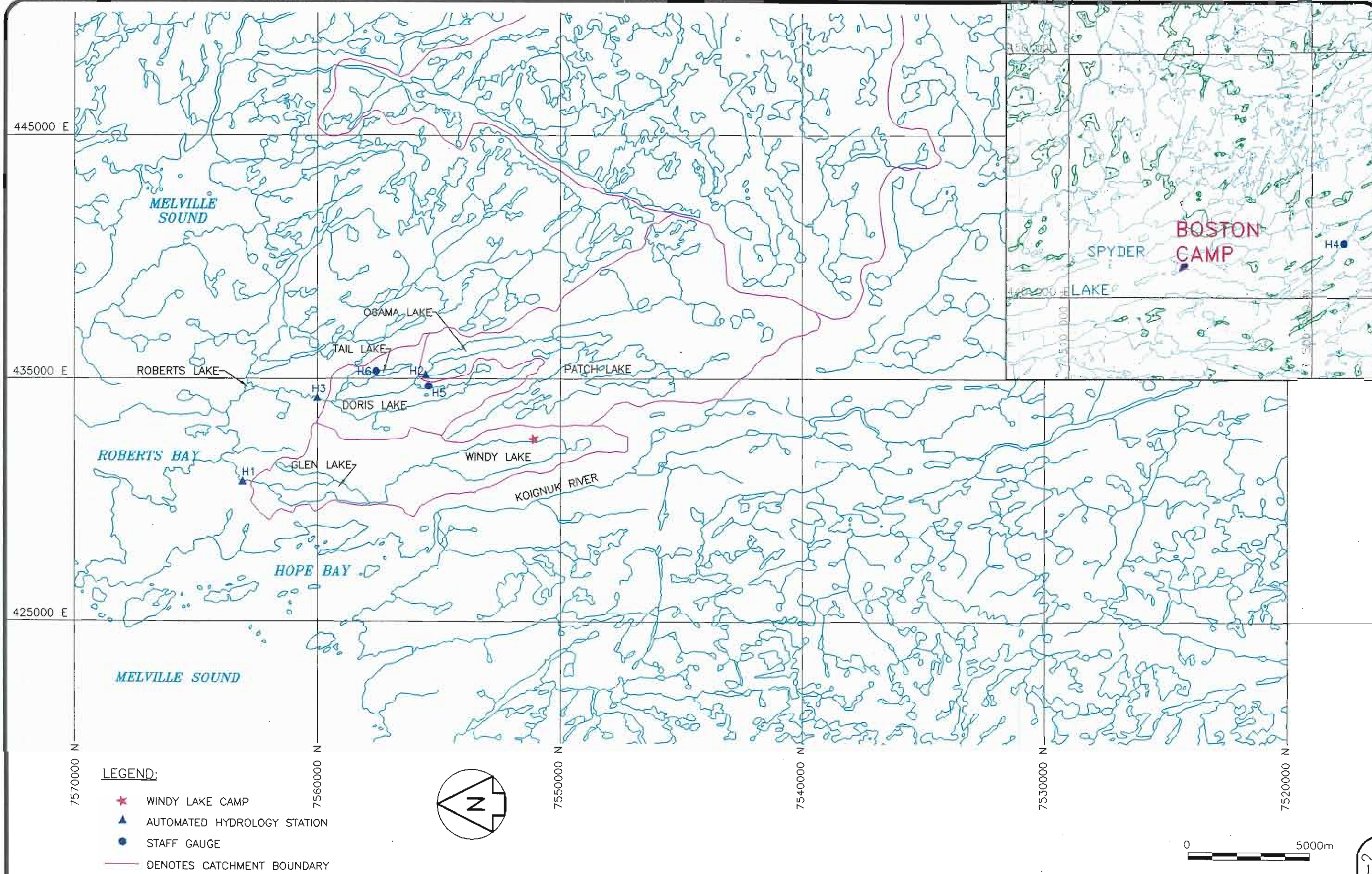
Locations of Regional Hydrometric Stations

Rescan

Fig 4.1-1

Source: Klohn-Crippen, 1995 fig1-1.dwg

Cad No. a2232s | Scale: 1:150 000 | Job No. 526-1 | 17/02/1997-06:38pm RES_BF




BHP

Locations of Site-Specific Hydrometric Stations

Rescan

Fig 4.1-2

Source: Klohn-Crippen, 1995

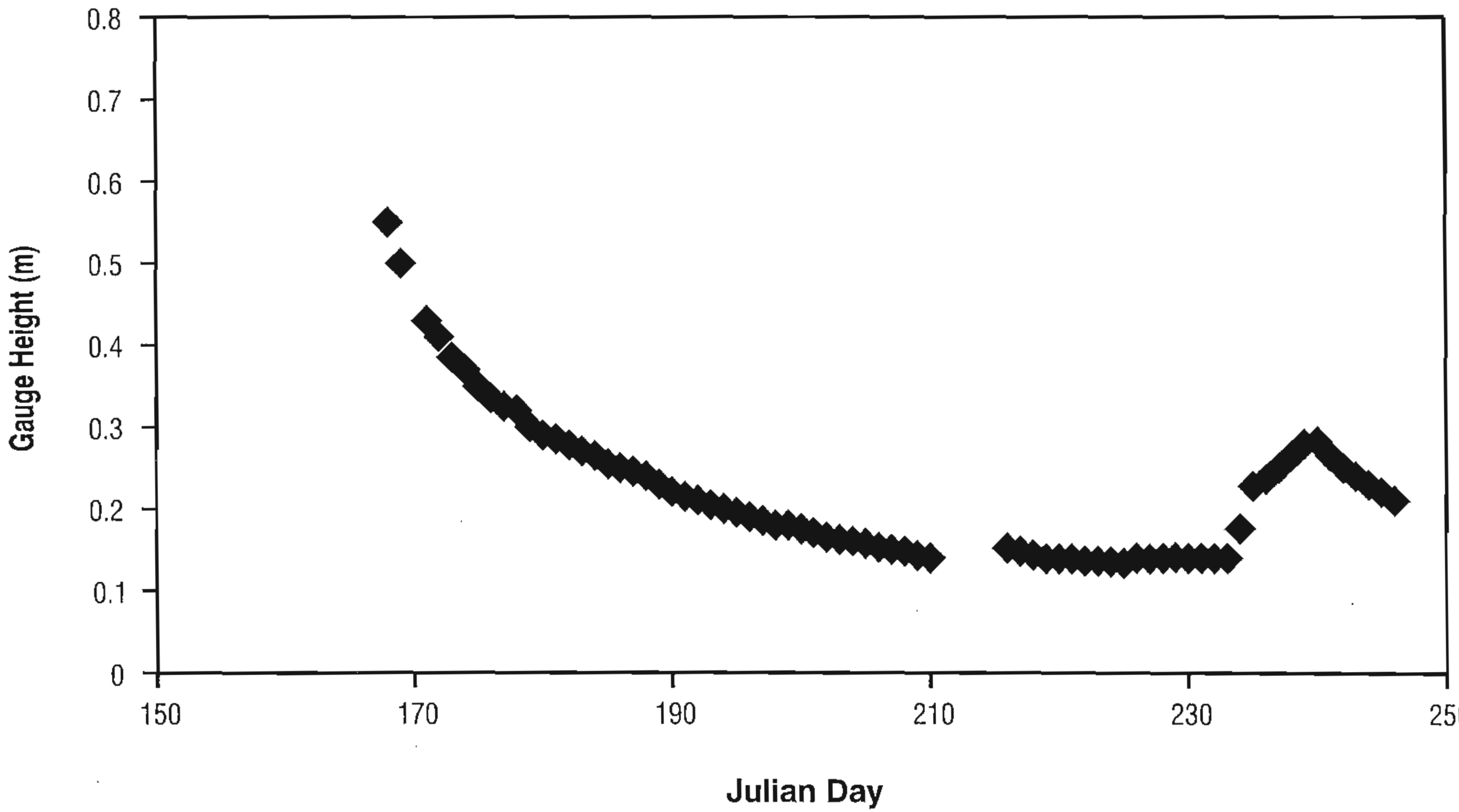



FIGURE 4.1-3

BHP

# 1996 Mean Daily Water Levels
# Glenn Lake Outlet

Rescan

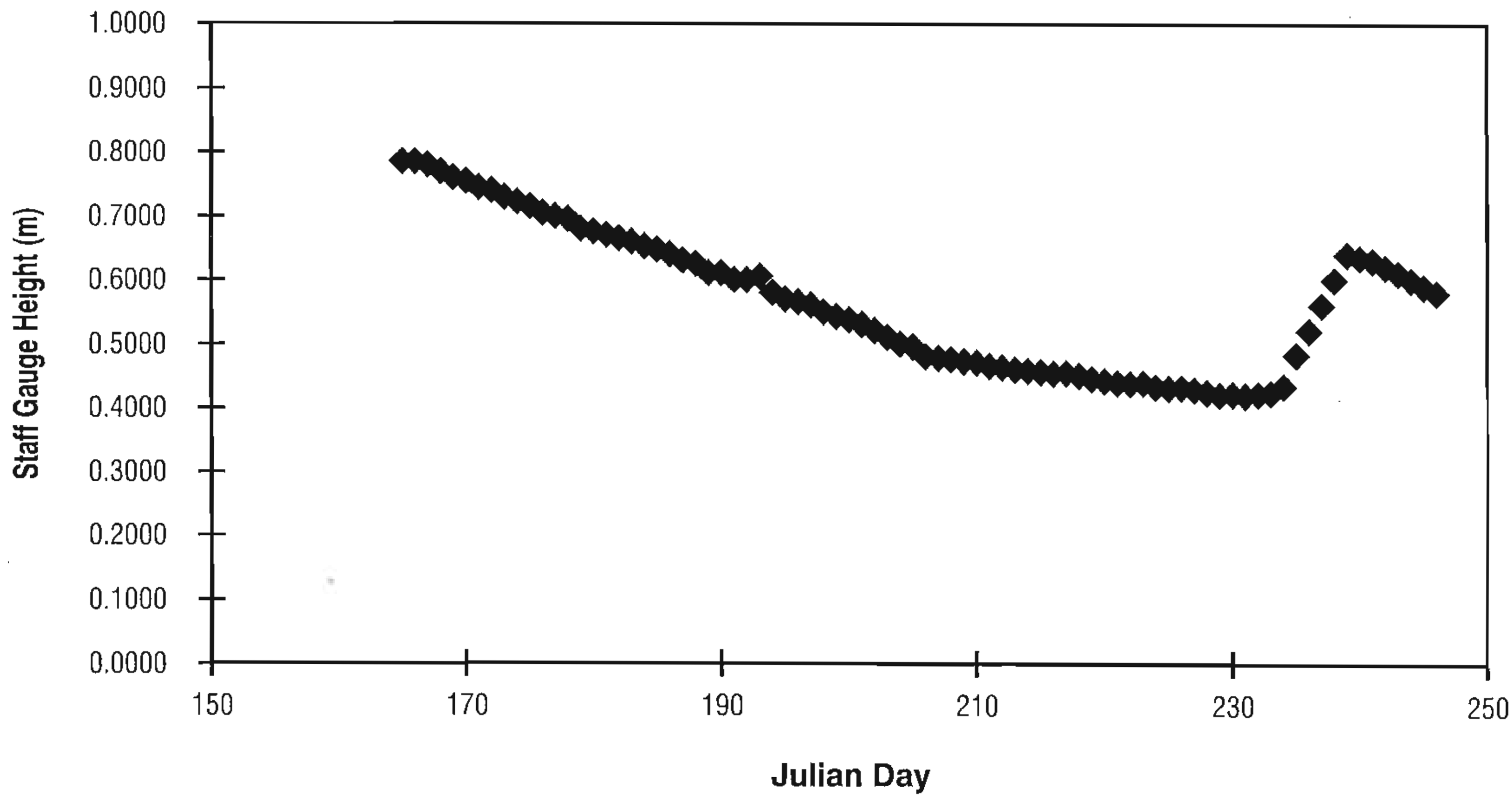



FIGURE 4.1-4

# 1996 Mean Daily Water Levels Ogama Lake Outlet

BHP Rescan

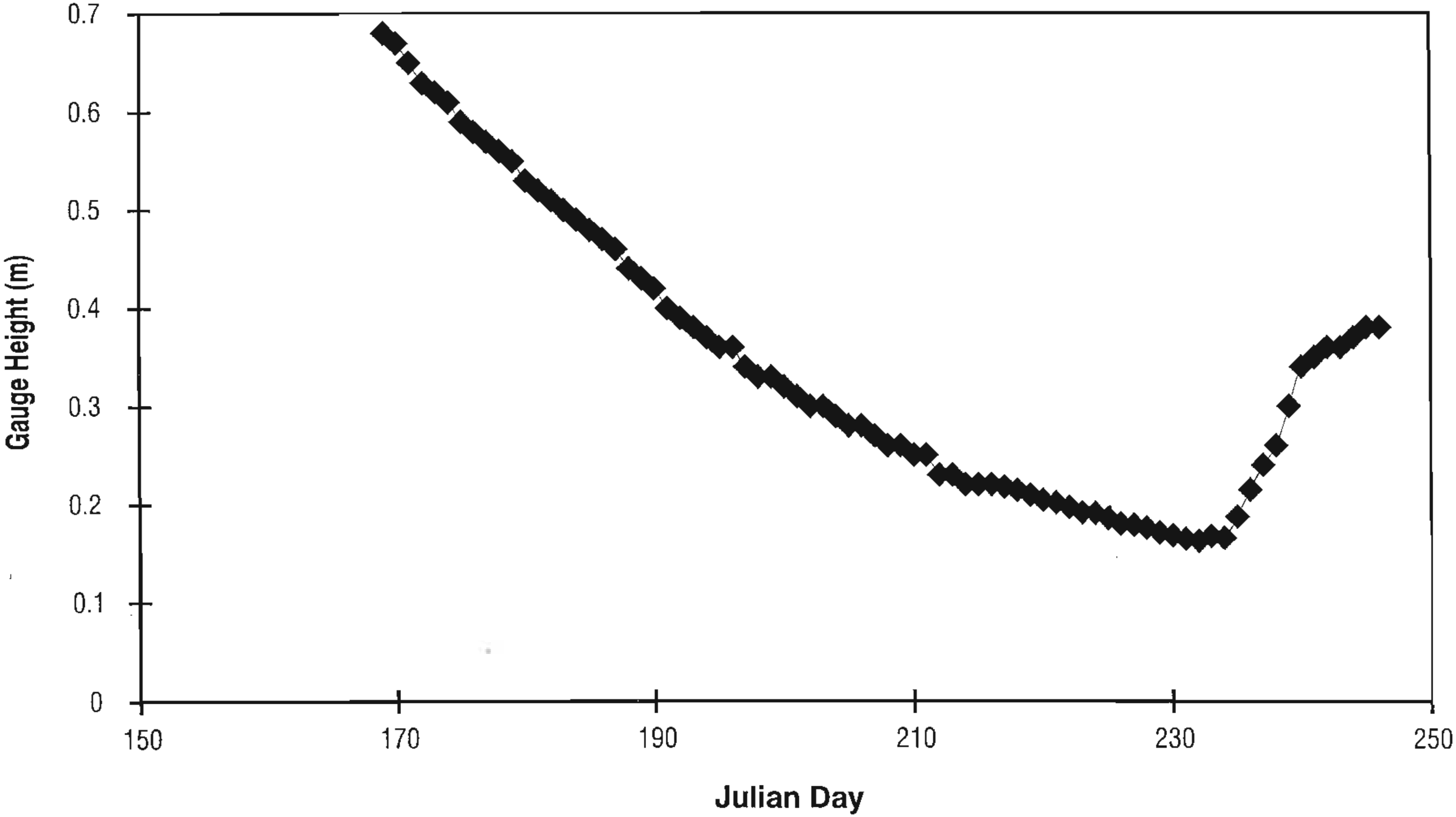
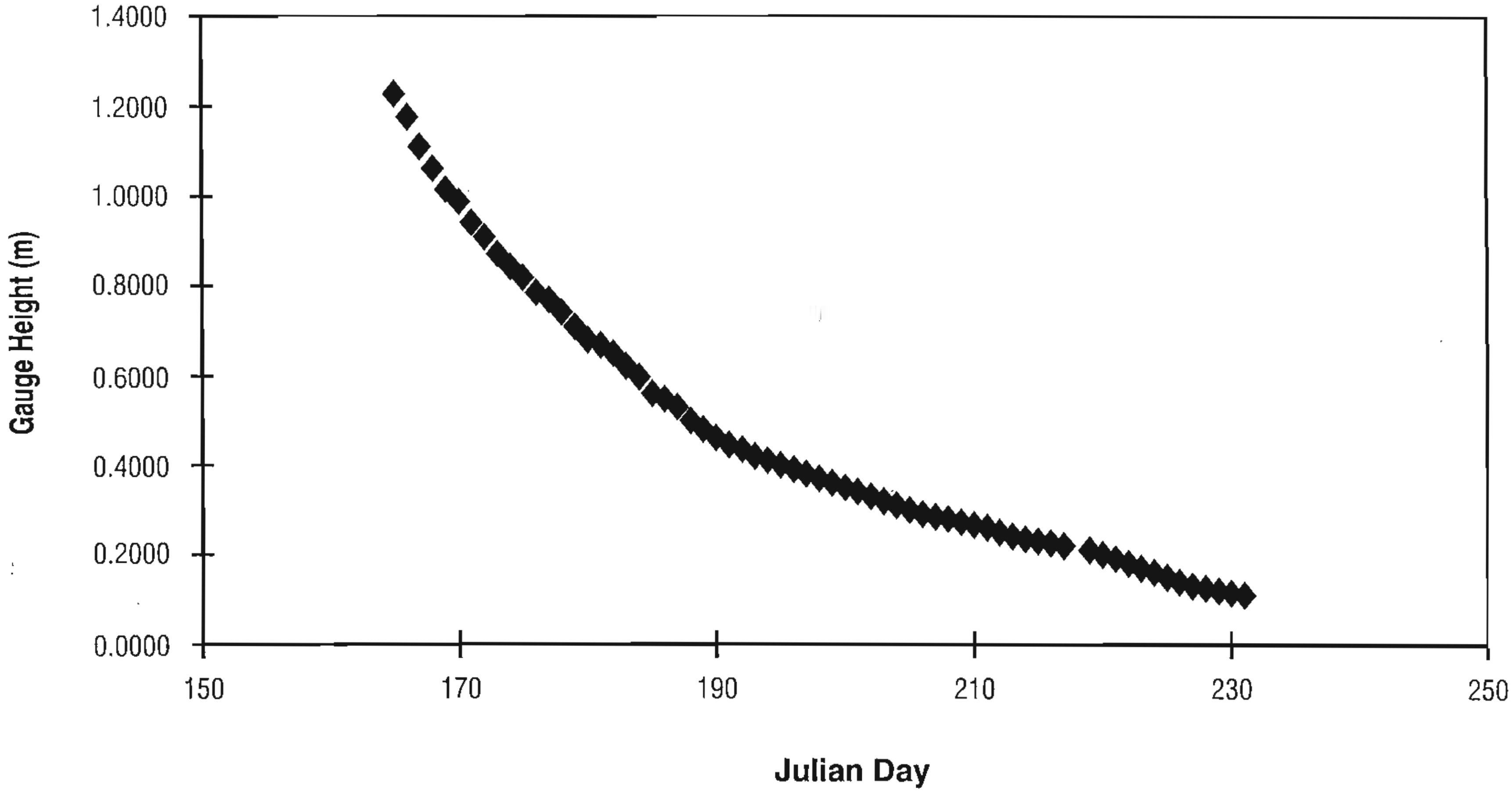



FIGURE 4.1-5

# 1996 Mean Daily Water Levels
# Doris Lake Outlet

BHP

Rescan




BHP

# 1996 Mean Daily Water Levels
# Koignuk River Upstream of Spyder Lake

FIGURE 4.1-6

Rescan

**Table 4.1-2**
**Summary of Site Specific Hydrology Stations**

| Station Name | Station Number | Latitude | Longitude | Drainage Area ($km^2$) |
|---|---|---|---|---|
| Glenn Lake at outlet | 1 | 68° 10' 22" N | 106° 39' 55" N | 31.6 |
| Ogama Lake at outlet | 2 | 68° 06' 12" N | 106° 33' 00" N | 71.9 |
| Doris Lake at outlet | 3 | 68° 08' 31" N | 106° 35' 16" N | 93.1 |
| Koignuk River near the mouth | 4 | 67° 33' 44" N | 106° 16' 56" N | 769 |
| Doris Lake lake levels | 5 | 68° 05' 46" N | 106° 34' 11" N | - |
| Tail Lake lake levels | 6 | 68° 07' 21" N | 106° 33' 15" N | - |

than both 1995 values and historical means. This was due to a higher than normal freshet runoff and a large rainfall event which centered over the region in mid-August. Table 4.2-1 shows 1995, 1996, and historical flows for the regional catchments considered. In Figure 4.2-1, a plot of mean daily discharge for the Ellice River for historical, 1995 and 1996 means, shows the higher than normal values observed in 1996.

### 4.2.1 Mean Flows

Stage-discharge curves were prepared for the hydrometric stations at Ogama, Glenn and Doris lakes. These curves were used to calculate mean daily discharge and unit yield. Flows in the Koignuk River during freshet were too high and it was not possible to safely or accurately measure discharge at that critical period. In turn, a stage-discharge curve could not be prepared for the station and flows could not be calculated throughout the entire open water season.

There is good correlation between the unit yields from the three site catchments and three regional catchments as shown in Figure 4.2-2. The plot clearly shows the highest peaks and thereafter declining flows during the freshet runoff. A common peak shown in late August is due to a regional precipitation event. The small peak in the early open water season for Burnside River is attributed to a

**Table 4.2-1**
**Mean Monthly Discharge, Burnside River, Ellice River and Freshwater Creek**

| Month | Burnside River (102C001) | | | Ellice River (102D001) | | | Freshwater Creek (10TF001) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Mean 1996 $m^3/s$ | Mean 1995 $m^3/s$ | Mean 1976-1996 $m^3/s$ | Mean 1996 $m^3/s$ | Mean 1995 $m^3/s$ | Mean 1971-1996 $m^3/s$ | Mean 1996 $m^3/s$ | Mean 1995 $m^3/s$ | Mean 1976-1992 $m^3/s$ |
| Jan. | 25.10 | 13.40 | 13.56 | 0.00 | 0.00 | 0.14 | 0.00 | 0.00 | 0.00 |
| Feb. | 20.70 | 10.40 | 9.69 | 0.00 | 0.00 | 0.05 | 0.00 | 0.00 | 0.00 |
| March | 16.40 | 9.43 | 8.13 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 |
| April | 11.90 | 8.68 | 7.64 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| May | 16.40 | 7.30 | 30.52 | 4.39 | 0.00 | 16.03 | 0.00 | 0.00 | 0.00 |
| June | 746.00 | 565.00 | 582.55 | 601.00 | 528.00 | 504.00 | 18.90 | 15.50 | 10.75 |
| July | 272.00 | 208.00 | 320.25 | 110.00 | 181.00 | 246.11 | 20.10 | 28.10 | 23.76 |
| August | 278.00 | 178.00 | 200.30 | 101.00 | 53.50 | 91.96 | N/A | 7.84 | 8.40 |
| Sept. | 572.00 | 140.00 | 185.15 | 388.00 | 41.40 | 108.68 | N/A | 2.39 | 3.74 |
| Oct. | 141.00 | 89.00 | 86.85 | 78.00 | 17.00 | 37.05 | 2.12 | 0.13 | 1.00 |
| Nov. | 76.20 | 55.80 | 36.77 | 5.65 | 1.32 | 5.88 | 0.30 | 0.00 | 0.04 |
| Dec. | 50.10 | 36.50 | 22.05 | 0.00 | 0.00 | 0.57 | 0.01 | 0.00 | 0.00 |
| Mean | 185.48 | 110.13 | 125.29 | 107.34 | 68.52 | 84.21 | 10.35 | 8.99 | 7.95 |

localized precipitation event in that catchment. It is also apparent that spring breakup (freshet) occurs at a later time for Freshwater Creek. This is attributed to the more northerly location of this catchment.

The unit yields for the Ogama and Doris catchments are thought to be somewhat low as compared to both Glenn Lake and the larger catchments. Typically, for smaller catchment basins, the peaks of the unit yield curve are sharper and steeper, as shown by the data from Glenn Lake. Continued monitoring of the runoff in all of the site catchments is recommended to confirm the runoff characteristics of the project area drainages.

### 4.2.2 Lake Hydrology

Lake water levels were monitored in Doris Lake and Tail Lake via manual staff gauge readings. Figure 4.2-3 shows lake water levels throughout the freshet and open water season. The staff gauge at Tail Lake was damaged in the late summer

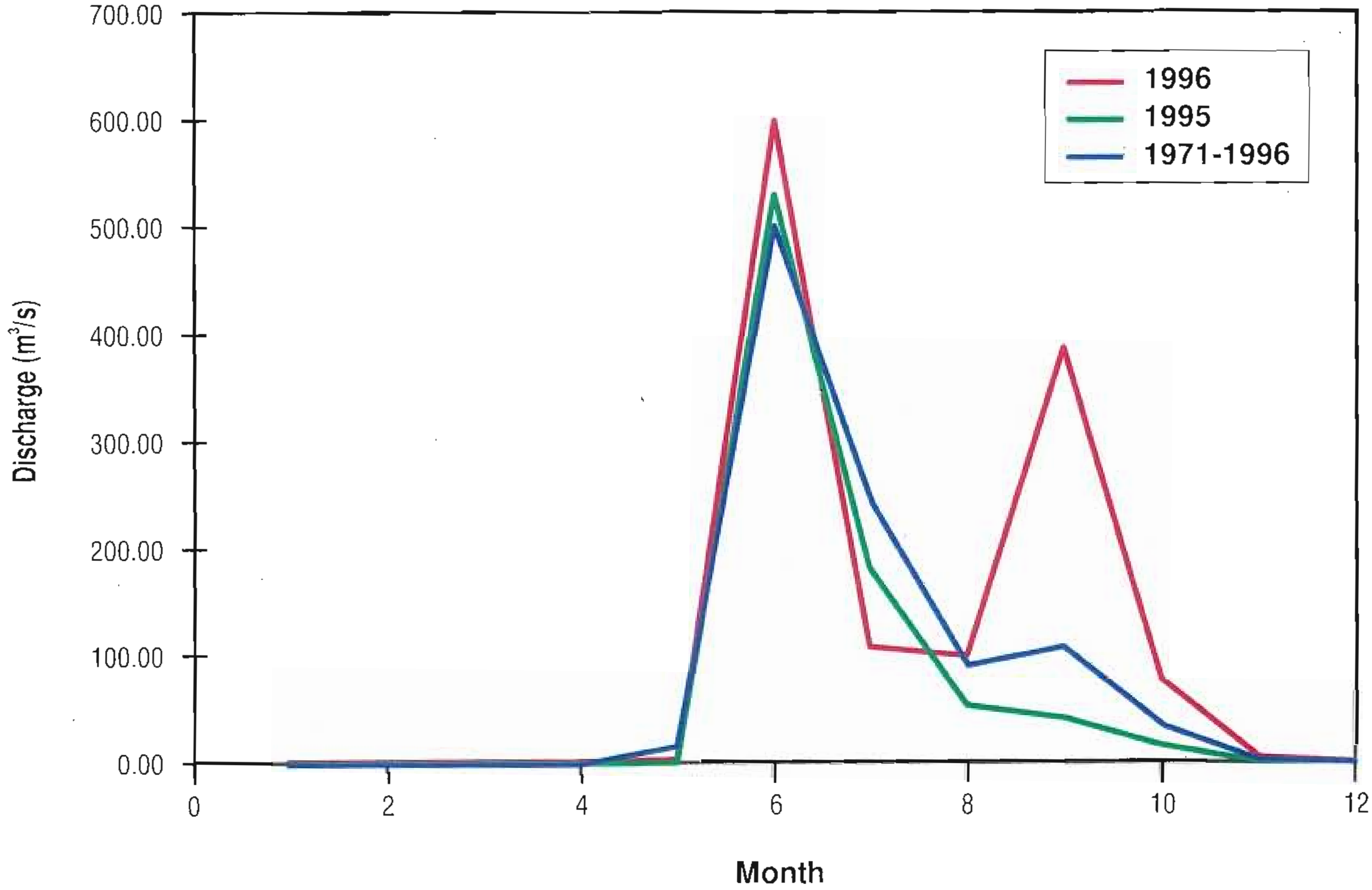



FIGURE 4.2-1

# Mean Daily Discharge
# Ellice River Near the Mouth

BHP

Rescan

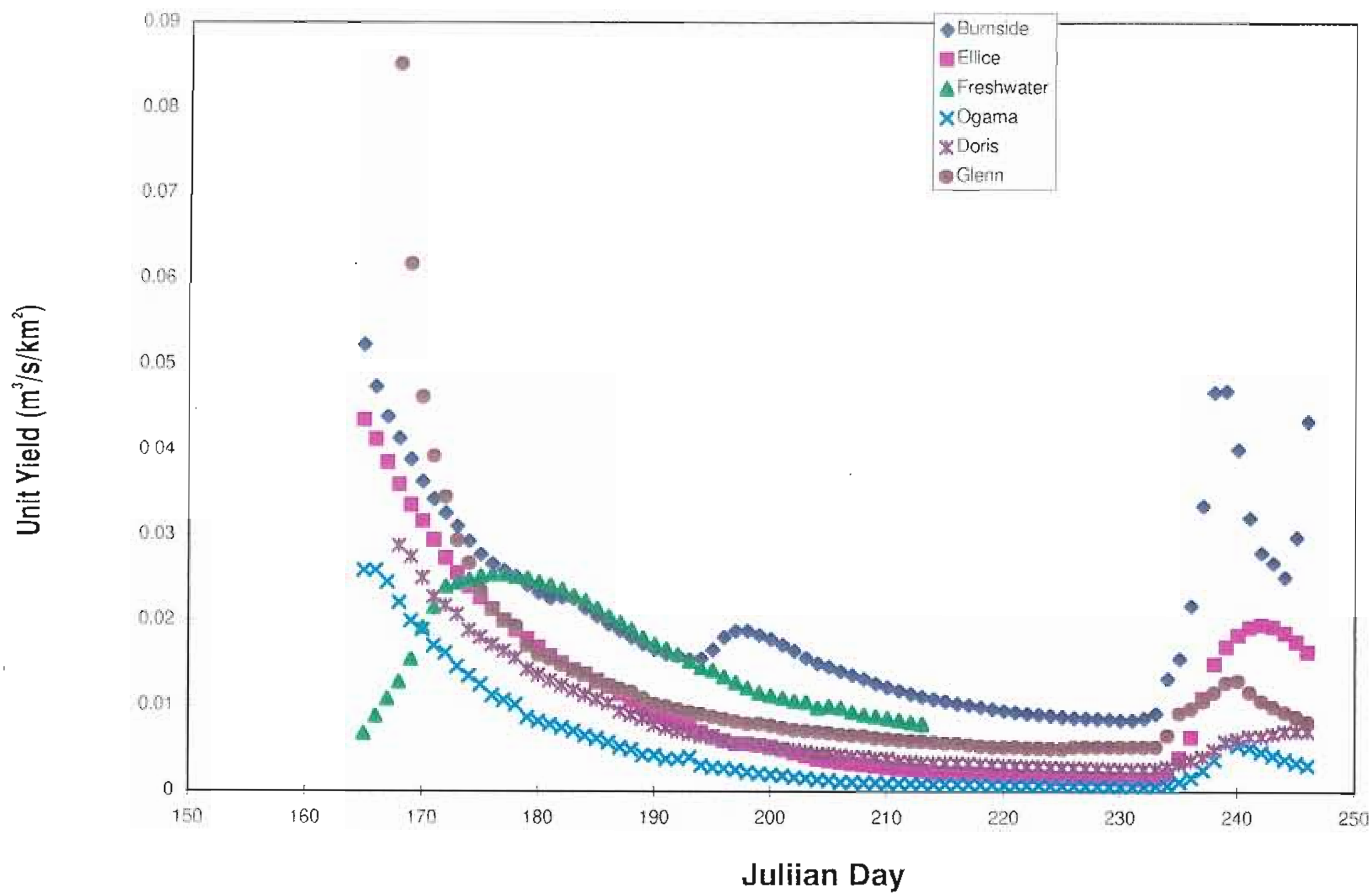



FIGURE 4.2-2

BHP

# Unit Yield for Site Specific and Regional Catchments

Rescan

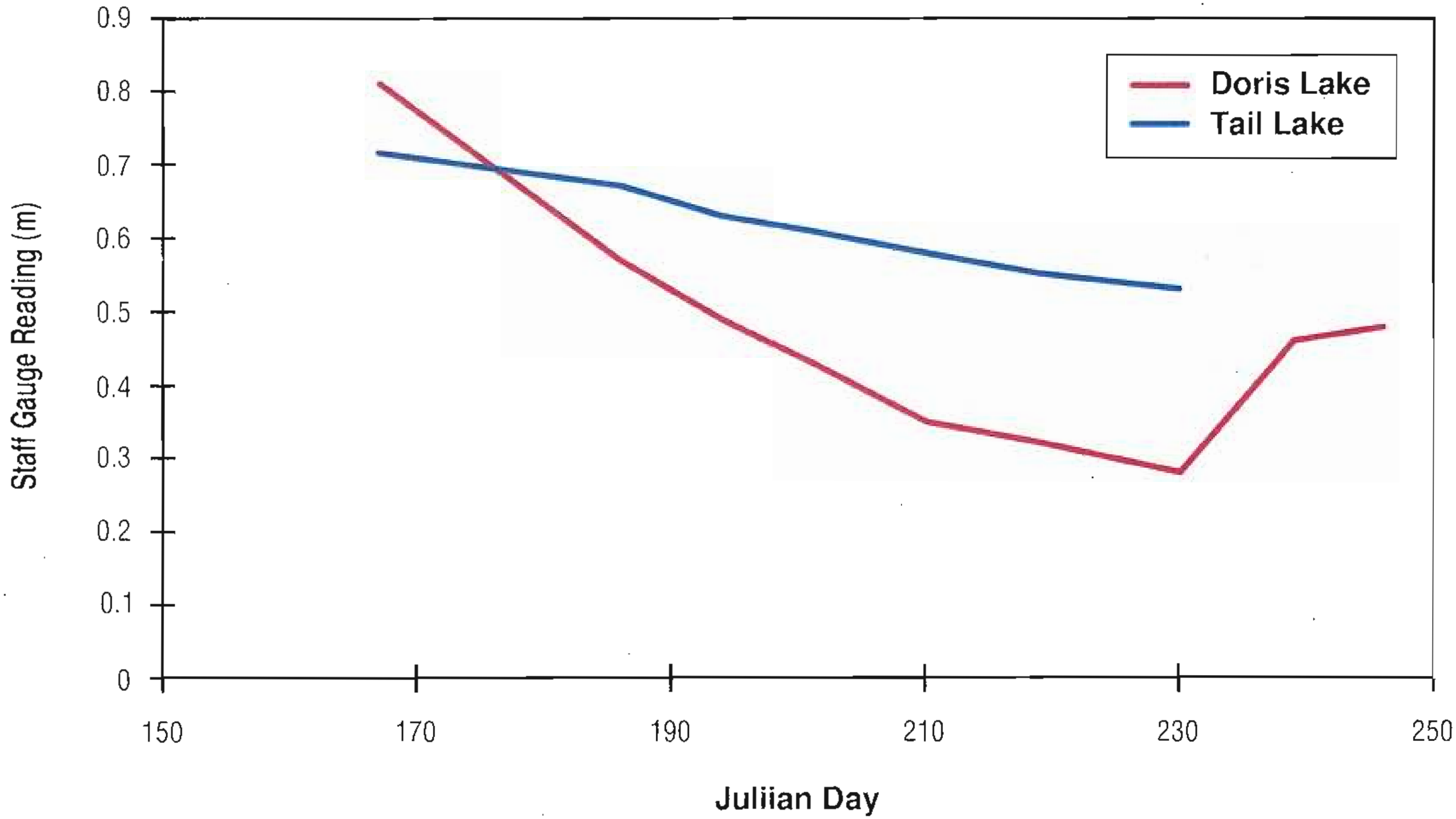



FIGURE 4.2-3

BHP

# 1996 Lake Water Levels from Staff Gauge Readings

Rescan

months and a rise in lake level similar to that noted in Doris Lake was not recorded. The maximum change in lake elevation was 0.185 m for Tail Lake and 0.53 m for Doris Lake. Since Tail Lake has a very small catchment and does not receive flow contribution from other upstream watersheds, the smaller recorded lake elevation change is reasonable.

### 4.2.3 Low Flows

The lowest flows within the project area occur in mid to late August. Discharge at the Glenn Lake Outlet reached a minimum of 0.16 $m^3$/s on August 12. Corresponding low flows from the outlets of Ogama and Doris lakes occurred on August 18 and were 0.04 and 0.233 $m^3$/s respectively. The timing of the low flows correlates well with those of the regional catchments.

Although a stage discharge curve does not exist for the Koignuk River, flow measurements taken on August 18 are considered representative of the low flow in this river. This date corresponds with the timing of low flows on the other project site catchments. The measured flow was 0.38 $m^3$/s.

### 4.2.4 High Flows

Maximum discharges were observed in the project area during the initial stages of the spring freshet in early June. Data recording, which started on June 13, did not clearly shown the timing or value of the peak flows which likely occurred hours prior to equipment installation. For practical purposes however, the flows recorded at the time of equipment setup are considered a good approximation of the maximum peak flows for the freshet.

The peak flows measured were 1.76 $m^3$/s at Ogama Lake Outlet on June 15, 2.59 $m^3$/s at Doris Lake on June 15 and 2.73 $m^3$/s at Glenn Lake Outlet on June 16. Although the flow could not be measured during freshet along the Koignuk River, the flow was estimated on June 13 to be 9.8 $m^3$/s.

## 4.3 Discussion

Comparison of 1996 and historical regional surface water flows in the region indicates that runoff was higher than usual in 1996 and it is therefore concluded that flows at the site were higher than normal. This was in part due to a large rainfall event which occurred in the late summer. The increased runoff from rainfall in August was clearly shown in the stream monitoring and in increased lake levels.

It is recommended that stream flow monitoring for the 1997 baseline program commence earlier than 1996 to ensure the recording of peak flows during the freshet and also that stream flow measurements be taken more frequently to allow the establishment of more reliable stage-discharge curves.

# 5. Water Quality and Sediments

# 5. WATER QUALITY AND SEDIMENTS

## 5.1 Water Quality

### 5.1.1 Boston Property

The Boston Property is located at the southern end of the Hope Bay Belt Project Area. Both lakes and streams were sampled for water quality and sediments in 1996. Figure 5.1-1 presents the sampling locations of both lakes and streams within the Boston exploration area.

#### *5.1.1.1 Lakes*

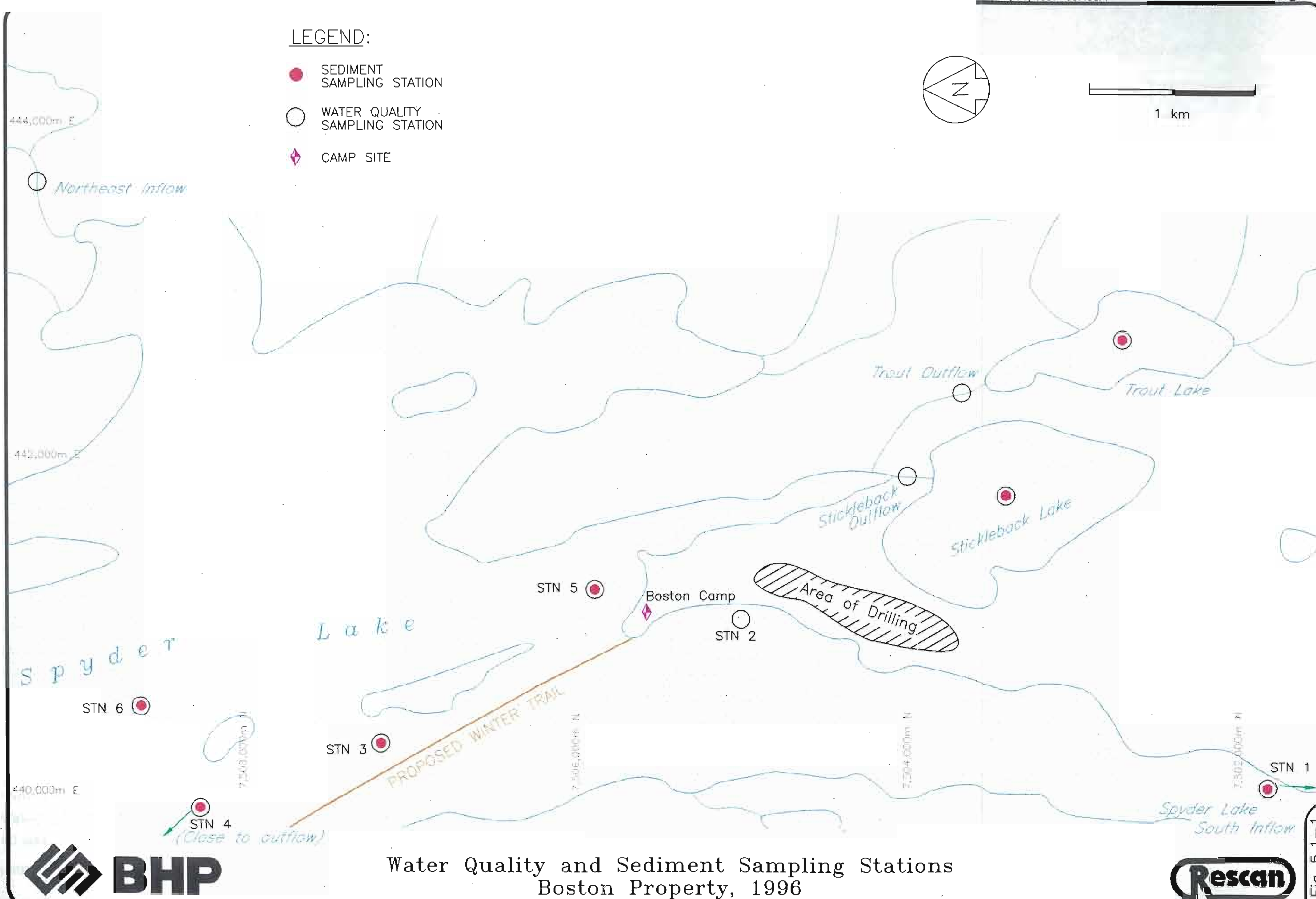
The largest lake in the area is Spyder Lake, with both Trout and Stickleback lakes draining into it. Several stations on Spyder Lake and single stations on both Trout and Stickleback lakes were sampled for water quality in 1996.

*Methods*

Water quality samples were collected in the winter (April 21, 24), summer (August 4, 5), and fall (August 23, 24) using a two litre acid-washed Go-Flo bottle. The bottle was suspended on a metered cable and lowered to the appropriate depth; closure was effected by use of a messenger. Immediately after the Go-Flo was retrieved, subsamples for the determination of physical parameters, nutrients, total and dissolved metals were collected in clean plastic bottles, with care taken to minimize any possible contamination. All bottles were rinsed three times before filling. Samples were kept cold and in the dark while in the field. Samples were transported in coolers with freezer packs to Analytical Service Laboratories (ASL) or Elemental Research Inc. (ERI), Vancouver, for all analyses. Samples for dissolved metals were filtered through 0.45 µm filters under a clean atmosphere in the analytical laboratories. Filtering was not done in the field to minimize artifacts resulting from possible sample contamination. Water quality samples were collected at each station, sometimes at multiple depths with additional samples for quality control monitoring. The various parameters analyzed and their applicable detection limits are given in Table 5.1-1

## Table 5-1.1
## Water Quality Monitoring Parameters with Applicable Detection Limits

| Parameter | Detection Limit (mg/L) |
|---|---|
| **Physical Tests** | |
| pH | 0.01 pH Units |
| Conductivity | 2 µmhos/cm |
| Total Dissolved Solids (TDS) | 1 |
| Total Suspended Solids (TSS) | 1 |
| Hardness (as $CaCO_3$) | 0.05 |
| Turbidity | 0.1 NTU |
| **Dissolved Anions** | |
| Alkalinity | 1 |
| Acidity | 1 |
| Chloride | 0.5 |
| Fluoride | 0.02 |
| Sulfate | 1 |
| **Nutrients** | |
| Ammonia | 0.005 |
| Nitrate | 0.005 |
| Nitrite | 0.001 |
| Dissolved Ortho-Phosphate | 0.001 |
| Total Dissolved Phosphate | 0.001 |
| Total Phosphorus | 0.002 |
| **Total and Dissolved Metals** | |
| Aluminum | 0.001 |
| Antimony | 0.00005 |
| Arsenic | 0.00005 |
| Barium | 0.00005 |
| Beryllium | 0.0005 |
| Boron | 0.001 |
| Cadmium | 0.00005 |
| Calcium | 0.05 |
| Chromium | 0.0001 |
| Cobalt | 0.0001 |
| Copper | 0.0001 |
| Iron | 0.01 |
| Lead | 0.00005 |
| Magnesium | 0.005 |
| Manganese | 0.00005 |
| Molybdenum | 0.00005 |
| Nickel | 0.0001 |
| Selenium | 0.0005 |
| Silver | 0.00001 |
| Uranium | 0.00001 |
| Vanadium | 0.0001 |
| Zinc | 0.001 |




Water Quality and Sediment Sampling Stations
Boston Property, 1996

Fig 5.1-1

*Results and Discussion*

Following are the results from the water quality sampling regime for lakes in the Boston exploration area. Water quality data were obtained from six stations in Spyder Lake and from a single station in Trout Lake (Appendix 5-1).

- *Physical Parameters and Nutrients*

  Table 5.1-2 presents the pH, total suspended solids (TSS), turbidity and total phosphorus (TP) for lakes in the Boston Property Area. The pH of all lakes ranged from slightly acidic (6.2) to just above neutral (7.4) with slightly lower values under ice-cover in April compared to August. This difference in pH likely resulted from reduced photosynthetic activity during the dark winter months. Turbidity of lake waters was variable, ranging from 0.4 to 30 NTU (Table 5.1-2). The concentration of total suspended solids (TSS) was also quite variable, ranging from below the detection limit (1 mg/L) to 20 mg/L. Total phosphorus is associated with particulate material and ranged from 0.005 to 0.050 mg/L.

  In general, turbidity and TSS were low in Spyder Lake year-round, except near the South Inflow (Station 1). The South Inflow (or Spyder River) is quite large, and undoubtedly transports sediment material into the lake. Trout Lake became much more turbid than Spyder Lake in the fall of 1996. This may have been due to vigorous mixing as storms came through, since Trout Lake is extremely shallow. The high TP also indicates bottom sediment suspension.

  Profiles of temperature and dissolved oxygen for all lakes and during all sampling periods are given in Appendix 5-2. During the April survey, the water column of Spyder Lake was of uniform temperature (1°C), resulting in a near homogeneous water column. Dissolved oxygen concentrations decreased slightly with depth, but no stratification of the water column below the ice was observed.

  During the summer survey (August 4, 5), temperature was again uniform with depth in Spyder Lake (~13°C). Trout and Stickleback lakes also had water columns of uniform temperature. Dissolved oxygen concentrations in all lakes were elevated in surface waters compared to deep waters, possibly the result of photosynthetic activity. In the fall (August 23, 24), water temperature for all lakes had decreased, likely the result of early winter conditions. Again, all lakes exhibited homogeneous water columns.

- *Metals*

Table 5.1-3 presents total metal concentrations that were measured for Spyder and Trout lakes during the 1996 sampling campaign. Dissolved metals are presented in Appendix 5-1. Canadian Federal Water Quality Guidelines for freshwater aquatic life (CCREM 1987, Health Canada and Environment Canada 1995) are also presented in Table 5.1-3.

The total metal concentrations of As, Cr, Pb, Ni, Ag, and Zn were all below the CCREM guidelines. The concentrations of total Cu and Cd were also quite low; however, Cu was above the guideline value at Stations 4 and 6 (Spyder Lake) in April and Trout Lake in late August. Stations 1, 2, 3, 4 and 6 (Spyder Lake) had concentrations of total Cd that exceeded the guideline in late August. Of all the metals, the concentrations of total Al and Fe were the highest relative to guideline values at some stations. In late August, Stations 1, 2 and Trout Lake had particularly high concentrations of total Al and Fe. An inter-station (Spyder Lake) comparison of the distribution of the total metal concentrations also revealed that during the August survey Al and Fe values were higher at Station 1, closer to the inflow than at other stations. This suggests that the incoming water which contained elevated concentrations of TSS was a major source of metals into Spyder Lake and that input via surface run-off may have been more important than atmospheric deposition. Similar conclusions can be made for other metals such as Cu, Zn, Cd and Ni. These elements may be introduced into lake waters in association with particulate matter of allochthonous origin.

In general, metal concentrations were quite low throughout the sampling period. The concentrations and distributions of the trace metals measured in the lakes in the vicinity of Boston Property reflect input pathways from natural sources, with the main likely inputs being surface run-off (stream inflows) and atmospheric deposition.

## Table 5.1-2
## pH, Total Suspended Solids (TSS),Turbidity, and Total Phosphorus (TP) for the Boston Property Lakes (1996)

| Parameter | Spyder Lake Station 1 Aug. 4 | Spyder Lake Station 1 Aug. 23 | Spyder Lake Station 2 Aug. 4 | Spyder Lake Station 2 Aug. 23 | Spyder Lake Station 3 Aug. 4 | Spyder Lake Station 3 Aug. 23 | Spyder Lake Station 4 Apr. 23 | Spyder Lake Station 4 Aug. 4 | Spyder Lake Station 4 Aug. 23 |
|---|---|---|---|---|---|---|---|---|---|
| pH (pH units) | 6.9 | 6.9-7.2 | 6.8 | 7.2 | 6.8 | 7.2-7.3 | 6.5 | 6.9 | 6.8-7.2 |
| TSS (mg/L) | 1.0 | 10-11 | 2 | 6 | 4 | 1-2 | <1 | <1-3 | <1.0-1.0 |
| Turbidity (NTU) | 1.0 | 9-14 | 0.4 | 7.0 | 0.8 | 2.6-3.2 | 0.5 | 0.6-1.0 | 0.8-1.8 |
| TP (mg/L) | 0.007 | 0.028-0.029 | 0.005 | 0.018 | 0.007 | 0.008-0.012 | - | 0.004-0.006 | 0.006 |

| Parameter | Spyder Lake Station 5 Aug. 5 | Spyder Lake Station 5 Aug. 24 | Spyder Lake Station 6 Apr. 23 | Spyder Lake Station 6 Aug. 4 | Spyder Lake Station 6 Aug. 24 | Trout Lake Aug. 5 | Trout Lake Aug. 25 |
|---|---|---|---|---|---|---|---|
| pH (pH units) | 6.8-6.9 | 7.3-7.4 | 6.2-6.4 | 6.8 | 7.3-7.4 | 7.1 | 7.2 |
| TSS (mg/L) | 1-2 | <1-6 | <1.0 | <1-2 | 1-5 | 3 | 20 |
| Turbidity (NTU) | 0.8 | 2.4-3.4 | 0.3-0.6 | 0.3-0.8 | 0.7-2.2 | 1 | 30 |
| TP (mg/L) | 0.004-0.007 | 0.009-0.011 | 0.005-0.013 | 0.005-0.007 | 0.006-0.011 | 0.012 | 0.050 |

**Note: Data presented are ranges from the entire water column. If no range is given, all values were the same.**

## Table 5.1-3
## Total Metal Concentrations Measured for the Boston Property Lakes (1996) along with CCREM Guidelines for Freshwater Aquatic Life

| Total Metals (µg/L) | Spyder Lake Station 1 Aug. 4 | Spyder Lake Station 1 Aug. 23 | Spyder Lake Station 2 Aug. 4 | Spyder Lake Station 2 Aug. 23 | Spyder Lake Station 3 Aug. 4 | Spyder Lake Station 3 Aug. 23 | Spyder Lake Station 4 Apr. 23 | Spyder Lake Station 4 Aug. 4 | Spyder Lake Station 4 Aug. 23 | CCREM guidelines |
|---|---|---|---|---|---|---|---|---|---|---|
| Aluminum | 11 | 446-508 | 15 | 256 | 10 | 40-83 | 13 | 7-10 | 33-40 | 5-100[1] |
| Arsenic | 2 | <1-1 | 1 | 1 | <1.0 | <1.0 | <1.0 | <1-2 | <1-2 | 50 |
| Cadmium | 0.10 | 0.23-0.28 | <0.05 | 3 | <0.05 | 0.06-0.30 | <0.05 | <0.05-0.07 | 0.14-0.45 | 0.2 |
| Chromium | 0.8 | - | 0.8 | - | <0.1 | - | 0.6 | 0.6-0.7 | - | 2 |
| Copper | 0.4 | 1.5-1.6 | 0.5 | 0.9 | 0.4 | 0.5-0.9 | 2.3 | 0.5-1.6 | 0.7-0.9 | 2 |
| Iron | <10 | 380-440 | <10 | 180 | <10 | 30-90 | 300 | <10 | 20-60 | 300 |
| Lead | <0.05 | 0.28-0.30 | 0.06 | 0.13 | 0.06 | <0.05-0.09 | 0.2 | <0.05-0.18 | <0.05-0.16 | 1 |
| Nickel | 0.3 | 1.0-1.3 | 0.2 | 0.2 | 0.4 | <0.1-1.5 | 0.8 | 0.4-1.2 | <0.1-0.6 | 25 |
| Silver | <0.01 | 0.06 | 0.02 | 0.02 | 0.02 | <0.01-0.02 | <0.01 | <0.01 | <0.01-0.04 | 0.1 |
| Zinc | 7 | 7-8 | <1 | 5 | 11 | 4-5 | 2 | <1-3 | 5-9 | 30 |

| Total Metals (µg/L) | Spyder Lake Station 5 Aug. 5 | Spyder Lake Station 5 Aug. 24 | Spyder Lake Station 6 Apr. 23 | Spyder Lake Station 6 Aug. 4 | Spyder Lake Station 6 Aug. 24 | Trout Lake Aug. 5 | Trout Lake Aug. 25 | CCREM guidelines |
|---|---|---|---|---|---|---|---|---|
| Aluminum | 9-10 | 88-112 | 10-15 | 9-14 | 28-80 | 25 | 346 | 5-100[1] |
| Arsenic | <1-2 | <1-3 | <1.0 | <1-1 | <1 | <1.0 | 1.0 | 50 |
| Cadmium | <0.05-0.09 | 0.17-0.19 | <0.05 | <0.05-0.08 | 0.22-0.51 | 0.06 | <0.05 | 0.2 |
| Chromium | 0.7-0.9 | - | 0.2-0.6 | 0.7-1.1 | - | 0.7 | - | 2 |
| Copper | 0.5-0.6 | 0.8-1.1 | 1.3-7.5 | 0.5-1.5 | 0.7-1.2 | 1.6 | 2.3 | 2 |
| Iron | <10 | 70-100 | <10-20 | <10-20 | 20-70 | 110 | 650 | 300 |
| Lead | <0.05 | 0.07-0.18 | <0.05-1.33 | <0.05 | <0.05-0.13 | 0.12 | 0.20 | 1 |
| Nickel | 0.3-0.5 | <0.1-0.2 | 0.5-0.8 | 0.2-1.0 | <0.1-0.5 | 1.1 | 1.8 | 25 |
| Silver | 0.01 | <0.01-0.04 | <0.01 | <0.01-0.02 | 0.02-0.04 | <0.01 | 0.04 | 0.1 |
| Zinc | 3-10 | 8-22 | <1-14 | 1-13 | 4-12 | 1 | 2 | 30 |

**1: Total aluminum should not exceed 5 µg/L in waters of pH < 6.5. 100 µg/L should not be exceeded at pH > 6.5.**
**Note: Data presented are ranges from the entire water column. If no range is given, all values were the same.**

A comparison of total and dissolved Al and Fe metal concentrations reveals that the dissolved fraction makes up, on average, only ~10% of the total metal concentration. Thus a large fraction of the total metal inventory in the lakes consists of a particulate fraction from detrital or allochthonous inputs. Detrital Al exists as aluminosilicate minerals which are abundant in most rock types and geologic materials, especially clay. Aluminum can be leached from minerals through natural weathering processes, with this process being activated by acidic waters. Aluminum can also enter the waterways through atmospheric deposition from local and remote sources. Particulate Fe is likely due to input after the leaching of Fe oxyhydroxides from crustal minerals. The chemical behavior of this element in the aquatic environment is determined by the prevailing redox conditions. In general, Fe is present in surface waters as $Fe^{3+}$ (ferric) which is insoluble in aerobic waters. This leads to the generally observed low dissolved Fe concentrations measured in the lake waters.

*5.1.1.2 Streams*

One inflow stream of Spyder Lake and the outflow streams of Trout and Stickleback lakes were sampled for water quality during 1996 (Figure 5.1-1).

*Methods*

Water quality samples from streams were collected just below the surface using clean plastic bottles. Samples were collected by carefully rinsing the bottle three times before filling. Samples were stored in the dark in a cooler filled with freezer packs. Care was taken to avoid collecting any particulate material as this could introduce sampling artifacts and result in altered water chemistry. Samples were obtained for nutrients, physical parameters and trace metals and were handled as described above for the lake samples.

*Results and Discussion*

Data for physical properties, nutrients and trace metals collected from streams within the Boston Property are presented in Appendix 5-1.

- *Physical Parameters and Nutrients*

  Table 5.1-4 presents physical parameters for the streams sampled within the Boston Property. All streams sampled had pH values ranging from 6.9 to 7.6. Total suspended solids (TSS) ranged from below detection limit to a high of 74 mg/L. Dissolved oxygen (DO), as one would expect in streams, was relatively high, ranging from 9.6 to 13.4 mg/L. Temperature was generally low, ranging from 5.5 to 5.9°C. Trout Outflow in June was somewhat of an anomaly, having a temperature of 10.7°C. Total phosphorus was highest in Trout Outflow, suggesting that the elevated input was likely a result of the higher observed concentration of TSS in the stream.

- *Metals*

  Selected metal concentrations are listed in Table 5.1-5 together with Canadian Federal Water Quality Guidelines for freshwater aquatic life (CCREM 1987, Health Canada and Environment Canada 1995). As in the lakes, the concentrations of most of the metals measured in the streams were quite low. The total concentrations of As, Cd, Cr, Pb, Ni, and Ag were all below the Canadian guidelines for freshwater aquatic life. Copper showed concentrations above the guideline level in Trout Outflow and the Northeast Spyder Inflow in late August. In early August, Northeast Spyder Inflow had a Zn concentration that was marginally higher than the guideline. Total Fe in Trout Outflow and total Al and Fe in Northeast Spyder Inflow were above the guidelines in late August. Samples collected from these outflows three weeks before (and also in June) did not display such high levels, suggesting that the high values may result from short-term seasonal variations in natural input functions.

### 5.1.2 Doris Lake Property

The Doris Lake Property is situated at the northern end of the Hope Bay Belt area. Figure 5.1-2 presents the lakes and streams within the Doris Lake Property that were sampled for water quality in 1996.

## Table 5.1-4
## pH, Total Suspended Solids (TSS), Turbidity, Dissolved Oxygen (DO), Temperature (T), and Total Phosphorus (TP) for the Boston Property Streams (1996)

| Parameter | Trout Outflow June 22 | Trout Outflow Aug. 5 | Trout Outflow Aug. 25 | Stickleback Outflow June 22 | Stickleback Outflow Aug. 5 | Stickleback Outflow Aug. 25[1] | Northeast Spyder Inflow Aug. 5 | Northeast Spyder Inflow Aug. 25 |
|---|---|---|---|---|---|---|---|---|
| pH (pH units) | 7.1 | 7.0 | 7.2 | 7.1 | 7.3 | 7.6 | 7.0 | 6.9 |
| TSS (mg/L) | 1.0 | 74 | 18 | <1.0 | 2.0 | 2.0 | 1.0 | 15 |
| Turbidity (NTU) | 2.4 | 40 | 25 | 1.1 | 0.6 | 2.0 | 3.0 | 6.4 |
| DO (mg/L) | 11.22 | - | 13.43 | 13.28 | - | 12.04 | - | - |
| T (°C) | 10.7 | - | 5.7 | 5.5 | - | 5.9 | - | - |
| TP (mg/L) | 0.016 | 0.039 | 0.036 | 0.008 | 0.008 | 0.0175 | 0.025 | 0.017 |

**1: n=2; reported values are averages.**

## Table 5.1-5
## Total Metal Concentrations Measured for the Boston Property Streams (1996) along with CCREM Guidelines for Freshwater Aquatic Life

| Total Metals (µg/L) | Trout Outflow June 22 | Trout Outflow Aug. 5 | Trout Outflow Aug. 25 | Stickleback Outflow June 22 | Stickleback Outflow Aug. 5 | Stickleback Outflow Aug. 25[1] | Northeast Spyder Inflow Aug. 5 | Northeast Spyder Inflow Aug. 25 | CCREM guidelines |
|---|---|---|---|---|---|---|---|---|---|
| Aluminum | 65 | 43 | 45 | 13 | <1 | 41 | 29 | 231 | 5-100[2] |
| Arsenic | <1 | <1 | <1 | <2 | <1 | <1 | <1 | 2 | 50 |
| Cadmium | <0.05 | 0.14 | <0.05 | 0.09 | 0.06 | 0.12 | 0.14 | <0.05 | 0.2 |
| Chromium | 1.0 | 0.8 | - | 0.6 | 0.5 | - | 0.7 | - | 2 |
| Copper | 1.1 | 1.3 | 2.2 | 0.5 | 0.2 | 0.6 | 1.5 | 2.7 | 2 |
| Iron | 210 | 180 | 640 | 50 | 30 | 130 | 220 | 420 | 300 |
| Lead | 0.06 | <0.05 | 0.15 | <0.05 | <0.05 | 0.12 | 0.09 | 0.24 | 1 |
| Nickel | 0.6 | 0.8 | 2.0 | 0.5 | 0.4 | <0.1 | 1.0 | 1.8 | 25 |
| Silver | <0.01 | 0.01 | 0.06 | <0.01 | <0.01 | 0.05 | <0.01 | 0.06 | 0.1 |
| Zinc | 2 | 5 | 2 | 1 | <1 | 18 | 31 | 6 | 30 |

**1: n=2; reported values are averages.**
**2: Total aluminum should not exceed 5 µg/L in waters of pH < 6.5. 100 µg/L should not be exceeded at pH > 6.5.**

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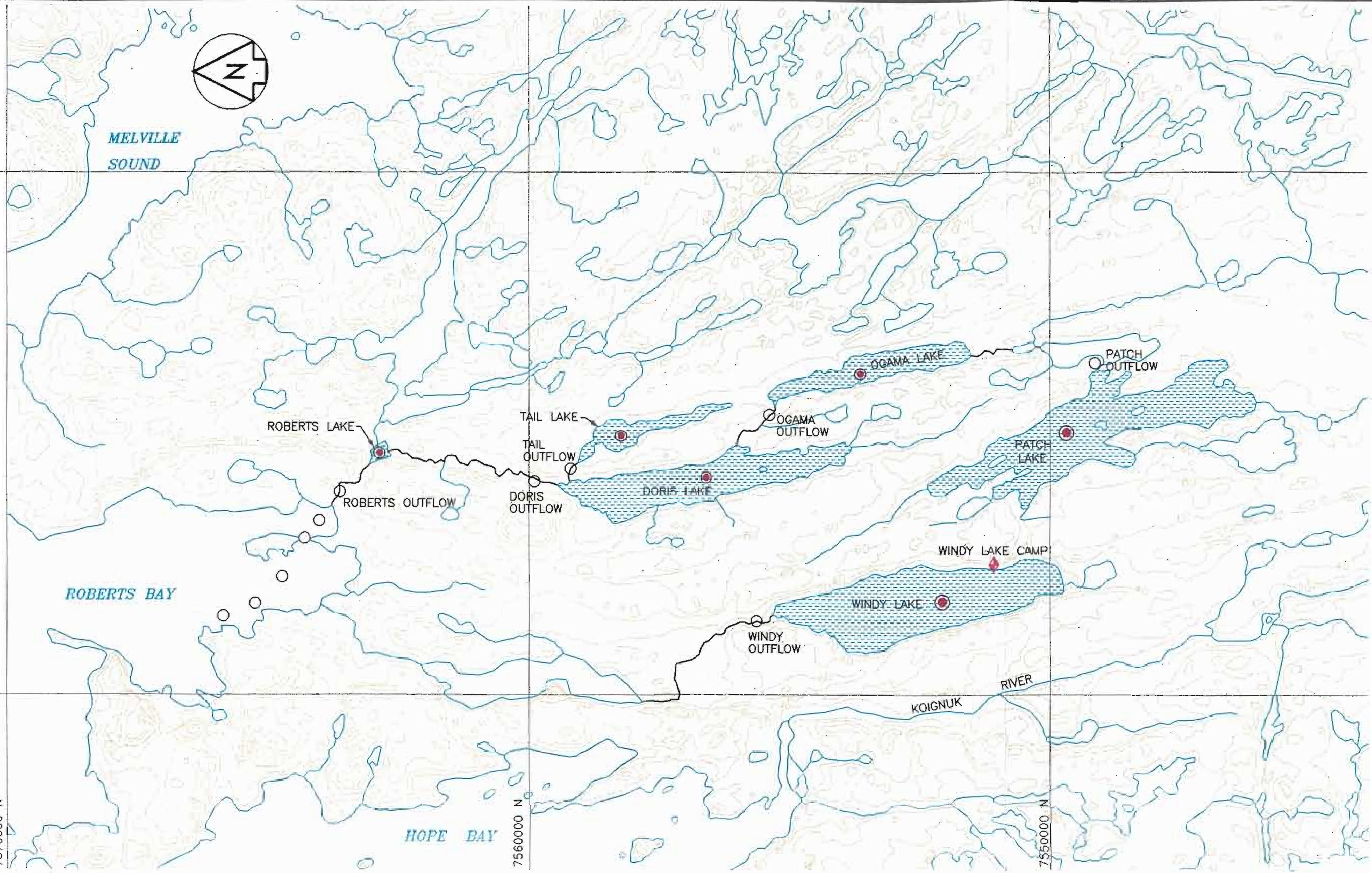


NOTE:
CONTOUR INTERVAL 20m

LEGEND:
SEDIMENT SAMPLING STATION
WATER QUALITY SAMPLING STATION
CAMP SITE

BHP

Water Quality and Sediment Sampling Stations
Doris Lake Property, 1996

Rescan

Fig 5.1-2

Source: Klohn-Crippen, 1995 fig3-11.dwg

*5.1.2.1 Lakes*

A total of six lakes and one marine site were sampled for water quality and sediments in 1996. The lakes sampled were Patch, Ogama, Doris, Tail, Roberts and Windy, and the marine site was Roberts Bay.

*Methods*

The water quality sampling methods were the same as those described previously in Section 5.1.1.1. Water quality samples were taken on April 23, 1996 (winter sampling period) for Patch and Doris lakes, and between August 26 and August 29, 1996 (fall sampling period) for all six lakes and the marine site. Samples were obtained for physical parameters, anions, nutrients, and trace metals. Parameters analyzed for and their detection limits are provided in Table 5.1-1. A single set of water quality samples was taken at each location. During the fall sampling period, samples were taken in triplicate at 2.5 m depth in Tail Lake and in duplicate at Site 3 in Roberts Bay. In the same period, sample splits were taken from the one metre sample at Windy Lake, the six metre sample at Patch Lake, and the two metre sample at Roberts Lake.

*Results and Discussion*

A complete list of the water quality parameters analyzed from all sites and locations is given in Appendix 5-3. Specific parameters were selected for more detailed analysis and are described below.

- *Physical Parameters and Nutrients*

  Selected physical parameters and nutrients (pH, total suspended solids (TSS), turbidity, and total phosphorus (TP)) are presented in Table 5.1-6. All of the sites sampled had a pH that was essentially neutral, ranging from 6.8 to 8.0. The marine site, Roberts Bay, had a pH of 7.9 in August.

  All of the lakes and the marine site had low TSS and turbidity, with TSS concentrations ranging from <1 to 7 mg/L and turbidity values ranging from 0.5 to 8 NTU. As with pH, the two lakes sampled in April (Patch and Doris) showed marked increases in TSS and turbidity from April to August. Total suspended solids increased significantly in Patch Lake (from <1 mg/L in April to as high as 7 mg/L in August). Turbidity increased by a factor of five in Patch Lake (0.5 to 0.8 NTU in April to 3 to 4 NTU in August) and doubled in Doris Lake (3 to 3.7 NTU to 6 to 8 NTU). During the fall sampling period, Roberts Lake had the clearest water, indicated by its low TSS and turbidity values. Tail Lake had the highest TSS concentration, while Doris Lake had the highest turbidity during the same period. Roberts Bay had TSS that ranged from <1 to 3 mg/L and turbidity that ranged from 0.8 to 3.1 NTU. Most of the lakes had low concentrations of total phosphorus, ranging from <0.001 to 0.010 mg/L, and can therefore be considered oligotrophic to oligo-mesotrophic (Wetzel 1983). Ogama and Doris lakes in April had higher concentrations (0.020 to 0.022 mg/L and 0.012 to 0.019 mg/L, respectively) and would probably be categorized as mesotrophic (Wetzel 1983).

Dissolved oxygen and temperature were measured in Patch, Doris, and Tail lakes on April 24, 1996 and in all six lakes between August 26 and 29, 1996. Vertical profiles for the six lakes at the Doris Lake Property are shown in Appendix 5-2. In the April sampling period, approximately two metres of ice had to be drilled through in order to obtain measurements for the three lakes. As one would expect, the lakes were non-stratified with respect to temperature (1°C throughout). Beneath the ice layer, DO decreased to approximately 6.0 mg/L in Tail Lake and 9.5 mg/L in Patch and Doris lakes. There was little variation in DO between the ice layer and bottom for Patch and Doris lakes. At the very bottom of these two lakes, however, DO increased slightly to between 10.5 and 11.0 mg/L.

In the fall sampling period, the six lakes were essentially non-stratified with respect to both temperature and dissolved oxygen. Temperature varied between 8.0 and 9.0°C and dissolved oxygen varied between 11.1 and 11.7 mg/L. A thermocline, where the temperature dropped by 1.2°C existed in Patch Lake between one and five metres depth.

- *Metals*

The concentrations of dissolved and total metals measured in the six lakes and one marine site are contained in Appendix 5-3. Selected total metals and the corresponding CCREM guidelines are provided in Table 5.1-7.

## Table 5.1-6
## pH, Total Suspended Solids (TSS), Turbidity, and Total Phosphorus (TP) for the Doris Lake Property Lakes (1996)

| Parameter | Patch Lake Apr. 23 | Patch Lake Aug. 26 | Ogama Lake Aug. 27 | Doris Lake Apr. 23 | Doris Lake Aug. 28 | Tail Lake Aug. 27 | Roberts Lake Aug. 27 | Windy Lake Aug. 29 | Roberts Bay Aug. 28 |
|---|---|---|---|---|---|---|---|---|---|
| pH (pH units) | 6.9-7.2 | 7.5-7.6 | 7.2-7.3 | 6.8-7.0 | 7.4 | 7.2-7.3 | 7.5 | 7.8-8.0 | 7.9 |
| TSS (mg/L) | <1 | <1-7 | 4-6 | <1-3 | <1-5 | 2-7 | <1-3 | 1-3 | <1-3 |
| Turbidity (NTU) | 0.5-0.8 | 3.0-4.0 | 6.3-7.2 | 3.0-3.7 | 6-8 | 5.2-5.5 | 0.8-1.0 | 5.0 | 0.8-3.1 |
| TP (mg/L) | 0.003-0.008 | 0.004-0.008 | 0.020-0.022 | 0.012-0.019 | <0.001-0.007 | 0.011-0.013 | <0.001 | <0.001 | 0.024-0.027 |

**Note: Data presented are ranges from the entire water column. If no range is given, all values were the same.**

## Table 5.1-7
## Total Metal Concentrations Measured for the Doris Lake Property Lakes (1996) and the CCREM Guidelines for Freshwater Aquatic Life

| Total Metals (µg/L) | Patch Lake Apr. 23 | Patch Lake Aug. 26 | Ogama Lake Aug. 27 | Doris Lake Apr. 23 | Doris Lake Aug. 28 | Tail Lake Aug. 27 | CCREM guidelines |
|---|---|---|---|---|---|---|---|
| Aluminum | 7-18 | 78-182 | 334-452 | 5-7 | 42-90 | 228-309 | 5-100[1] |
| Arsenic | 0.5-0.8 | <1.0-2.0 | <1.0-1.0 | 0.55-0.69 | 1-15 | <1.0-2.0 | 50 |
| Cadmium | <0.05-0.14 | <0.05-0.13 | <0.05 | <0.05-0.42 | <0.05 | <0.05-0.12 | 0.2 |
| Chromium | 0.7-0.9 | 1.9-2.4 | 2.1-2.3 | 0.4-0.6 | 1.8-3.4 | 1.8-2.3 | 2 |
| Copper | 3.6-6.6 | 1.1-2.7 | 1.9-3.9 | 2.4-3.5 | 1.6-2.2 | 1.8-2.3 | 2 |
| Iron | 30-70 | 40-120 | 270-330 | <10 | 130-150 | 200-230 | 300 |
| Lead | 0.1-0.6 | 0.1-0.2 | 0.2-0.4 | 0.12-0.24 | 0.26-0.31 | 0.1-0.3 | 1 |
| Nickel | 0.7-1.0 | 0.5-1.4 | 1.1-2.2 | 0.3-0.5 | 1.2-1.7 | 0.8-1.0 | 25 |
| Silver | <0.01 | <0.01 | <0.01-0.01 | <0.01 | <0.01-0.08 | <0.01-1.0 | 0.1 |
| Zinc | 1-9 | <1.0-3.0 | <1.0-13 | 2-3 | 3-5 | <1.0-3.0 | 30 |

**1: Total aluminum should not exceed 5 µg/L in waters of pH < 6.5. 100 µg/L should not be exceeded at pH > 6.5.**
**Note: Data presented are ranges from the entire water column. If no range is given, all values were the same.**

| Total Metals (µg/L) | Roberts Lake Aug. 27 | Windy Lake Aug. 29 | CCREM guidelines | Roberts Bay Aug. 28 | BC MELP guidelines[2] | US EPA guidelines[3] |
|---|---|---|---|---|---|---|
| Aluminum | 209-256 | 63-147 | 5-100[1] | 108-200 | - | - |
| Arsenic | 2-4 | <1.0-5.0 | 50 | <5 | 36 | 36 |
| Cadmium | <0.05 | <0.05 | 0.2 | <0.05-5.06 | 9.0 | 9.3 |
| Chromium | 2.2-2.7 | 2.2-3.2 | 2 | 2.2-3.1 | 50 | 50 |
| Copper | 2.9-3.4 | 0.8-1.4 | 2 | 9.1-15.5 | ≤2 | 2.9 |
| Iron | 240-260 | 100-150 | 300 | <10-150 | 50 | - |
| Lead | 0.54-0.66 | 0.2-0.4 | 1 | 0.48-2.13 | ≤2 | 7.1 |
| Nickel | 2.3-2.5 | 1.1-1.3 | 25 | 15.5-21.8 | 8.3 | 5.0 |
| Silver | <0.01 | <0.01-0.01 | 0.1 | 0.47-1.41 | 2.3 | 62.3 |
| Zinc | 6-8 | 3-5 | 30 | 6-9 | 86 | 58 |

**2: Based on British Columbia's Ministry of Environment, Lands and Parks Water Quality Guidelines for the protection of marine life (used either 4-day or 30-day average).**
**3: Based on United States Environmental Protection Agency's Quality Guidelines for Water for the protection of marine life (used either 4- day or 24-hr average).**

Dissolved metals were not tabulated because CCREM guidelines do not exist for dissolved metals. Of the two lakes sampled in April, Doris Lake had the lowest total metal values for every parameter listed in Table 5.1-7 except Cd. In the August sampling period, Patch Lake had the lowest total metal concentrations of Fe, Pb, Ni and Zn while Ogama and Roberts lakes had the highest concentrations of Al, Cu, Fe, Zn and Cu, Pb, Ni, Zn, respectively. Roberts Bay had concentrations of Al, As, Cr, Fe, and Zn that were within the ranges measured in the lakes. Roberts Bay had higher concentrations of Cd, Cu, Pb, Ni and Ag than any of the lakes.

In Table 5.1-7, the background concentrations of total metals are compared to the CCREM guidelines. None of the freshwater sites exceeded the guidelines for As, Pb, Ni, Ag or Zn. Only Doris Lake exceeded the guideline for Cd. With respect to Al and Cr, almost all of the freshwater stations exceeded the guidelines. The exceptions were Patch and Doris lakes in April and Doris Lake in August which did not exceed the guideline for Al, and Patch and Doris lakes in April which did not exceed the Cr guideline. For Cu, all of the stations, with the exception of Windy Lake, exceeded the guideline. Roberts Bay was below the guidelines for the protection of marine life for As, Cd, Cr, Ag and Zn. No marine guidelines exist for Al and only British Columbia guidelines exist for Fe. Site 1 in Roberts Bay exceeded the BC MELP guideline for Fe and Site 5 exceeded the BC MELP guideline for Pb. All five Roberts Bay sites exceeded the marine guideline (both BC MELP and U.S. EPA) for Ni. The total metal concentrations measured in these lakes represent natural background concentrations. A number of these background concentrations exceed the water quality guidelines for the protection of aquatic life, and this must be taken into consideration if and when the project goes into development and monitoring results are reviewed.

- *Comparison with Previous Data*

A water quality sampling program was initiated in May 1995 by BHP personnel. During this program, only the six lakes were sampled. Surface grab samples were collected through the ice in May and June at Roberts, Doris, Ogama, Windy and Patch lakes. In July, after the melt, samples were collected from shore at locations close to the May and June sampling sites. Early August sampling by Klohn-Crippen occurred in the deepest parts of Windy, Tail, Doris and Patch lakes. Surface samples were taken at Windy and Patch lakes and other samples were taken at various depths from Tail and Doris lakes. A second set of samples was collected in late August by BHP personnel at the same sites identified during the July sampling campaign. In order to avoid possible seasonal differences, only the data collected by Klohn-Crippen in August 1995 will be compared to the data collected in August 1996.

In general, the key physical parameters measured in 1996 (pH, conductivity, total dissolved solids and total suspended solids) were slightly lower than they were in 1995. The 1996 parameters were approximately 10% lower than the 1995 parameters, with the exception of conductivity which was approximately 10% higher in 1996 compared to 1995.

In 1995, most of the lakes displayed both oxyclines and thermoclines, while in 1996 most of the lakes were non-stratified with respect to dissolved oxygen and temperature. In 1995, the concentration of dissolved oxygen ranged from 10 to 11 mg/L, whereas in 1996, the DO concentration never dropped below 11.0 mg/L. The temperature in the lakes in 1995 ranged from 12.5 to 14.0°C above the thermocline and decreased to as low as 10.0°C below the thermocline. In 1996, the temperature in the lakes did not exceed 9.2°C and averaged approximately 8.5°C.

The total metal concentrations in the lakes were very similar in 1995 and 1996. The concentrations varied by only 5 to 10% for most metals. Some notable exceptions to this trend were Al and Fe which were occasionally much lower in 1995 compared to 1996 and K and Zn which were occasionally much higher in 1995 compared to 1996.

#### *5.1.2.2 Streams*

The outflows of the six lakes at the Doris Lake Property were sampled for water quality in 1996. These outflows were named after their respective lakes (*e.g.*, Patch Outflow) and are shown in Figure 5.1-2.

*Methods*

Sampling occurred twice in 1996; once between June 22 and 24 (spring sampling period) and again between August 22 and 23 (fall sampling period). The methods followed those outlined in Section 5.1.1.2 for stream sampling at the Boston Property. As with the lake sampling, samples were analyzed for physical parameters, anions, nutrients, and trace metals. The parameters analyzed for and their detection limits are provided in Table 5.1-1. A single set of samples was taken at each location. Field blanks were included for the Patch Outflow samples in both sampling periods, while duplicates were collected at Patch and Ogama outflows in the fall sampling period.

*Results and Discussion*

A complete list of the water quality parameters analyzed for in all of the Doris Lake Property outflows is given in Appendix 5-3. Specific parameters were selected for more detailed analysis and are described below.

- *Physical Parameters and Nutrients*

  Selected physical parameters and nutrients (pH, total suspended solids (TSS), turbidity, dissolved oxygen (DO), temperature and total phosphorus (TP)) are presented in Table 5.1-8. Most of the sites had a pH that was essentially neutral, ranging from 7.1 to 7.4, but a few of the sites were well out of this range. In most cases, the pH increased slightly (~0.2 pH units) from the spring sampling period to the fall sampling period.

  In general, the lake outflows had relatively low TSS and turbidity, ranging from <1.0 to 4.0 mg/L and 0.7 to 5.0 NTU, respectively. The TSS and turbidity of Patch, Tail, and Roberts outflows in the fall sampling period were significantly elevated with respect to the other samples, ranging from 18 to 20 mg/L and 12 to 25 NTU, respectively. With the exception of TSS for the Doris and Windy outflows, which were below the detection limit in both the spring and fall, all of the samples showed increases in TSS and turbidity between the spring and fall sampling periods.

  As one would expect, due to the turbulence associated with streams, the outflows had relatively high concentrations of dissolved oxygen, ranging from 8.7 to 14.2 mg/L. Stream turbulence causes air entrainment, resulting in high concentrations of dissolved oxygen. Most of the streams increased in temperature between the spring and fall sampling periods and exhibited a corresponding decrease in their dissolved oxygen concentration. An early winter in late August is likely responsible for the decrease in temperature observed for Tail and Windy outflows. The other outflows were affected by the cold weather as well but due to their low June temperatures, the difference in temperature between June and August was not as noticeable. The exceptions to the above trend were the Tail and Windy outflows, both of which decreased in temperature and increased in dissolved oxygen concentration from the spring to the fall sampling period. With the exceptions of Tail and Windy outflows in the spring sampling period, all of the outflows in both sampling periods exceeded the CCREM minimum guideline for dissolved oxygen of 5.0 to 9.5 mg/L.

The outflows had somewhat elevated concentrations of total phosphorus, ranging from 0.004 to 0.035 mg/L. With the exception of Roberts Outflow, all of the outflows had similar levels of total phosphorus (0.004 to 0.010 mg/L) in the spring sampling period. As observed for pH, TSS, and turbidity, the concentration of total phosphorus markedly increased (50 to 300%) between the spring and fall sampling periods. The only exception to this trend was Roberts Outflow, which decreased in total phosphorus from 0.026 to 0.020 mg/L between the spring and fall sampling periods. This correlation with TSS and turbidity is understandable, as total phosphorus is associated with particulate matter. As mentioned in Section 5.1.2.1, no CCREM guideline exists for total phosphorus.

- *Metals*

Selected total metals and the corresponding CCREM guidelines are presented in Table 5.1-9. Chromium was not measured in the samples taken during the fall sampling period. As with the lakes, dissolved metals were not tabulated because of a lack of CCREM guidelines for dissolved metals. In the spring sampling period, Windy Outflow had the lowest total metal concentrations of Cr, Cu, Fe and Ni while Roberts Outflow had the highest concentrations of Al, Cr, Cu, Fe, Pb and Ni. In the fall sampling period, Windy Outflow again had the lowest total metal concentrations of

## Table 5.1-8
## pH, Total Suspended Solids (TSS), Turbidity, Dissolved Oxygen (DO), Temperature (T), and Total Phosphorus (TP) for the Doris Lake Property Outflows (1996)

| Parameter | Patch Outflow June 23 | Patch Outflow[1] Aug. 23 | Ogama Outflow June 23 | Ogama Outflow[1] Aug. 22 | Doris Outflow June 23 | Doris Outflow Aug. 22 | Tail Outflow June 23 | Tail Outflow Aug. 22 | Roberts Outflow June 24 | Roberts Outflow Aug. 23 | Windy Outflow June 22 | Windy Outflow Aug. 23 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pH (pH units) | 7.3 | 7.7 | 7.2 | 6.4 | 7.2 | 7.3 | 7.1 | 7.3 | 7.2 | 7.4 | 7.2 | 7.8 |
| TSS (mg/L) | <1.0 | 19.5 | 2.0 | 3.5 | <1.0 | <1.0 | <1.0 | 20 | 4.0 | 18 | <1.0 | <1.0 |
| Turbidity (NTU) | 4.0 | 25 | 5.0 | 7.5 | 3.0 | 6.5 | 0.7 | 12.0 | 13.0 | 18.0 | 1.1 | 4.5 |
| DO (mg/L) | 14.20 | 11.70 | 12.44 | 11.47 | 11.66 | 10.88 | 8.71 | 10.80 | 12.18 | 12.09 | 9.12 | 11.24 |
| T (°C) | 4.9 | 6.3 | 5.7 | 7.4 | 6.7 | 9.4 | 12.5 | 5.2 | 5.6 | 5.9 | 13.4 | 8.5 |
| TP (mg/L) | 0.010 | 0.033 | 0.006 | 0.022 | 0.006 | 0.015 | 0.008 | 0.035 | 0.026 | 0.020 | 0.004 | 0.006 |

**1: n = 2; reported values are averages.**

## Table 5.1-9
## Total Metal Concentrations Measured for the Doris Lake Property Outflows (1996) along with CCREM Guidelines for Freshwater Aquatic Life

| Total Metals (µg/L) | Patch Outflow June 23 | Patch Outflow[1] Aug. 23 | Ogama Outflow June 23 | Ogama Outflow[1] Aug. 22 | Doris Outflow June 23 | Doris Outflow Aug. 22 | Tail Outflow June 23 | Tail Outflow Aug. 22 | Roberts Outflow June 24 | Roberts Outflow Aug. 23 | Windy Outflow June 22 | Windy Outflow Aug. 23 | CCREM guidelines |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Aluminum | 58 | 197 | 179 | 260 | 75 | 19 | 16 | 45 | 398 | 245 | 24 | 42 | 5-100[2] |
| Arsenic | 2.0 | 5.0 | <2.0 | 3.5 | <4.0 | 3.0 | <2.0 | <1.0 | <1.0 | 4.0 | <1.0 | <1.0 | 50 |
| Cadmium | <0.05 | <0.05 | 0.13 | <0.05 | 0.19 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | 0.15 | <0.05 | 0.2 |
| Chromium | 0.8 | - | 1.3 | - | 0.8 | - | 0.9 | - | 1.8 | - | 0.6 | - | 2 |
| Copper | 1.4 | 1.2 | 1.4 | 2.6 | 1.5 | 1.6 | 1.2 | 1.7 | 1.9 | 2.3 | 1.0 | 1.3 | 2 |
| Iron | 70 | 260 | 260 | 315 | 100 | 170 | 50 | 111 | 430 | 290 | 30 | 80 | 300 |
| Lead | 0.08 | 0.135 | 0.3 | 0.25 | 0.14 | 0.07 | 0.09 | 0.15 | 0.32 | 0.08 | 0.12 | 0.11 | 1 |
| Nickel | 0.3 | 0.8 | 0.9 | 1.5 | 0.6 | 1.3 | 0.5 | 0.7 | 0.9 | 1.5 | 0.2 | 1.4 | 25 |
| Silver | <0.01 | 0.045 | <0.01 | 0.055 | <0.01 | 0.03 | <0.01 | 0.07 | <0.01 | 0.07 | <0.01 | 0.01 | 0.1 |
| Zinc | 1.0 | 1.0 | 1.0 | 3.0 | 2.0 | <1.0 | 1.0 | <1.0 | 2.0 | 4.0 | 1.0 | <1.0 | 30 |

**1: n = 2; reported values are averages.**

**2: Total aluminum should not exceed 5 µg/L in waters of pH < 6.5. 100 µg/L should not be exceeded at pH > 6.5.**

As, Fe and Ag while Ogama Outflow had the highest concentrations of Al, Cu, Fe, Pb and Ni. Aside from Ogama, Doris and Windy outflows in June, the concentration of Cd was below the detection limit for all of the lake outflows.

Table 5.1-9 compares the total metal concentrations to the CCREM guidelines. None of the outflows in either of the sampling periods exceeded the guidelines for As, Cd, Cr, Pb, Ni, Ag or Zn. Ogama and Roberts outflows in the fall exceeded the Cu guideline, while Ogama Outflow in the fall and Roberts Outflow in the spring exceeded the Fe guideline. Patch Outflow in the fall and Ogama and Roberts outflows in both spring and fall exceeded the Al guideline.

## 5.2 Sediments

The natural cycling of trace metals and other water column components is intimately linked to sediment composition. Thus, changes in water chemistry as a result of natural or anthropogenic perturbations are generally reflected in sediment geochemistry. As a result, it is important to establish baseline conditions in order to assess any potential impact of future mining operations on lacustrine sediments.

This section focuses on lacustrine (as opposed to riverine) sediments, since lake environments are the potentially most affected by mining activities. Moreover, lake sediments represent the most accurate pre-mining records of accumulation. Interfacial sediments are subtly altered on seasonal timescales; however, such variations are beyond the scope of this study. Thus, temporal variability in the bulk composition of sediments integrated over the upper few centimetres of the surficial sediment layer can be assumed to be negligible. Sediment samples were collected from a number of lakes and were analyzed for metal concentrations and for total organic carbon content. A description of sediment geochemistry for Boston and Doris properties follows, along with a brief discussion of regional geology.

### 5.2.1 Regional Geology

Mineralization in the Boston and Doris Lake areas occurs in the Archean age Hope Bay Volcanic Belt (HBVB) which itself is within the fault-bounded Bathurst

Block in the northeast corner of the Slave Structural Province. The north-south trending supracrustal belt is 90 km long and 15 to 20 km wide. The belt was first mapped in 1964 and most recently in 1990.

The HBVB is dominated by mafic volcanics (~70%) and intrusives; lesser amounts of intermediate to felsic volcanics, volcaniclastics, metasediments and ultramafic sills and dykes are present. This supracrustal assemblage is considered to be geologically and temporally equivalent to the Yellowknife Supergroup.

The mafic components of the belt are pillowed volcanic flows interlayered with more massive flows and associated gabbroic sills. In the northern section of the belt (Ida Point area), major elemental data indicates that the mafic volcanics are tholeiitic. Ash and lapilli tuffs of dacitic and, to a lesser degree, rhyolitic composition, make up the majority of the felsic volcanics. Synvolcanic felsic intrusives include quartz feldspar porphyry dykes which are clustered in the north central section of the belt.

Metasedimentary lithologies include a conglomerate unit exposed in the northwest and a poorly exposed turbidite sequence (bedded siltstones, and graphitic argillites) found mainly along the belt’s central axis. Proterozoic aged diabase dykes of both the Franklin and Mackenzie affinity cut the stratigraphy.

The HBVB is bordered to the east and west by felsic intrusives of granitic to granodioritic composition and, to the southeast, by a heterogeneous gneissic terrain. The regional granitoid on the west side of the belt has been dated at 2,608 Ma and a synvolcanic felsic intrusive on the northeast side has been dated at 2,672 Ma. No basement to the supracrustal succession has definitely been identified within the belt.

### 5.2.2 Methods

Following collection using an Ekman grab sampler (for detailed methods, see Chapter 6), sediment samples were shipped from the field directly to Elemental Research Inc. for analysis. Metals were analyzed by acid digestion followed by inductively-coupled plasma mass spectrometry. Total organic carbon ($C_{org}$) is reported as the difference between total carbon and carbonate carbon which were determined by gas chromatography and carbon dioxide analysis, respectively.

### 5.2.3 Boston Property Results and Discussion

Lake sediment samples were collected from Trout, Stickleback and Spyder lakes (Figure 5.1-1). Metal concentrations generally reflected a range of average abundances from granitic to basaltic composition.

The surficial (interfacial) sample taken from Trout Lake was enriched in organic carbon ($C_{org}$; 7 wt%) and relatively depleted in Fe and Mn (Table 5.2-1). It is possible that degradation of the relatively abundant $C_{org}$ in sediments at this site fosters reducing conditions in the upper sediment layer such that oxides of Fe and Mn are unable to accumulate. This may be evident in the elevated Cd seen in this sample (relative to other sites) which is known to associate strongly with authigenic sulphides rather than with oxides. However, a more likely explanation for increased metals concentrations, including Cd, Cu and Ni is their occurrence in association with organic matter.

Samples were collected at Stickleback Lake from both interfacial (0 to 1 cm) and near-surface (1 to 2 cm) zones. Organic carbon content was much lower than in the Trout Lake sample, and decreased from 0.81 to 0.58 wt% with depth (Table 5.2-1). Fe and Mn concentrations were relatively low, with Fe substantially lower than other samples taken at the Boston Property. A decrease in metals such as Fe, Mn, As, Cu, and Co with sediment depth is suggestive of more reducing conditions; however, similar decreases in Cd and Ag concentrations imply that the interfacial sample may also have contained authigenic sulphides.

Five stations were sampled at Spyder Lake; interfacial (0 to 1 cm) and near-surface (1 to 3 cm) sediments were collected at each for a total of ten samples. Organic carbon values ranged from 0.32 to 1.18 wt %, with deeper samples (Station 6, 30 m depth; 1.18 wt%) more enriched than at shallower sites (Station 5, 4 m depth; 0.32 wt%; Table 5.2-1). With the exception of Station 6, Fe and Mn were also generally enriched in samples collected from deeper depths. Organic matter is hydrodynamically equivalent to fine silts and clays, as are metal oxides; hence the occurrence of increased $C_{org}$ and most metals (Fe, Mn, As, Cu, Co, Ni and others) at the deepest sites may be a result of their transport via resuspension and redeposition in the deeper lake areas.

Surface sediments are generally enriched in Fe and Mn suggesting that the interfacial sediments are oxic despite the implication of fine-grained, organic-rich material. Moreover, diagenetic oxide cycling likely accounts for much of the enrichment in metals rather than sulphide precipitation since the water column contains minimal sulfate to create authigenic sulphides. The deepest samples (Station 6) do not display the same enrichment in oxide-associated metals as samples at other deeper stations (*e.g.*, Station 4). This may be the result of reducing conditions in the upper sediment layer produced by the degradation of increased concentrations of organic matter, which inhibit the formation of Fe and Mn oxides. Sediments generally appear to become more reducing with depth below the sediment-water interface. This is evinced at all sites by an increase in Fe and Mn from the interfacial to near-surface zones, concurrent with a general decrease in oxide-associated metals such as As and Co, although metals concentrations are variable as seen at Stations 3 and 5 (Table 5.2-1).

In summary, though intra-lake variability at the Boston Property is high, the trends between lakes are relatively consistent and predictable. It is likely that metals are introduced to surficial lake sediments in part through their association with organic matter in addition to the accumulation of authigenic phases. Ultimately, the combined effects of post-depositional and physical processes probably determine the distribution of sediments within each basin.

### 5.2.4 Doris Lake Property Results and Discussion

Lake sediment samples were collected from Doris, Ogama, Patch, Roberts, Tail and Windy lakes (Figure 5.1-2). Element concentrations were generally within a range between average granite and basalt compositions. This is not unexpected, given that regional geology is dominated by mafic volcanics and intrusives with lesser amounts of intermediate to felsic volcanics. In addition to provenance, the bulk composition of the sediment samples is likely controlled in part by grain size and by the presence of organic matter; however, quantitative assessment of the relative importance of these parameters with respect to metals concentrations is beyond the scope of this report.

In general, the sediment samples were moderately enriched in total organic carbon ($C_{org}$) which ranged from 0.14 wt% (Windy Lake) to 1.94 wt% (Tail Lake; Table 5.2-2). Interfacial sediments (0 to 1 cm) were slightly enriched in $C_{org}$

**Table 5.2-1**
**Sediment Data, Boston Property Lakes, 1996**

| | | Trout Lake (2 m) Aug. 25, 1996 | Stickleback Lake (3 m) Aug. 25, 1996 | | Spyder Lake Stn. 1 (1 m) Aug. 23, 1996 | | Spyder Lake Stn. 3 (12 m) Aug. 23, 1996 | | Spyder Lake Stn. 4 (21 m) Aug. 24, 1996 | | Spyder Lake Stn. 5 (4 m) Aug. 24, 1996 | | Spyder Lake Stn. 6 (30 m) Aug. 24, 1996 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Surface** | **0-1 cm** | **1-2 cm** | **0-1 cm** | **1-3 cm** | **0-1 cm** | **1-3 cm** | **0-1 cm** | **1-3 cm** | **0-1 cm** | **1-3 cm** | **0-1 cm** | **1-3 cm** |
| **PHYSICAL PARAMETERS** | | | | | | | | | | | | | | |
| Moisture | % | 68.9 | 37.5 | 29.1 | 48.2 | 30.3 | 71.6 | 64.8 | 75.0 | 60.1 | 45.0 | 42.3 | 63.3 | 56.8 |
| TOC | wt % | 7.05 | 0.81 | 0.58 | 0.56 | 0.53 | 0.82 | 0.70 | 0.88 | 0.84 | 0.32 | 0.32 | 1.18 | 1.08 |
| **METALS** | | | | | | | | | | | | | | |
| Antimony | ppm | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | 0.29 | 0.06 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Arsenic | ppm | 6 | 2 | 1 | 4 | 1 | 15 | 60 | 50 | 20 | 6 | 20 | 4 | 4 |
| Cadmium | ppm | 0.41 | 0.11 | <0.05 | <0.05 | <0.05 | 0.28 | 0.16 | 0.34 | 0.20 | <0.05 | <0.05 | 0.16 | 0.10 |
| Chromium | ppm | 35.7 | 18.3 | 14.6 | 26.7 | 21.8 | 72.3 | 85.6 | 71.6 | 98.5 | 35.1 | 41.6 | 91.1 | 90.6 |
| Cobalt | ppm | 8.7 | 3.3 | 3.0 | 6.4 | 3.2 | 31.1 | 19.4 | 33.2 | 17.9 | 9.0 | 7.6 | 18.2 | 15.7 |
| Copper | ppm | 96.4 | 11.7 | 7.4 | 8.4 | 6.8 | 26.4 | 27.2 | 28.6 | 30.4 | 9.8 | 10.7 | 23.8 | 22.6 |
| Iron | ppm | 22800 | 13100 | 12200 | 35100 | 13100 | 105000 | 96600 | 127000 | 75300 | 40400 | 50300 | 53100 | 47700 |
| Lead | ppm | 10.3 | 2.07 | 1.93 | 3.92 | 3.21 | 10.0 | 10.8 | 9.94 | 12.8 | 4.14 | 4.75 | 10.2 | 9.37 |
| Manganese | ppm | 146 | 105 | 104 | 522 | 129 | 21800 | 3230 | 25400 | 2010 | 1330 | 750 | 762 | 659 |
| Mercury | ppm | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Nickel | ppm | 42.0 | 7.7 | 7.5 | 10.0 | 8.4 | 35.6 | 30.5 | 41.3 | 34.4 | 12.5 | 14.1 | 34.1 | 31.8 |
| Selenium | ppm | 0.5 | <0.5 | <0.5 | <0.5 | <0.5 | 1.0 | 1.3 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 |
| Silver | ppm | 0.16 | 0.31 | <0.01 | <0.01 | <0.01 | <0.01 | 0.13 | 0.22 | 0.31 | 0.04 | <0.01 | 0.22 | 0.15 |
| Zinc | ppm | 93 | 17 | 15 | 29 | 25 | 98 | 93 | 87 | 116 | 35 | 39 | 103 | 90 |

## Table 5.2-2
## Sediment Data, Doris Lake Property Lakes, 1996

| | | Patch Lake (12 m) Aug. 26, 1996 | | Ogama Lake (4 m) Aug. 27, 1996 | | Doris Lake (17 m) Aug. 28, 1996 | | Tail Lake (5 m) Aug. 27, 1996 | | Roberts Lake (3 m) Aug. 27, 1996 | | Windy Lake (8 m) Aug. 28, 1996 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **0-1 cm** | **1-3 cm** | **0-1 cm** | **1-3 cm** | **0-1 cm** | **1-3 cm** | **0-1 cm** | **1-3 cm** | **0-1 cm** | **1-3 cm** | **0-1 cm** | **1-3 cm** |
| **PHYSICAL PARAMETERS** | | | | | | | | | | | | | |
| Moisture | % | 64.2 | 48.0 | 57.8 | 47.7 | 31.2 | 54.7 | 66.8 | 68.3 | 59.0 | 50.3 | 31.3 | 32.6 |
| TOC | wt % | 0.82 | 0.78 | 0.89 | 0.83 | 1.29 | 1.19 | 1.94 | 1.93 | 0.86 | 0.75 | 0.17 | 0.14 |
| **METALS** | | | | | | | | | | | | | |
| Antimony | ppm | 0.08 | 0.09 | <0.05 | <0.05 | <0.05 | <0.05 | 0.26 | 0.11 | <0.05 | <0.05 | <0.05 | <0.05 |
| Arsenic | ppm | 12 | 4 | 44 | 12 | 4 | 4 | 7 | 3 | 2 | 2 | 9 | 6 |
| Cadmium | ppm | 0.15 | 0.11 | <0.05 | 0.06 | 0.05 | 0.16 | 0.10 | 0.14 | 0.07 | <0.05 | 0.07 | <0.05 |
| Chromium | ppm | 108 | 108 | 93.6 | 107 | 102 | 109 | 105 | 132 | 68.1 | 62.6 | 41.1 | 49.5 |
| Cobalt | ppm | 17.5 | 16.0 | 15.6 | 15.4 | 13.6 | 14.9 | 16.3 | 19.3 | 10.3 | 9.9 | 9.1 | 8.3 |
| Copper | ppm | 36.7 | 34.4 | 30.8 | 30.1 | 39.5 | 42.4 | 44.7 | 64.0 | 23.8 | 22.0 | 15.8 | 17.3 |
| Iron | ppm | 68400 | 53100 | 71600 | 58700 | 52100 | 47600 | 79800 | 71300 | 38900 | 35000 | 25700 | 26900 |
| Lead | ppm | 10.1 | 10.3 | 9.05 | 9.76 | 9.86 | 10.8 | 9.27 | 11.5 | 6.04 | 5.52 | 4.67 | 5.19 |
| Manganese | ppm | 2150 | 1000 | 4410 | 1410 | 692 | 750 | 1390 | 830 | 395 | 365 | 590 | 386 |
| Mercury | ppm | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Nickel | ppm | 44.3 | 40.7 | 33.4 | 40.2 | 41.5 | 43.8 | 41.9 | 54.0 | 24.4 | 23.1 | 16.1 | 24.0 |
| Selenium | ppm | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | 0.6 | <0.5 | 0.9 | <0.5 | <0.5 | <0.5 | <0.5 |
| Silver | ppm | 0.41 | 0.30 | 0.14 | 0.12 | 0.25 | 0.16 | 0.27 | 0.40 | 0.07 | 0.09 | 0.11 | 0.09 |
| Zinc | ppm | 84 | 82 | 74 | 84 | 91 | 94 | 90 | 115 | 60 | 56 | 25 | 34 |

relative to near-surface sediments (1 to 3 cm) at all sites, probably due to the rapid oxidation of organic matter following deposition.

Both Fe and Mn are sensitive to redox conditions, forming solid oxides in oxic regimes and dissolved species under reducing conditions; hence they have a tendency to accumulate and become enriched in oxic surface sediments. Due to the affinity of many trace metals toward oxide surfaces, there is often a corresponding enrichment in metals such as As, Co and Cu, among others. Interfacial sediment samples from the Doris Lake Property are generally replete in Fe and Mn, and host commensurate increases in As, Cu and Co (relative to near-surface samples), suggesting that authigenic oxides exist within the interfacial sediments. Thus, interfacial sediments appear to be oxic despite the degradation of organic material. This is particularly notable at the Ogama site, where As concentrations in interfacial and near-surface sediments are 44 and 12 ppm, respectively (Table 5.2-2). Similar trends are also evident to a lesser degree at the remainder of the sites.

It is possible that reducing conditions develop within the upper few centimetres of the sediments such that Fe and Mn oxides accumulate to a lesser degree below the interfacial zone. The development of such conditions may be manifest as the decrease in Fe and Mn concentrations generally seen in near-surface sediment samples. Nevertheless, metals such as Cd, Ag and Hg which are known to associate with authigenic sulphides rather than oxides do not significantly increase with sediment depth, with the exception of Cd at the Doris and Tail lake sites. Thus, diagenetic alteration may be slightly more intense in near surface sediments at these sites, however cannot be fully constrained without a mineralogical assessment.

In summary, the trends between lake sediments are relatively consistent and predictable. It is likely that metals are introduced to surficial lake sediments in part through their association with organic matter in addition to the accumulation of authigenic phases. Although areal variability within each basin cannot be constrained, the combined effects of post-depositional and physical processes probably determine the distribution of sediments within each basin.

## 5.3 Acid Generation Testwork

Any action generated from waste rock, bulk samples and drill core can affect receiving water quality and for this reason is discussed in this section. This section outlines the results of the Acid Rock Drainage (ARD) characterization from the rock removed from the Boston bulk sample adit and Doris Lake drill core. The sampling program was conducted during the 1996 exploration season by BHP geologists and the analytical work was conducted by Chemex Laboratories in North Vancouver.

### 5.3.1 Geological Setting

The Boston Property is centred on a carbonatized, mineralized shear zone. The bulk sample adit encounters three major rock types: mafic volcanics; gabbro; and sediments. The B2 mineralized zone lies on the variable contact between Greenschist facies mafic volcanics and their clastic derivatives. The mafic volcanics are tholeiitic basalts found in pillowed and massive flows. Sediments in the shear zone are intensely folded fine-grained phyllites that may or may not contain graphite. Gabbroic sills are also encountered exclusively in the mafic volcanic domain. In the vicinity of the bulk sample the rocks have been affected by widespread hydrothermal alteration. The most strongly carbonatized portions of the shear are comprised of fine-grained masses of dolomite (ankerite) and sericite. These portions are typically enveloped within a less altered domain comprised of strongly foliated, calcite-bearing, chlorite sericite schists. Quartz veins are localized within the shear generally trending sub-parallel to the structure. The veins are comprised of coarsely crystalline, translucent quartz with varying amounts of carbonate present. Sulphide accumulation of up to 1 to 2% is observed.

The Doris Lake exploration target consists of a series of near parallel quartz veins hosted within iron carbonate shears within tholeiitic basalts at the northern tip of Doris Lake. The largest of these veins is the “Lakeshore” vein which has been traced discontinuously over 1.92 km; it averages 7.00 m wide and has been located at depths of 390 m. West of the Lakeshore vein, 20 to 50 m, is the next largest vein, the “Central” vein. It can be traced discontinuously for 1.8 km and averages 3.4 m wide in the northern 700 m where it is best developed. This vein has been located at depths of 350 m. A third vein, the “West Valley Wall” is present approximately 90 m west of the Lakeshore vein. This has been outlined over 700 m and averages 2.0 m wide. These veins usually contain 1 to 2% fine tourmaline ribbons, and trace to 1% pyrite. Accessory minerals include chlorite, actinolite, fuchsite and talc. The host rock is sericite, ± iron/magnesium carbonate, altered and sheared basalt. The width of this alteration is typically two to ten metres on either side of the veins. The Lakeshore and Central veins are normally discrete veins but the West Valley vein is generally a series closely spaced veins.

The units sampled include the mafic volcanics, gabbro and quartz veins. The mafic volcanics have been divided into six categories based on alteration, mineralization and rheology. Quartz veins have been categorized based on mineralization and vein location (Table 5.3-1).

**Table 5.3-1**
**Rock Units**

| Rock Type | Label | Description |
|---|---|---|
| Mafic Volcanic | H | Strong hematite staining, trace-1% magnetite |
| Mafic Volcanic | D1 | Strong dolomite/sericite alteration <1% disseminated pyrite |
| Mafic Volcanic | D2 | Strong dolomite/sericite alteration >1-2% pyrite |
| Mafic Volcanic | F | Moderately to weakly foliated >1% disseminated magnetite |
| Mafic Volcanic | L | Finely banded to laminated, possibly a pyroclastic, 1% pervasive calcite |
| Mafic Volcanic | P | Pillow flow, trace - <1% pyrite |
| Gabbro | M | Coarse grained massive |
| Quartz | Q1 | >1% pyrite; >5% tourmaline; Lakeshore Vein |
| Quartz | Q2 | <1%-rare pyrite; >1% tourmaline; Lakeshore Vein |
| Quartz | Q3 | <1%-rare pyrite; >3-5% tourmaline; Central Vein |
| Quartz | Q4 | >1% pyrite; >5% tourmaline; Central Vein |

## 5.3.2 Methods

### *5.3.2.1 Analytical Methods*

The analytical results were processed at Chemex Labs in North Vancouver, BC. Chemex laboratory was used exclusively for the duration of the ABA testing program. The methods pertaining to the results obtained for the Boston and Doris

Lake project are presented below. The parameters measured include: paste pH, neutralization potential and total sulfur (%S). The remaining parameters, net neutralization potential and the ratio of neutralization potential (NP) to maximum potential acidity (MPA) are calculations based on the measured results.

Paste pH in itself is not a predictor of the acid generating potential of the sample and cannot be used directly to determine whether material can be safely stored. However, it does indicate the current drainage chemistry associated with the sample. The paste pH was initially determined on site and then at the laboratory. Consistent results between the on-site paste pH and the lab were obtained. Paste pH is determined by measuring the pH from a water saturated sample of rock, finely crushed. The consistency of the rock and water blend should resemble a gummy paste. The pH was then taken using a Hanna Instrument S1900 pH meter.

The neutralization potential (NP) is expressed as tonnes $CaCO_3$ per 1,000 t of material. The NP is determined by treating a sample with a specified volume and normality of HCl which is dependent on the sample's fizz rating. The acidified sample is gently heated and diluted with $CO_2$-free deionized water. Following a minute of boiling, the solution is covered and allowed to cool. The titration of the sample with NaOH to pH 7.0 determines the NP according to the calculation found in equation (1).

$$Neutralization\ Potential\ (NP) = \frac{50a\left(x - \frac{b}{a}y\right)}{c} \qquad (1)$$

$a$ = normality of HCl
$b$ = normality of NaOH
$c$ = sample weight in grams
$x$ = volume of HCl added in milligrams
$y$ = volume of NaOH added in milligrams to pH 7.0

The total sulfur (%S) is reported in parts per thousand (ppt). To determine the total sulfur, the sample is heated to approximately 1,350ºC in an induction furnace while passing a stream of oxygen through the sample. The sulfur dioxide released is measured by an infrared detection system. This entire process occurs in a Leco sulfur analyzer. The maximum potential acidity (MPA), given as tonnes $CaCO_3$

per 1,000 t of material, is a theoretical calculation measuring the acidity that could be produced assuming all sulfur occurs as iron sulphide (pyrite). The formula used is: MPA = 31.25 × (%S).

The net neutralization potential is the difference between the Neutralization Potential (NP) and the maximum potential acidity (MPA) and is expressed as tonnes of $CaCO_3$ /t of sample. The neutralization potential ratio (NPR) is simply the ration of NP to MPA.

#### *5.3.2.2 Sampling Methods*

Boston Property ABA samples were obtained from every second round blasted during the advancement of the underground adit. A total of 157 samples was obtained from the blasted muck using a random grab sample methodology. The sampling from the Boston Property samples are meant to represent a volume of rock removed from the working area unlike the Doris Lake Sampling which represents specific rock types. Therefore, a sample from Boston is identified as belonging to a general rock type, however, it may include minor components of other rock types. The Doris Lake Property ABA samples were obtained from drill core. The samples were chosen to represent the rock types and units defined in Table 5.3-1. A total of 76 samples was submitted for analysis. Sampling was concentrated near the mineralized zone to better represent rock types which may be disturbed should bulk sampling proceed.

### 5.3.3 Results

The results of the 1996 ABA analyses completed on the Boston and Doris Lake Properties indicate that the majority of rock sampled has a very low potential to generate acid. The results of these analyses are presented in Appendix 5-4 and discussed below.

#### *5.3.3.1 Boston Property*

Acid generating capacity is estimated using the total sulfur content, which provides a conservative estimate of acid generating potential, by assuming all sulfur present in a sample is capable of generating acid. Acidic conditions are produced by the oxidation of sulphide minerals which release acidity and metals.

Sulfate sulfur is an oxidized form of sulfur and does not contribute to acid production. The sulfur contents presented herein, report total sulfur which includes sulfate-sulfur in addition to sulphide-sulfur, thus likely providing a slight overestimation of the acid generating capacity.

The ABA results from the Boston Property indicate that sulfur contents vary over a wide range (Figure 5.3-1). This is partially a function of the sampling methodology which has been designed to provide a representation of the total mass of rock being removed from each round and not a specific rock type. However, the basalt samples (Unit BA) typically have sulfur contents less than 1% reflecting the lower degree of mineralization in this unit.

The acid neutralizing capacity of a sample is dependent on the availability of minerals which will dissolve under acidic conditions. These minerals are typically carbonate minerals such as calcite or slower dissolving aluminosilicate minerals. Neutralizing potential (NP) is a measure of the amount of acid neutralized by the sample, expressed in tonnes of $CaCO_3$ per 1,000 t of rock.

The Boston ABA samples have high NP values. Only three samples have values less than 100 t of $CaCO_3$ per 1,000 t of rock and have median and average values of 301 and 294 t of $CaCO_3$ per 1,000 t of rock respectively.

Maximum potential acidity (MPA) is a measure of the total sulfur content expressed in tonnes of $CaCO_3$ per 1,000 t of rock, the same units as neutralization potential (NP), allowing direct comparison of MPA with NP. Two methods are used to determine the net acid generating capacity of the samples. The net neutralizing potential (NNP) is the difference between NP and MPA as indicated in the previous section. Theoretically, a sample with a NNP less than zero is considered acid generating. However, NNP values between -20 and +20 may be acid generating. A NP/MPA ratio or NPR is also used to determine the overall acid generating capacity of a sample. Samples with an NPR greater than three can be considered acid consuming. Samples with a NPR less than one can be considered likely to produce acid. However, samples with an NPR between one and three are classified as uncertain without additional kinetic testing (DIAND 1992). A more recent set of available and relevant guidelines published

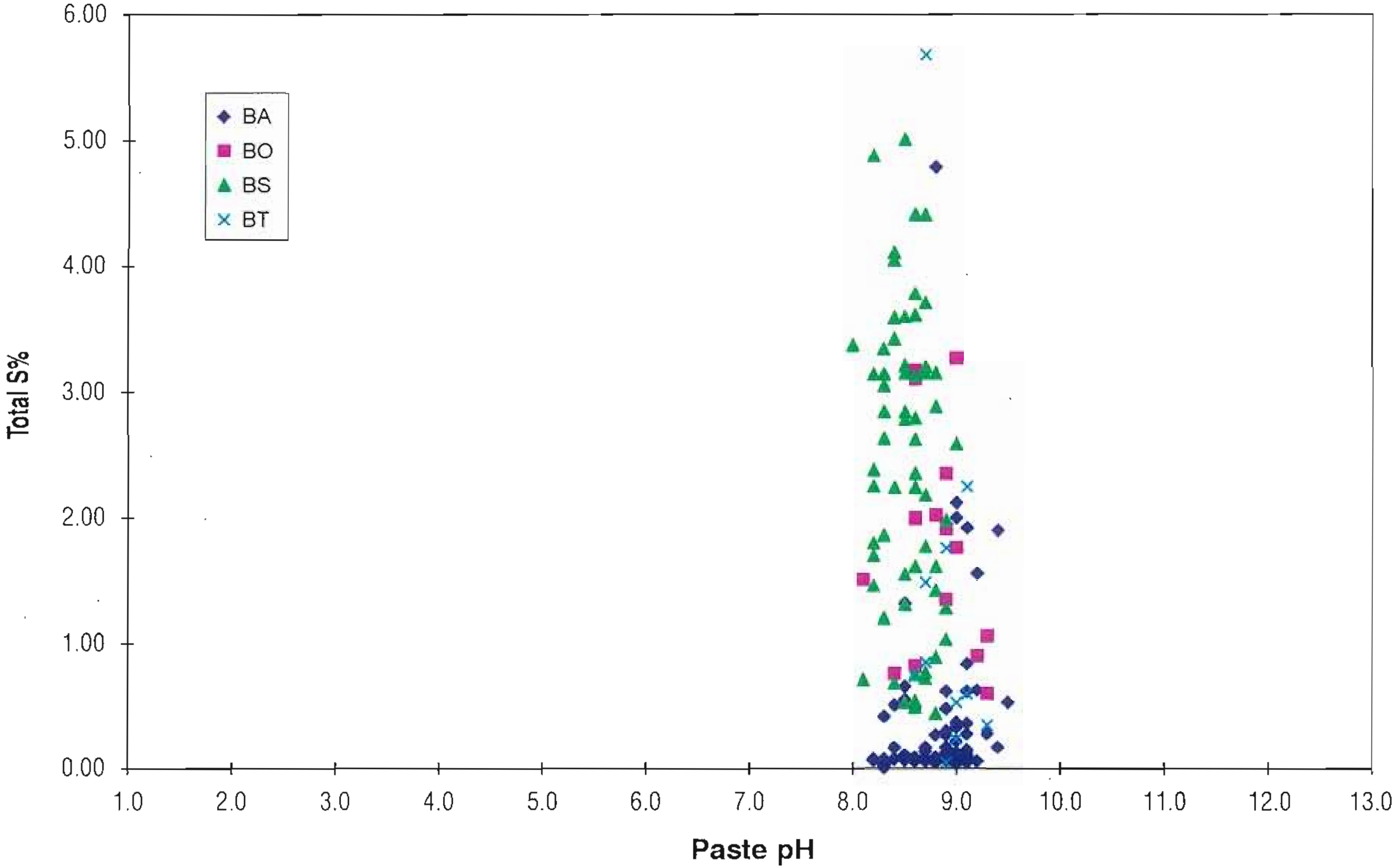


FIGURE 5.3-1

BHP

**Boston Percent S vs Paste pH**

Rescan

by the former BC Ministry of Energy Mines and Petroleum Resources ( now it is the BC Ministry of Employment and Investment) has established a more conservative NPR criterion of four for the upper bound of the uncertain range (Price & Errington 1995).

The results of the ABA tests at Boston indicate that there is a high amount of NP available to neutralize acid generation. This phenomenon is responsible for the low acid generating potential from most of the mass removed during the bulk sampling program. All NNP values are greater than +20 t of $CaCO_3$ per 1,000 t of rock with a median value of 267 t of $CaCO_3$ per 1,000 t of rock. However, 33 samples have NPR values in the uncertain range between 1.0 and 3.0. These samples have NP values less than the median value of 301 t $CaCO_3$/1,000 t and typically belong to the Basalt-Sediment Ore Horizon (Figure 5.3-2). An additional ten samples exhibited NPR values between three and four. Nine of these values are from the Basalt-Sediment Ore Horizon in the B2 drift. A spatial representation of the samples in the uncertain range are concentrated in the B2 ore drift (Figure 5.3-3). Two other samples are in the uncertain range are located in the B3 ore drift. No samples from the decline had NPR values less than three.

#### *5.3.3.2 Doris Lake Property*

The majority of samples contain less than 0.5% S as indicated in Figure 5.3-4. Lakeshore and Central quartz veins identified with high sulphide and tourmaline content (Q1 & Q4) and the strongly altered mafic volcanic unit (D2) contain elevated levels of sulfur up to 4.2% S. However, the results of the acid-base accounting (ABA) tests indicate that acidic conditions were not prevalent when the samples were obtained from the Doris Lake drill core. Paste pH varied from 9.8 to 7.4 independent of the total sulfur content, indicating that all the samples still contained adequate quantities of neutralizing minerals to maintain a basic pH range.

Figure 5.3-5 indicates that all samples have a paste pH ranging between 7.4 and 9.8 showing a slight decrease in paste pH in Quartz samples with low NP levels. All mafic volcanic samples have NP values greater than 28 t $CaCO_3$/1,000 t and are clustered within specific NP ranges based on the units identified from geological logs. The strongly altered volcanics have the greatest NP, gabbro NP values range from 322 to 31 t CaCO3/1,000 t, and Quartz NP values range from 108 to 1 t CaCO3/1,000 t.

Test results from Doris Lake indicate that samples with greater sulfur contents, and correspondingly high MPA values, have increased acid generating potential. Figure 5.3-6 indicates the range of materials that may be acid generating (NPR<1), non-acid generating (NPR>3), or uncertain (1<NPR<3). The majority of samples fall within the non-acid generating range including all gabbro samples and mafic volcanics with less than 1% visible pyrite. Three samples from the mafic volcanic unit, designated as having strong alteration with greater than 1 to 2% pyrite (Unit D2), exhibit NPR values in the uncertain range. However the NNP values for these samples range from 179 to 204 which is well above the NNP value of +20 t $CaCO_3$/1,000 t. Fourteen of the eighteen samples taken from the Q1, Q2, and Q4 quartz veins exhibit NPR values less than the 3.0 criterion designated by DIAND, indicating that a large percentage of each of these units are potentially acid generating.

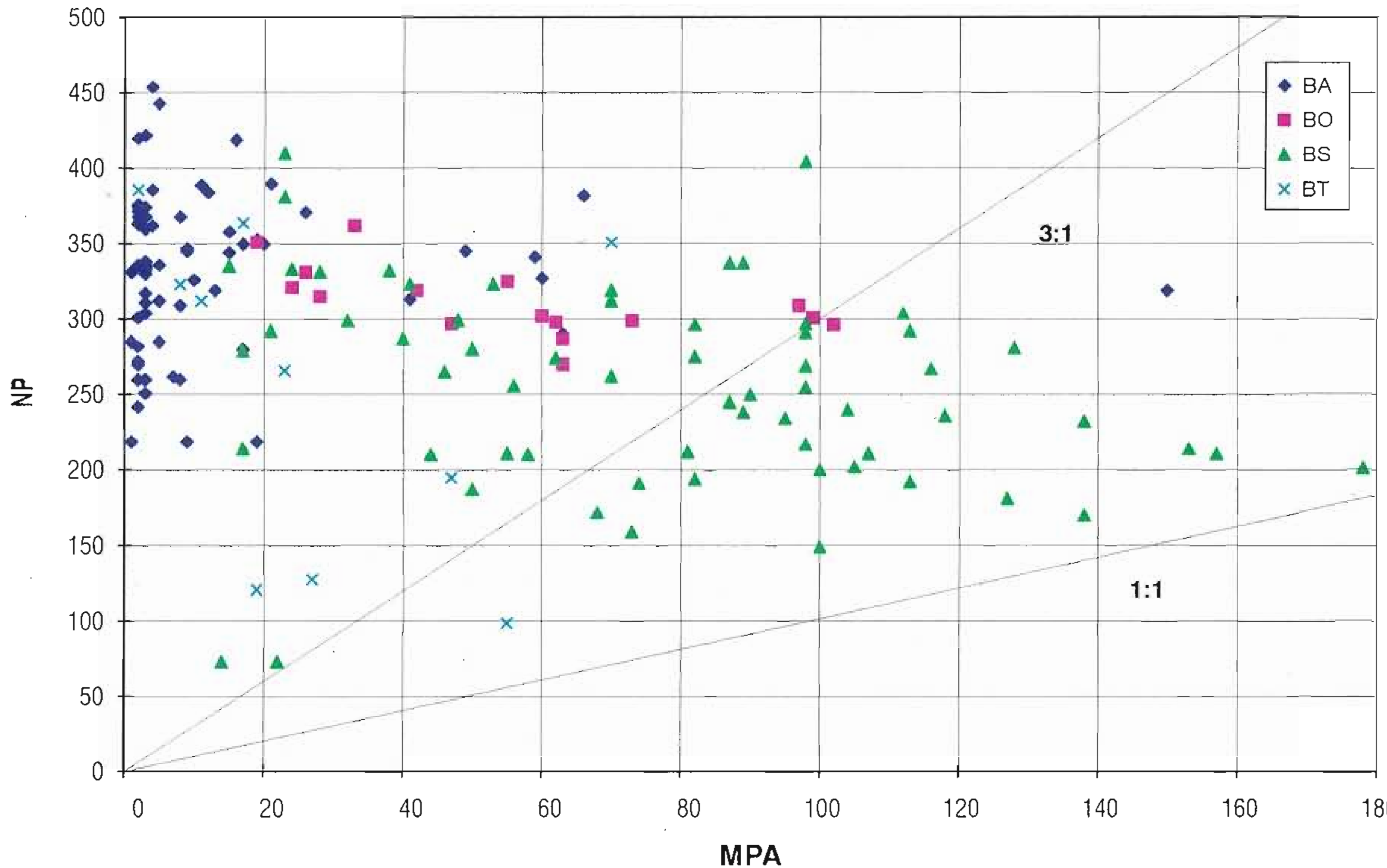


FIGURE 5.3-2

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**Boston NP vs MPA**

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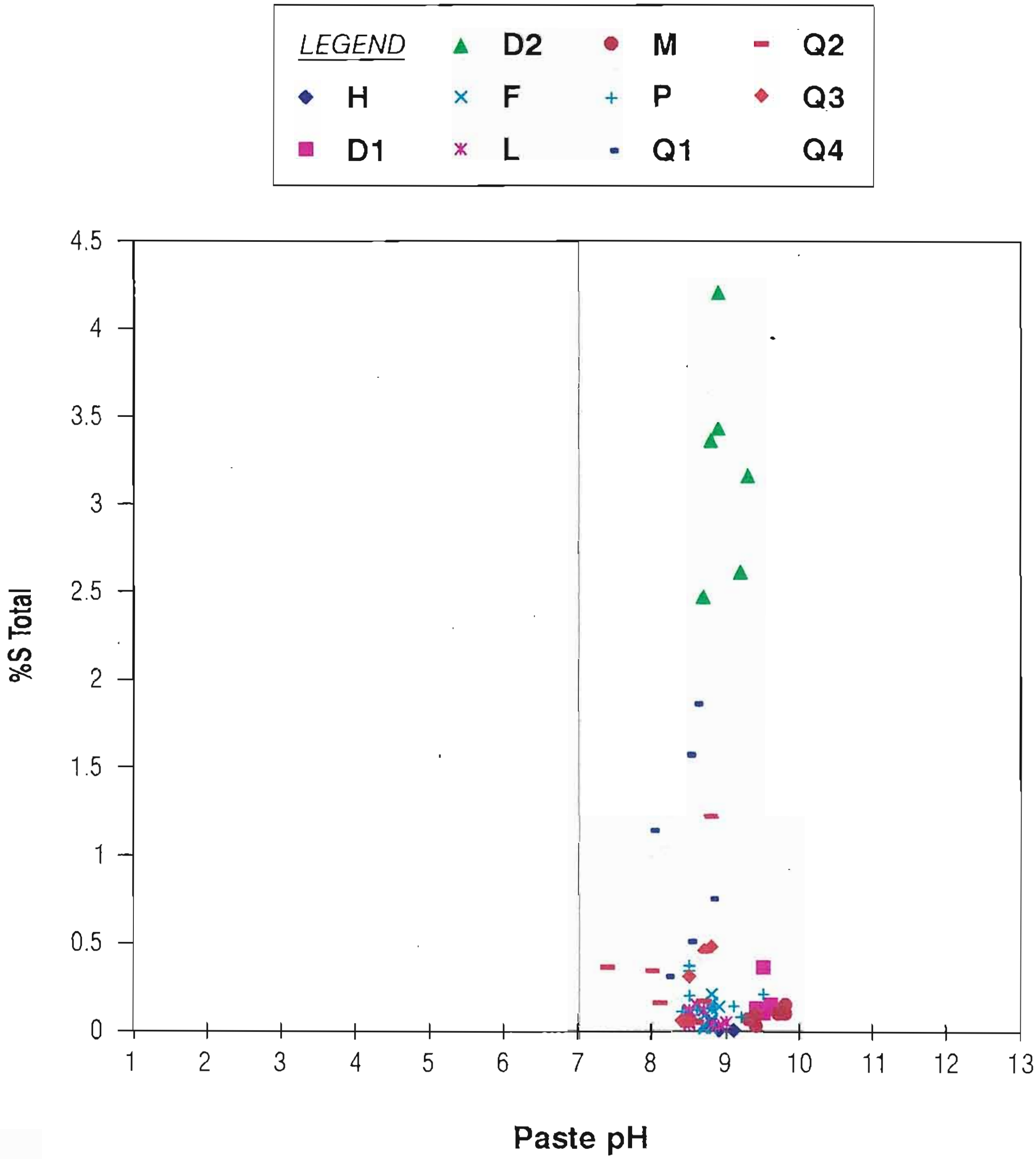
Boston Bulk Sample ARD Potential

Rescan

Fig 5.3-3




# Doris Lake Percent S vs Paste pH

FIGURE 5.3-4

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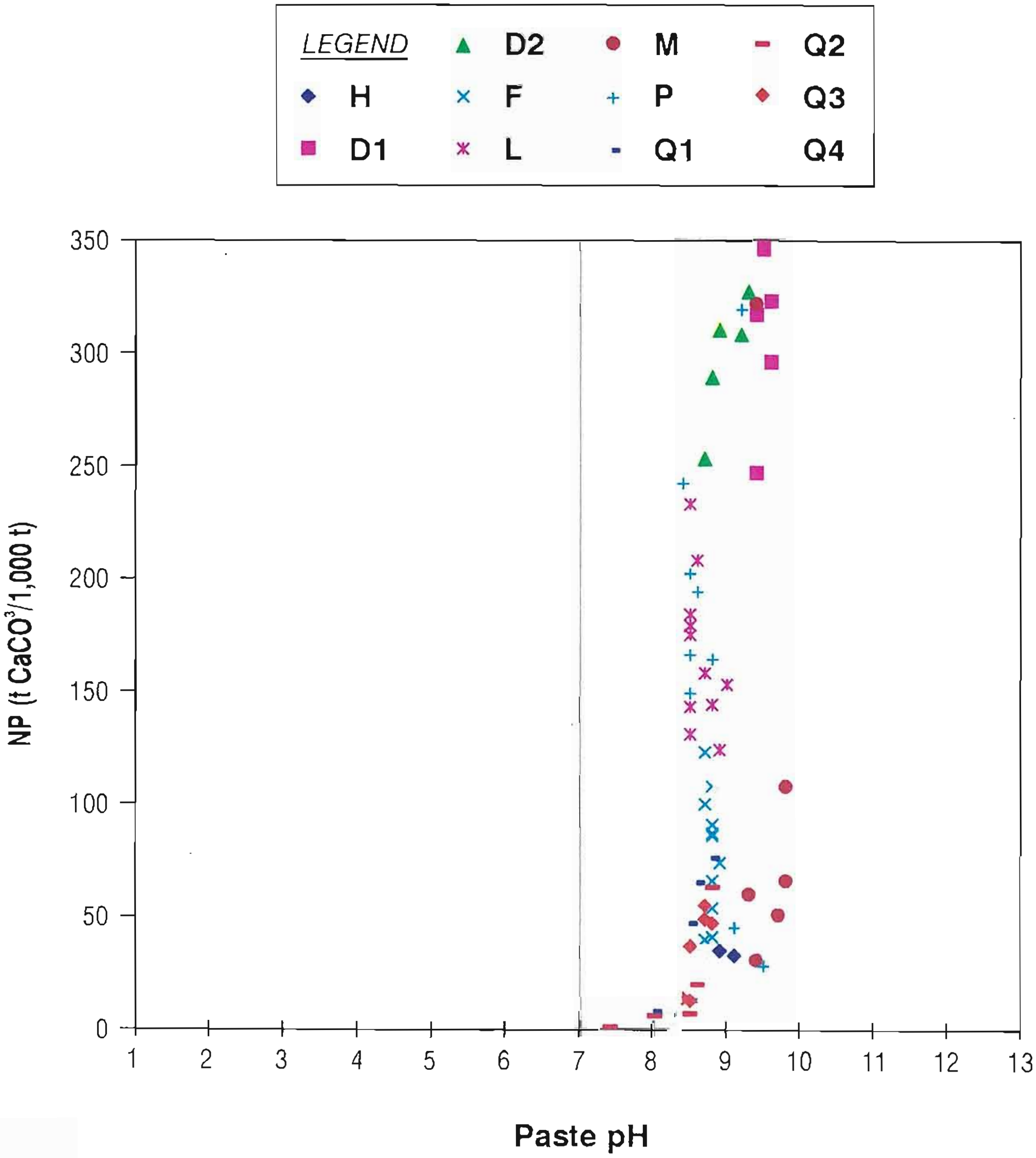


# Doris Lake NP vs Paste pH

FIGURE 5.3-5

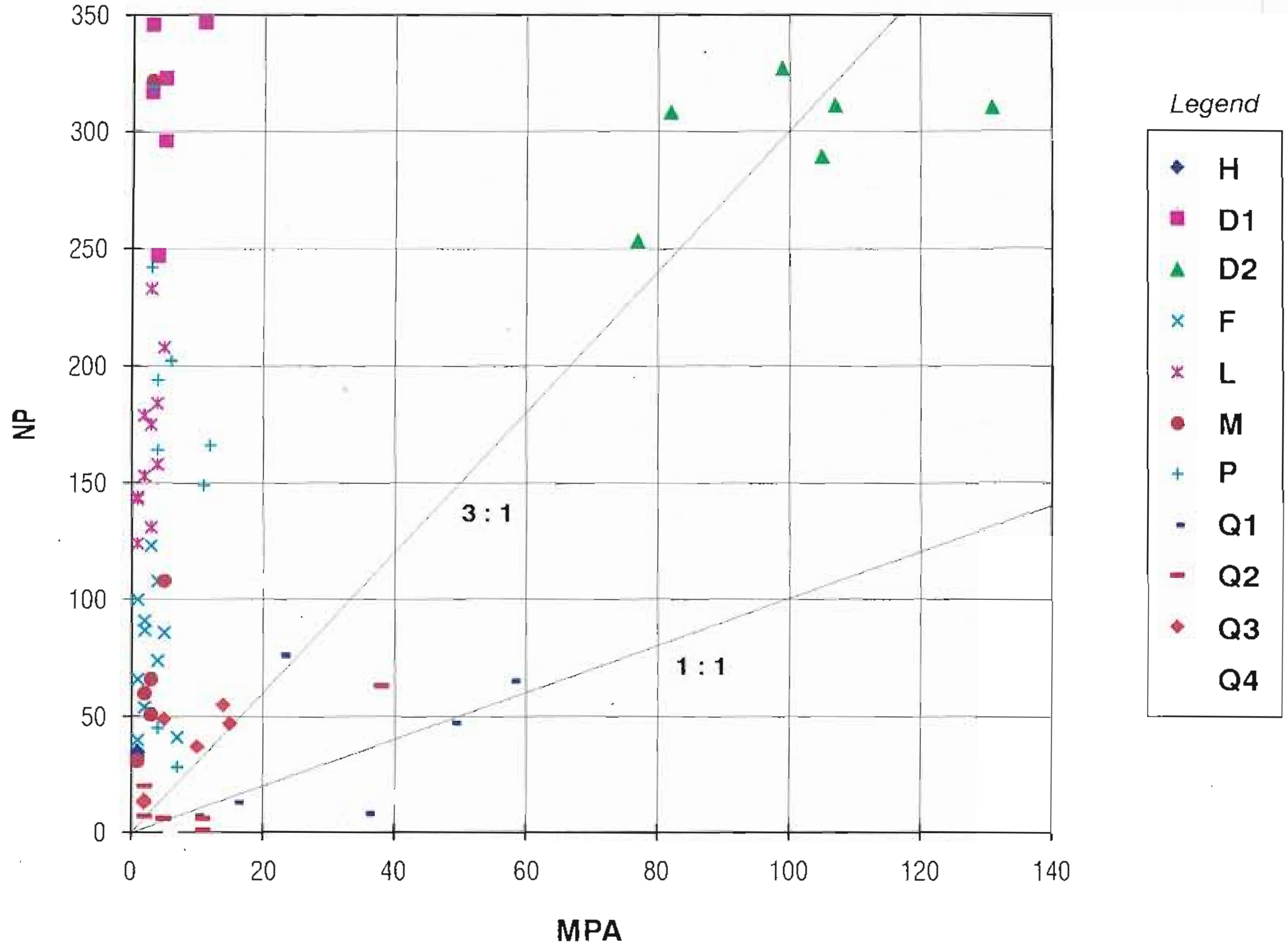


FIGURE 5.3-6

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# Doris Lake NP vs MPA

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# 6. Aquatic Life - Primary and Secondary Producers

# 6. AQUATIC LIFE - PRIMARY AND SECONDARY PRODUCERS

Primary and secondary producers in lakes and streams form the base of the aquatic food web. Changes in the abundance and biomass of these organisms are important in determining effects of development on higher trophic community dynamics. Lakes and streams on both the Boston and Doris Lake properties (Figure 1-2) were sampled for periphyton, phytoplankton, zooplankton, larval drift and benthic invertebrates (benthos). The results garnered in summer and fall sampling trips are presented and discussed below.

## 6.1 Boston Property

The Boston Property is located at the southern end of the Hope Bay Belt Project area, and is dominated by a large lake, Spyder Lake. All of the lakes and streams that were sampled for primary and secondary producers during the 1996 field season are presented in Figure 6.1-1.

### 6.1.1 Lakes

Stickleback and Trout lakes, and two stations on Spyder Lake were sampled for physical characteristics, primary producers, and secondary producers in both the summer and fall of 1996. The location of all sampling sites is presented in Figure 6.1-1. Lakes in the Boston Property area were sampled in summer and fall, allowing seasonal comparisons.

#### *6.1.1.1 Primary Producers (Phytoplankton)*

Primary producers are organisms capable of utilizing the sun's energy to make their own food through the process of photosynthesis. In aquatic environments, these organisms are referred to as phytoplankton in lakes and periphyton in streams.

Phytoplankton are single-celled, photosynthetic organisms that live free-floating within the water column. Because they photosynthesize and hence make their own food, they constitute the base of the food web in lake ecosystems. These organisms require light to photosynthesize, and must remain in the upper sun-lit part of the water column to do so.

Chlorophyll concentrations can be used a measure of primary producer biomass, as all photosynthetic organisms posses this pigment. Chlorophyll *a* is the form of chlorophyll most commonly found in primary producers, and it is the form of chlorophyll that is measured by the analytical method employed in this study.

*Methods*

Samples for phytoplankton species identification and chlorophyll *a* were taken from Spyder, Stickleback, and Trout lakes twice during the 1996 ice-free season (August 5 to 6, and August 24 to 25). Two sites in Spyder Lake were sampled, the deepest part of the lake (Station 6) and a station in close proximity to Boston camp (Station 5). All sampling locations are shown in Figure 6.1-1. Phytoplankton samples were collected in triplicate at 0.5 m depth in 250 mL bottles, preserved in Lugol’s solution and sent to Fraser Environmental Services (Vancouver) for species identification and enumeration. Water for chlorophyll *a* analysis was collected in one litre bottles (0.5 m depth) and filtered onto 0.45 µm filters back at camp. Samples were wrapped in aluminum foil (to prevent photo-degradation) and frozen. Frozen samples were sent to the University of British Columbia where chlorophyll *a* was determined by the spectrophotometer method of Parsons *et al.* (1984).

For purposes of site comparisons, characteristics for the four sites sampled were determined using the COMM program (Piepenburg and Piatkowski 1993; Appendix 6-1). Triplicate sample results from each site were averaged and used in the statistical calculations to the level of genus. The characteristics obtained included density, richness (number of taxa per site), number of taxa contributing to 90% of the density (S(90%)), maximum dominance (by one taxon), and the Shannon Diversity Index (H'). Diversity is a measure of both the number of taxa present and the uniformity with which the taxa are distributed.

*Results and Discussion*

Phytoplankton taxa identified for all four lake sites are given in Appendix 6-2. Table 6.1-1 presents the percent taxa composition (to phylum/subphylum), average

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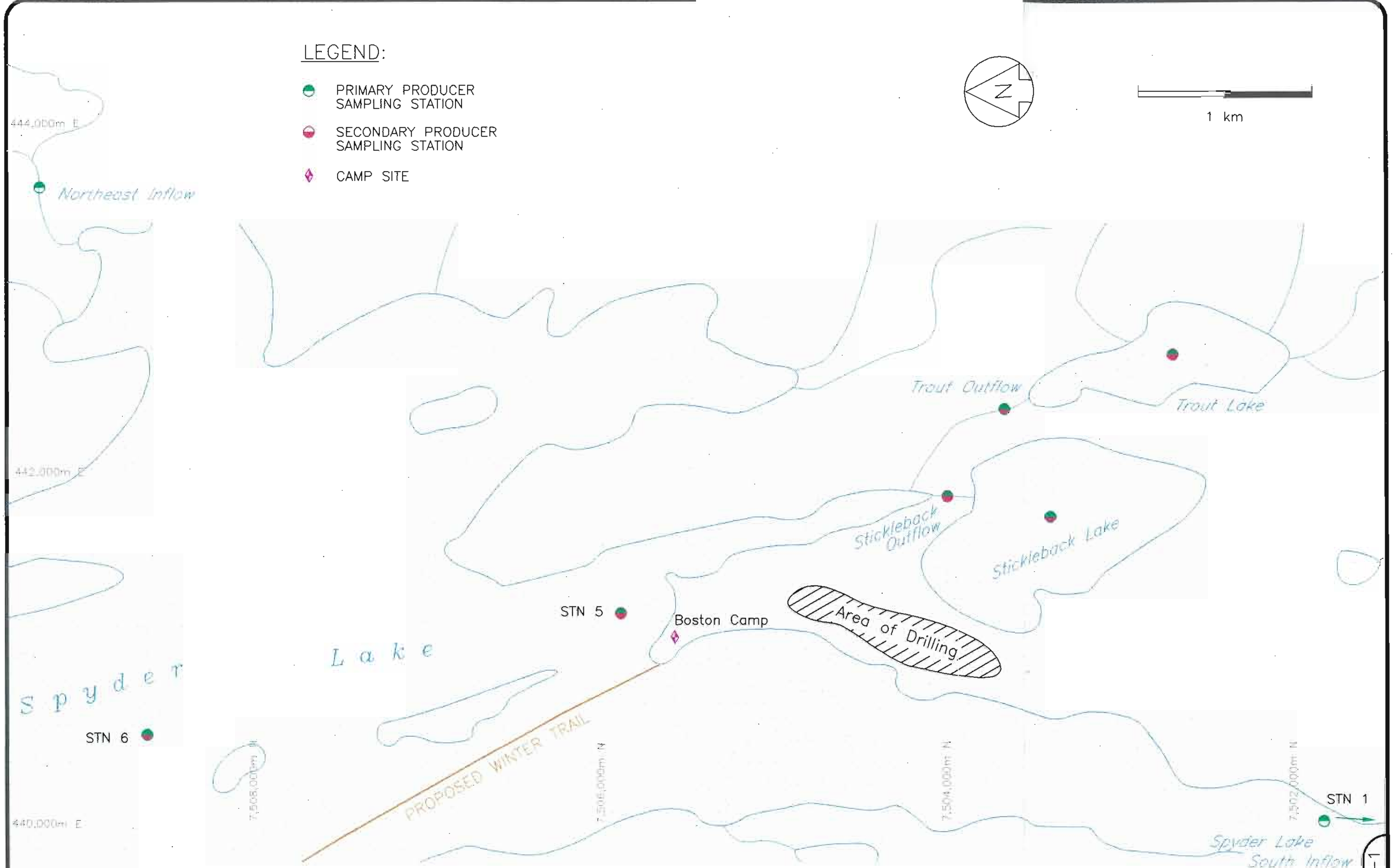


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Aquatic Biology Sampling Stations
Boston Property, 1996

Rescan

Fig 6.1-1

**Table 6.1-1**
**Phytoplankton Taxa Composition, Abundance, and Biomass for Boston Property Lakes, August 1996**

| | % Composition | | | |
|---|---|---|---|---|
| **Phylum/Subphylum** | **Spyder, Stn. 5 August 4, 1996** | **Spyder, Stn. 6 August 4, 1996** | **Stickleback August 5, 1996** | **Trout August 5, 1996** |
| Bacillariophyceae | 3 | 2 | 4 | 2 |
| Chlorophyta | 37 | 38 | 13 | 13 |
| Chrysophyta | 2 | 2 | 2 | 12 |
| Cyanophyta | 47 | 52 | 77 | 72 |
| Pyrrophyta | 11 | 6 | 4 | 1 |
| Ave. Cell Density (cells/mL): | 1,678 | 2,059 | 7,962 | 3,900 |
| Ave. Biomass (µg Chl *a*/L): | 2.29 | 1.21 | 1.79 | 4.46 |
| **Phylum/Subphylum** | **Spyder, Stn. 5 August 24, 1996** | **Spyder, Stn. 6 August 24, 1996** | **Stickleback August 25, 1996** | **Trout August 25, 1996** |
| Bacillariophyceae | 16 | 14 | 26 | 5 |
| Chlorophyta | 43 | 51 | 27 | 16 |
| Chrysophyta | 1 | 1 | 5 | 0 |
| Cyanophyta | 36 | 32 | 28 | 77 |
| Pyrrophyta | 4 | 2 | 14 | 2 |
| Ave. Cell Density (cells/mL): | 2,660 | 3,471 | 1,386 | 1,447 |

cell density, and average biomass as chlorophyll *a* for all lake sites during both sampling periods. Chlorophyll *a* samples were only available from the first sampling period (August 4, 5). During this sampling period, the phytoplankton assemblages in Stickleback and Trout lakes were dominated by cyanobacteria (Cyanophyta), with the phytoplankton assemblage consisting of 77 and 72% cyanobacteria by abundance, respectively (Table 6.1-1, Figure 6.1-2a). Spyder Lake phytoplankton consisted of both green algae (Chlorophyta) and cyanobacteria, with 37 to 38% and 47 to 52% of the abundance being attributable to each taxon (Figure 6.1-2a).

During the second sampling period (August 24, 25), the phytoplankton assemblage in Trout Lake was still dominated by cyanobacteria (77%; Figure 6.1-2b). The assemblage of Stickleback Lake, however, consisted of nearly equal proportions of diatoms (Bacillariophyceae), green algae, and cyanobacteria (~27% each; Figure 6.1-2b). Spyder Lake phytoplankton still consisted of cyanobacteria and green algae, but diatoms accounted for ~15% of the total abundance, compared to only 2% during the first sampling period. In general, diatoms constituted a larger portion of the phytoplankton abundance during the second sampling period (August 24, 25) compared to the first sampling period (August 4, 5).

During the first sampling period, Stickleback Lake had the greatest total abundance of phytoplankton (Table 6.1-1). However, the lake was dominated by small cyanobacteria, which may not contribute significantly to available primary producer biomass for higher trophic levels. Trout Lake had the greatest chlorophyll *a* concentration of the four lake sites sampled. All lake sites would be considered oligo- to mesotrophic based on the measured phytoplankton biomass and nutrient levels in August of 1996 (Wetzel 1983).

Table 6.1-2 presents the results from the COMM program analysis. During the first sampling period, Spyder Lake stations exhibited the greatest diversity in their phytoplankton assemblages, having only 26% of the composition being dominated by a single genus. Stickleback and Trout lakes showed less diversity, having 70 and 61% of their phytoplankton composition being dominated by a single genus. The Diversity Indices were 2.26 to 2.34 for the Spyder Lake sites, compared to 1.37 and 1.54 for Stickleback and Trout lakes, respectively (Table 6.1-2).

During the second sampling period, diversity remained fairly constant for the Spyder Lake sites, with Diversity Indices of 2.53 and 2.22 for stations 5 and 6, respectively (Table 6.1-2). However, phytoplankton diversity increased in Stickleback Lake from a value of 1.37 to 2.51. Only 21% instead of 70% of the phytoplankton abundance was accounted for by a single genus. Trout Lake phytoplankton diversity remained fairly uniform between the two sampling periods. Overall, Diversity Indices ranged from 1.36 to 2.53 for all sites during both sampling periods.

The predominant genus at all lake sites during the first sampling period belonged to the phylum Cyanophyta. During the late August sampling, the dominant genus in Spyder Lake changed from cyanobacteria to green algae. Both stations sampled in Spyder Lake were dominated by the same genus during both sampling periods. The predominant genera at Stickleback and Trout lakes remained the same for the two sampling periods (Table 6.1-2).

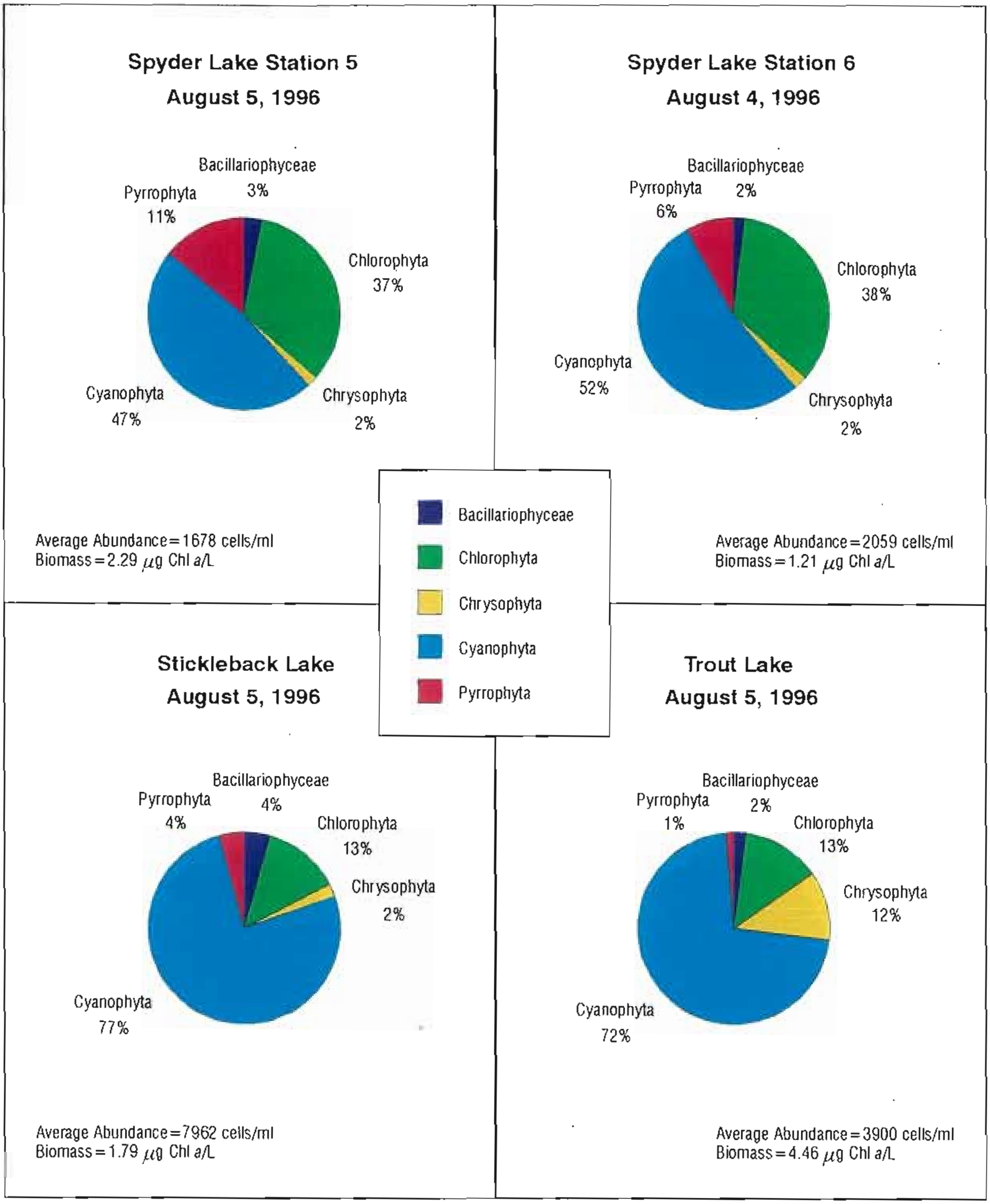


FIGURE 6.1-2a

**Phytoplankton Taxa Composition for Boston Property Lakes August 4-5, 1996**

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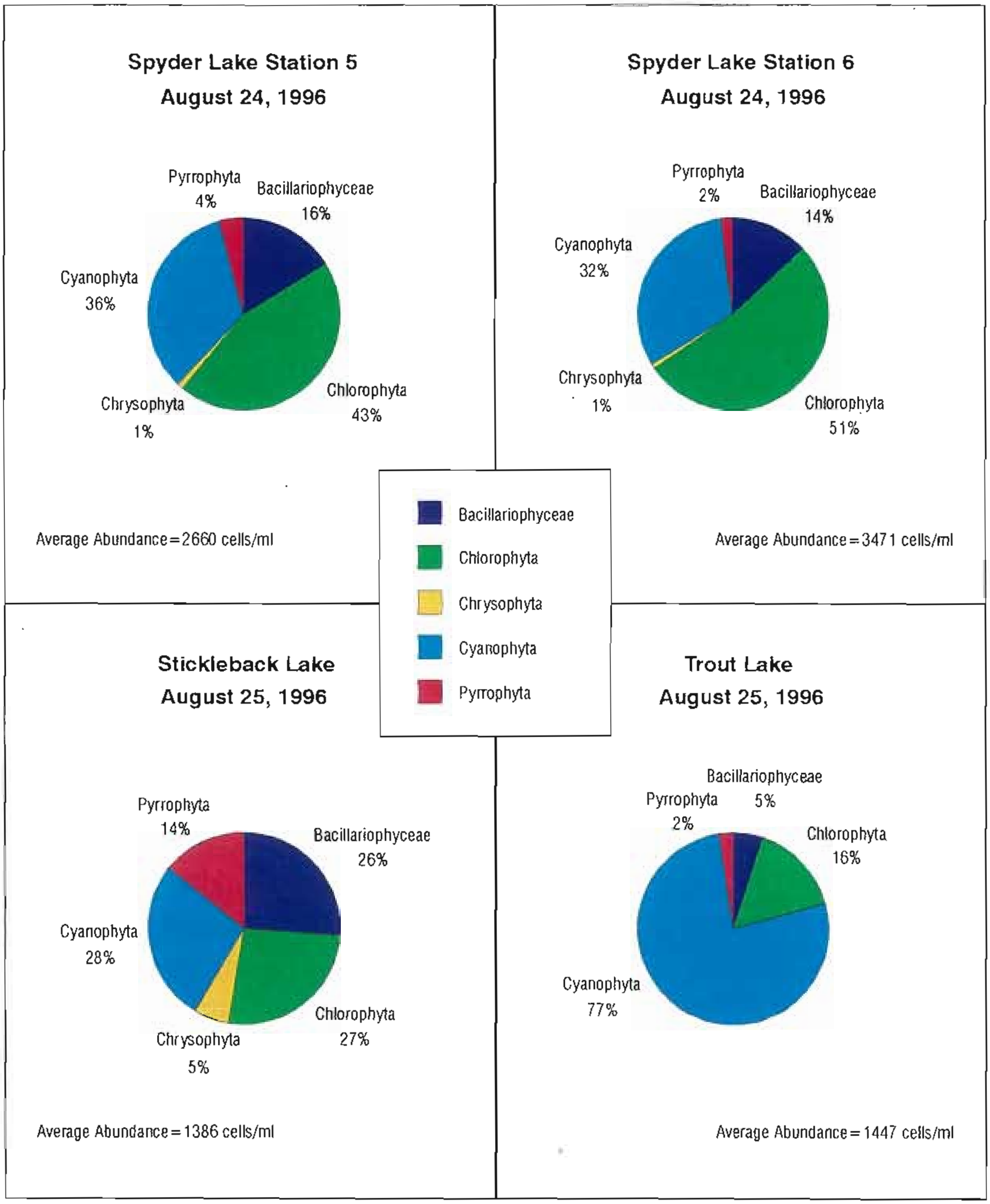


**Phytoplankton Taxa Composition for Boston Property Lakes August 24-25, 1996**

FIGURE 6.1-2b

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## Table 6.1-2
## Site Characteristics of Phytoplankton Assemblages in Boston Property Lakes, August 1996

| Lake | Sample Size | Density (cells/L) | Richness (S) | S(90%) | Max. Dom. (%) | Max. Dom. Genus (numerically) | Diversity (H') |
|---|---|---|---|---|---|---|---|
| Spyder, Stn. 5 August 4, 1996 | n = 3 | $1.69 \times 10^6$ | 28 | 11 | 26.3 | *Gomphosphaeria* | 2.34 |
| Spyder, Stn. 6 August 4, 1996 | n = 3 | $2.06 \times 10^6$ | 22 | 9 | 25.5 | *Gomphosphaeria* | 2.26 |
| Stickleback Lake August 5, 1996 | n = 3 | $7.96 \times 10^6$ | 20 | 8 | 70.2 | *Anacystis* | 1.37 |
| Trout Lake August 5, 1996 | n = 3 | $3.90 \times 10^6$ | 27 | 6 | 60.8 | *Anabaena* | 1.54 |
| Spyder, Stn. 5 August 24, 1996 | n = 3 | $2.66 \times 10^6$ | 29 | 14 | 23.5 | *Crucigenia* | 2.53 |
| Spyder, Stn. 6 August 24, 1996 | n = 3 | $3.47 \times 10^6$ | 25 | 10 | 34.6 | *Crucigenia* | 2.22 |
| Stickleback Lake August 25, 1996 | n = 3 | $1.39 \times 10^6$ | 23 | 11 | 20.8 | *Anacystis* | 2.51 |
| Trout Lake August 25, 1996 | n = 3 | $1.45 \times 10^6$ | 22 | 5 | 66.9 | *Anabaena* | 1.36 |

**S = the number of genera per site.**
**S(90%) = the number of genera contributing to 90% of the density.**
**Max. Dom. = the maximum dominance accounted for by a single genus.**
**H' = Shannon Diversity Index.**

In previous years (1993 to 1995), cyanobacteria have been a major component of the phytoplankton assemblages. In early August of 1995 (August 1 to 3), Spyder Lake consisted of 56% cyanobacteria with a total cell density of 1,570 cells/mL (Rescan 1995). This was very similar to what was found during the August 4 to 5 sampling in 1996 (50% cyanobacteria, 1,869 cells/mL). In early August of 1996, both Trout and Stickleback lakes were dominated by cyanobacteria, while in early August of 1995, Trout but not Stickleback Lake was dominated by cyanobacteria, with Stickleback Lake being dominated by green algae. In 1996 the composition of the phytoplankton assemblage in Stickleback Lake changed from being dominated by cyanobacteria in early August to being dominated by green algae in late August.

In general, cyanobacteria are a strong component of the phytoplankton assemblages of all of the lakes in early summer, with shifts towards green algae and diatoms likely occurring later in the season. This reflects the low amount of nitrogen available in these lakes (Appendix 5-1), which favors the growth of nitrogen-fixing organisms. Later in the season, nitrogen in the form of ammonium is available to primary producers (via excretion and decomposition processes), allowing other non-nitrogen-fixing organisms to become more abundant.

#### *6.1.1.2 Secondary Producers*

Two invertebrate groups, zooplankton and benthos, are the most important secondary producers in lakes. These groups are vital food sources for all juvenile and many adult fish, and decreases in the densities or changes in the taxonomic composition of these communities are potentially damaging to fish communities. Changes in the invertebrate communities can also indicate disturbances in water quality and bottom sediments.

*Zooplankton*

The zooplankton community consists of very small invertebrate animals inhabiting the pelagic, or open-water, region in lakes. The taxonomic diversity and biomass are important indicators of changes in water quality, and zooplankton are also a major food source for fish.

- *Methods*

  A 118 µm-mesh net with a 0.3 m diameter net mouth was pulled vertically through the water column to obtain three replicate samples of the water column. Samples collected were transferred from the collection vessel to 500 mL jars and preserved in a 10% formalin solution. Identification and enumeration of zooplankton samples were conducted by Applied Technical Services (Saanichton, BC). Methods of analyses are the same as those conducted in 1995 (Rescan 1995). Genera richness and diversity were calculated using the COMM program (Piepenburg and Piatkowski 1993; Appendix 6-1).

  Samples were taken from three locations: Stickleback Lake and Stations 5 and 6 in Spyder Lake (Figure 6.1-1).

- *Results and Discussion*

Zooplankton data are presented in Appendix 6-3 and a list of the organisms that were found is given in Table 6.1-3.

## Table 6.1-3
## Zooplankton Identified from Boston Property Lakes, 1996[1]

| | | Spyder Lake Stn. 5 | | Spyder Lake Stn. 6 | | Stickleback Lake | | Trout Lake | |
|---|---|---|---|---|---|---|---|---|---|
| **Group/Genus** | **Stage[2]** | **Aug. 4** | **Aug. 24** | **Aug. 6** | **Aug. 24** | **Aug. 4** | **Aug. 25** | **Aug. 5** | **Aug. 25** |
| ROTIFERA | | | | | | | | | |
| *Kellicottia longispina* | | + | + | | + | + | | + | + |
| *Keratella cochlearis* | | | | | | + | | | + |
| *Polyarthra* | | + | | | | | | + | |
| *Filinia* | | | | | | + | | | + |
| *Asplanchna* | | | | | | + | | + | + |
| *Lepadella* | | | | | | | | + | |
| *Brachionus* | | | | | | | + | | |
| Trichotriidae | | | | | | | | | + |
| Unidentified | | | | + | + | + | | | + |
| CLADOCERA | | | | | | | | | |
| *Holopedium gibberum* | | + | + | + | + | + | | + | |
| *Daphnia middendorffiana* | | | | + | + | | | | |
| *Daphnia longiremis* | | + | + | + | + | + | | + | + |
| *Bosmina longirostris* | | + | + | + | + | + | | + | + |
| *Chydorus sphaericus* | | + | + | | + | + | + | + | + |
| *Alona guttata* | | | | | | | + | | |
| *Alona rectangulata* | | | | | | | | | + |
| *Alona rustica* | | | | | | | | + | |
| *Alonella* sp. | juv | | | | | | | | + |
| COPEPODA | | | | | | | | | |
| Calanoida | | | | | | | | | |
| *Diaptomus pribilofensis* | M | | + | + | | | | | |
| | F | | + | + | + | | | | |
| *Diaptomus ashlandi* | M | | + | + | + | | | | |
| | F | | + | + | + | | | | |
| *Diaptomus spp.* | cop. V | | + | + | + | + | | | |
| | IV | | | + | | | | | |
| | III | | | | | + | | | |
| | II | | | | | | | + | |
| | I | | | | | | | + | |

**(continued)**

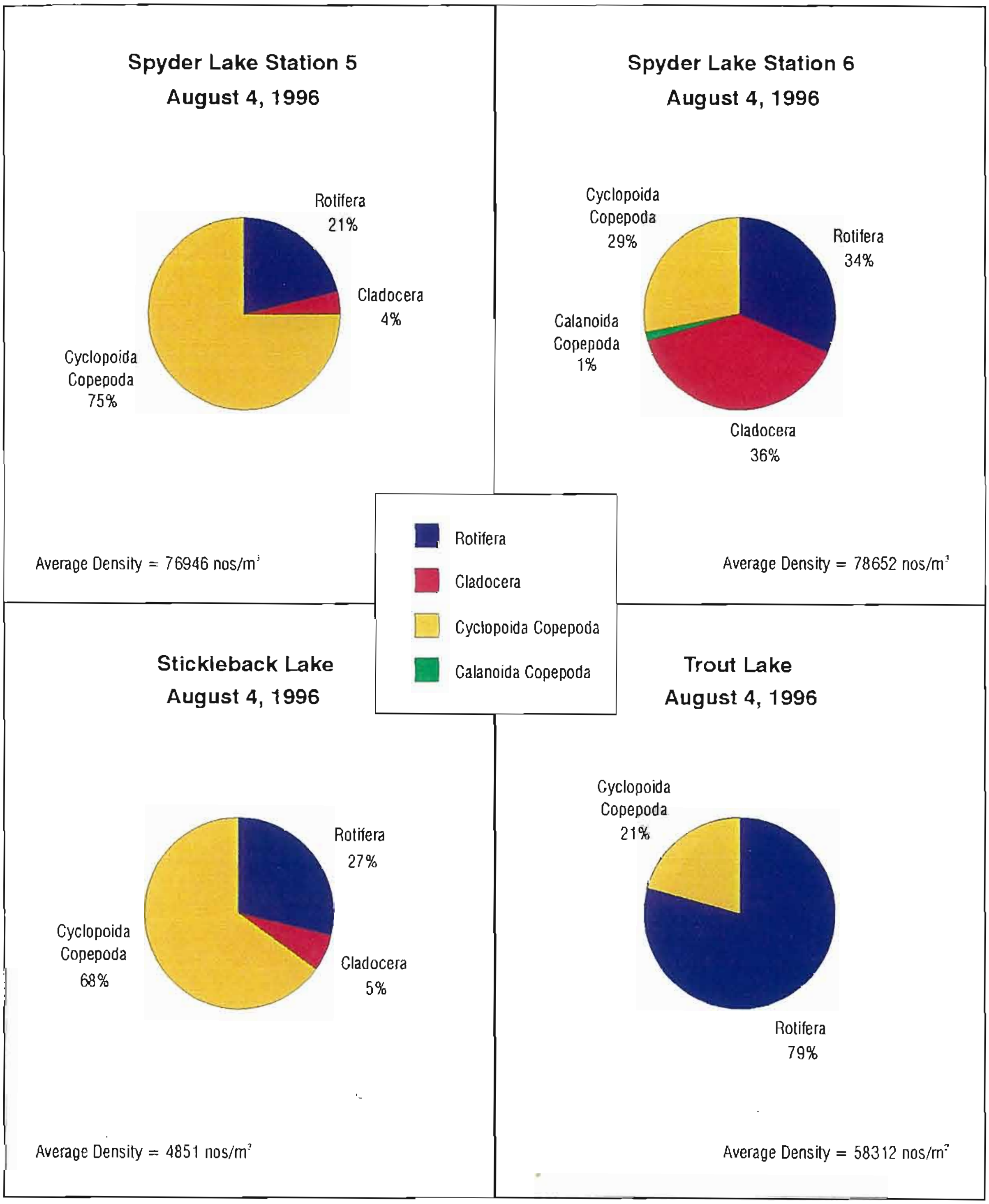
## Table 6.1-3 (completed)
## Zooplankton Identified from Boston Property Lakes, 1996[1]

| Group/Genus | Stage[2] | Spyder Lake Stn. 5 Aug. 4 | Spyder Lake Stn. 5 Aug. 24 | Spyder Lake Stn. 6 Aug. 6 | Spyder Lake Stn. 6 Aug. 24 | Stickleback Lake Aug. 4 | Stickleback Lake Aug. 25 | Trout Lake Aug. 5 | Trout Lake Aug. 25 |
|---|---|---|---|---|---|---|---|---|---|
| *Limnocalanus macrurus* | M | + | + | + | + | | | | |
| | F | | + | + | + | | | | |
| | cop. V | | | | + | | | | |
| *Epischura lacustris* | M | | + | + | + | | | | + |
| | F | | + | + | + | | | | |
| | V | | | + | | | | | + |
| | IV | | | | | | | | + |
| | I | | | | + | | | | |
| Calanoid | nauplius | | | + | | | | + | + |
| Cyclopoida | | | | | | | | | |
| *Cyclops b. thomasi* | F | | | | + | | | | |
| *Cyclops scutifer* | M | + | + | + | + | | + | | |
| | F | + | + | + | + | + | + | + | |
| *Cyclops capillatus* | M | | | | | | | + | |
| *Cyclops* sp. | M | | | | | | | | + |
| Cyclopoida | cop. | + | + | + | + | + | + | + | + |
| Lichomolgidae (parasitic) | cop. | | | | | | + | | |
| | nauplius | + | + | + | + | + | + | + | + |

**1: + sign indicates taxa as present at sampling site.**
**2: M = male, F = female, cop. = copepodite, roman numerals refer to copepodite stages.**

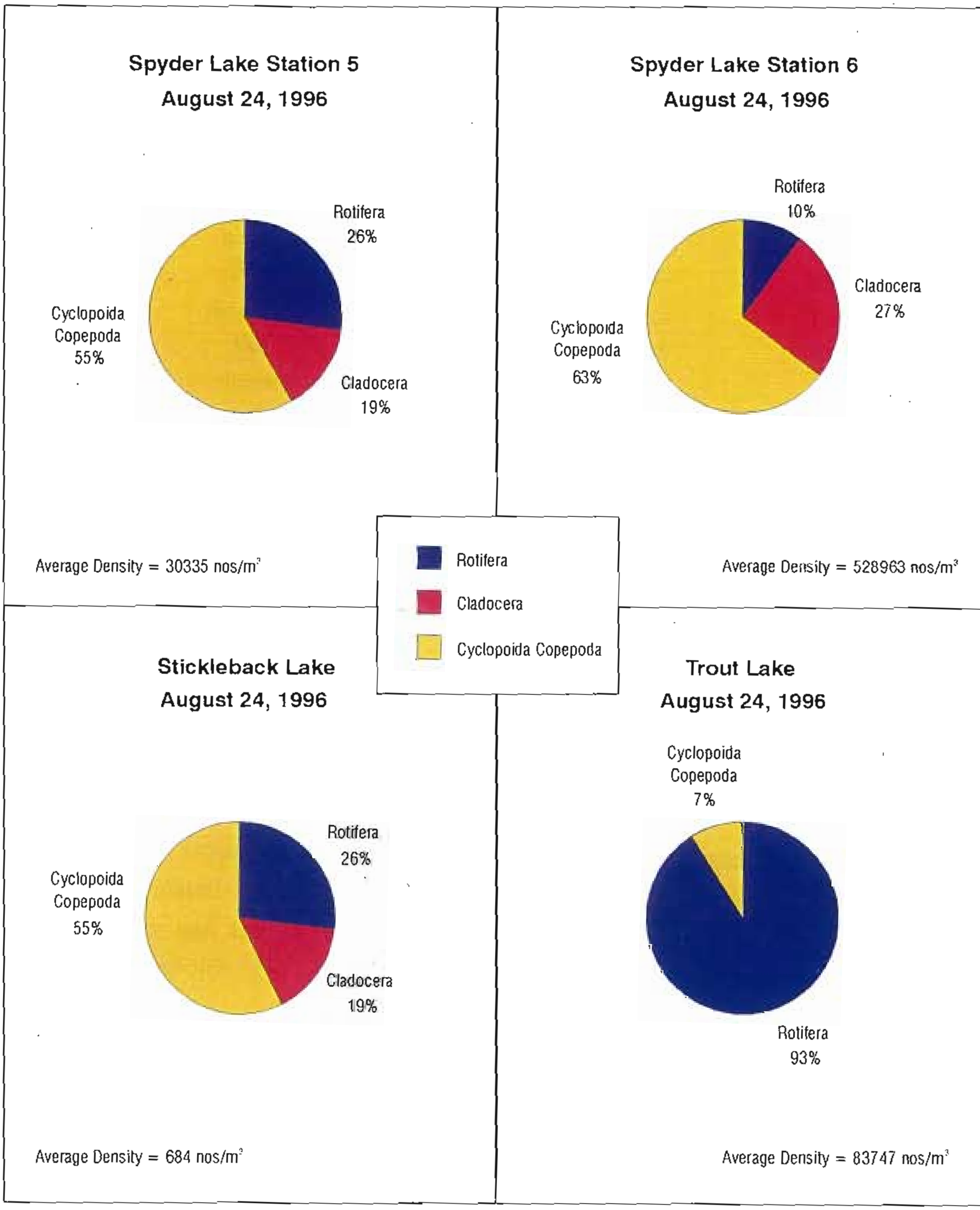
Summer densities (Figure 6.1-3) ranged from 4,851 individuals/$m^3$ in Stickleback Lake to 78,652 individuals/$m^3$ at Station 6 in Spyder Lake. Samples taken at Station 5 in Spyder Lake had similar densities to Station 5 (76,946 and 78,652 individuals/$m^3$, respectively). Trout Lake samples had an average summer density of 58,312 individuals/$m^3$, which increased to 83,747 individuals/$m^3$ in the fall (Figure 6.1-4). Station 6 had a greater zooplankton density than Station 5 in the fall (52,896 and 30,335 individuals/$m^3$, respectively), but both stations exhibited a decrease in density as compared to summer. The summer densities of zooplankton were greater than fall densities for all stations, with the exception of Trout Lake.

Nineteen genera were identified from lakes sampled on the Boston Property. Trout Lake had the highest richness in genera for both seasons (S=12; Table 6.1-4). Fall samples taken from Stickleback Lake had the fewest




# Taxonomic Composition and Abundance of Zooplankton Samples, Boston Property, August 4, 1996

FIGURE 6.1-3




**Taxonomic Composition and Abundance of Zooplankton Samples, Boston Property, August 24, 1996**

FIGURE 6.1-4

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**Table 6.1-4**
**Site Characteristics of Zooplankton Communities**
**for Boston Property Lakes, 1996**

| Sampling Site | Season | Richness | S(90%) | Max. Dom. | Shannon Diversity Index (H') |
|---|---|---|---|---|---|
| Spyder Lake - Stn. 5 | Summer | 9 | 4 | 60.9 | 1.02 |
| Shallow | Fall | 10 | 3 | 47.8 | 1.15 |
| Spyder Lake - Stn. 6 | Summer | 8 | 4 | 39.4 | 1.33 |
| Deep | Fall | 9 | 3 | 61.4 | 0.92 |
| Stickleback Lake | Summer | 11 | 4 | 62.0 | 1.19 |
| | Fall | 5 | 2 | 60.6 | 0.97 |
| Trout Lake | Summer | 12 | 2 | 78.3 | 0.58 |
| | Fall | 12 | 2 | 60.8 | 0.98 |

genera (S=5), which was less than half the number present in summer samples. The Spyder Lake stations were similar in genera present in both summer and fall sampling periods. Station 5 contained one more genus (S=9) than Station 6 (S=8) in the summer and both stations in Spyder Lake had more genera in summer samples than in the fall samples (S=10 and 9, respectively).

All samples, with the exception of summer samples from Station 6 in Spyder Lake and all Trout Lake samples, were dominated by cyclopoid copepods (Figures 6.1-3 and 6.1-4). Rotifers and cladocerans were the second or third most abundant organisms in the samples. Spyder Lake summer samples were equally dominated by all three groups (Rotifera, Cladocera and Copepoda). Both summer and fall Trout Lake samples were dominated by rotifers, and included cyclopoids. No calanoid copepods were present in any samples.

Comparison of 1996 zooplankton results with previous years has shown that taxonomic composition has varied from year to year. However, sampling time alone could account for differences in zooplankton composition. In 1993 Spyder Lake samples, taxa composition was almost entirely Rotifera (>90%). However, in 1995, Spyder Lake was dominated by Cycolpoida Copepoda (>80%; Rescan 1995). The taxa composition in Trout Lake in 1995 was dominated by Calanoida Copepoda, which were not present at all in 1996. Stickleback Lake was co-dominated by Rotifera and Cyclopoida. Annual variations in zooplankton composition could be the result of variations in their food source, predation, or purely physical factors (*e.g.*, water temperature).

According to the Shannon Diversity indices (Table 6.1-4), the summer sample taken at Station 6 was the most diverse overall, however the fall samples from the station were the least diverse overall. In the summer the order of diversity was:

Spyder Station 6 > Stickleback Lake > Spyder Station 5 > Trout Lake.

In the fall the order of diversity was:

Spyder Station 5 > Stickleback Lake = Trout Lake > Spyder Station 6.

*Lake Benthos*

Benthic invertebrates (benthos) inhabiting soft bottom substrates are the other main contributors to secondary production in lakes. Benthos, especially those inhabiting the littoral sediments of lakes, are an important food source for fish.

- *Methods*

Benthic invertebrate sampling locations in Spyder and Stickleback lakes are shown in Figure 6.1-1. An Ekman grab (0.0232 $m^2$) was used to collect replicate samples of soft-bottom sediments at two or three lake depths, depending on maximum lake depth (Plate 6-1). Samples were then screened through a 493 µm sieve and invertebrates were preserved in a 10% formalin solution. Identification and enumeration were performed by Biologica (Victoria, BC), and methods of analyses were the same as those used in past years (Rescan 1995). Organisms in certain groups were not identified to the genus or species level and therefore only the dipteran community was used to calculate diversity indices. Genera richness and diversity were calculated using the COMM program (Piepenburg and Piatkowski 1993; Appendix 6-1).

- *Results and Discussion*

Ekman grab data are presented in Appendix 6-4 and a list of the taxa found to be present is given in Table 6.1-5. Zooplankton captured incidentally during retrieval of the sampler were not included in the sample analysis.

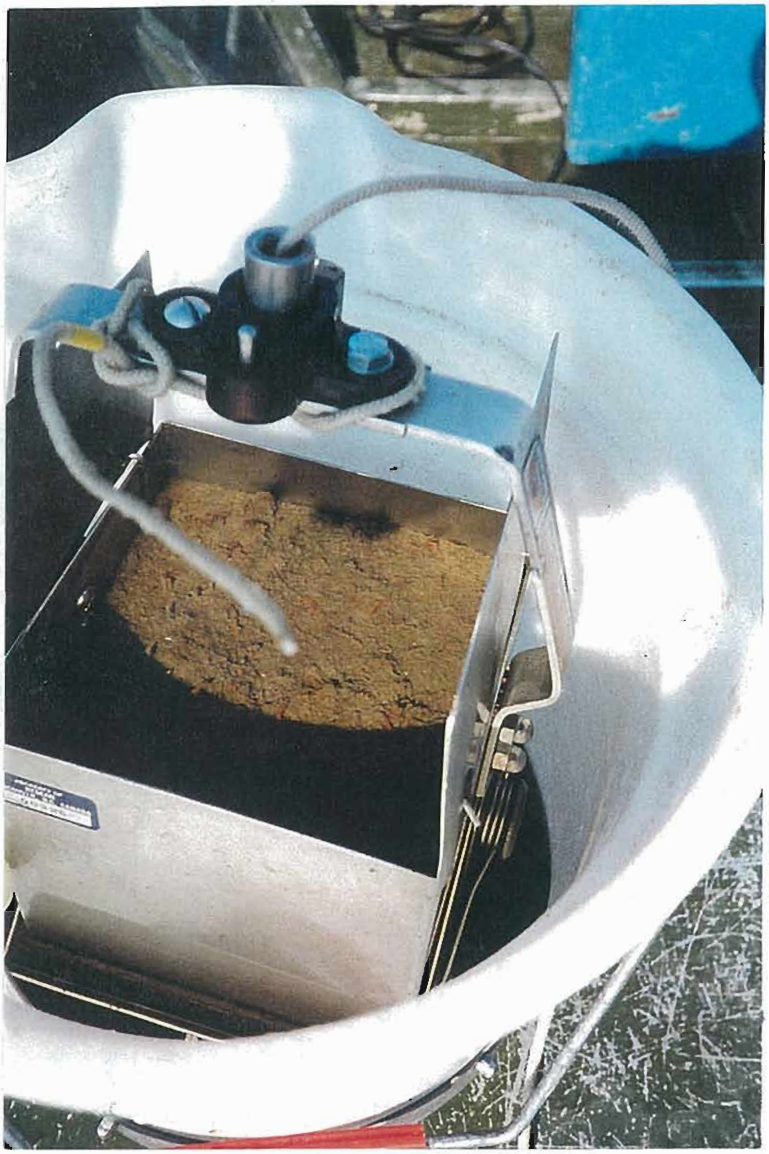


Plate 6-1: Successful sediment grab using an Ekman Sampler. Sampler was immediately placed inside a sieve bucket.

## Table 6.1-5
## Lake Benthos Identified from Boston Property Lakes, 1996[1]

| | | | Spyder Lake | | Stickleback Lake | Spyder Lake | | Stickleback Lake |
|---|---|---|---|---|---|---|---|---|
| | | | Stn. 5 - Shallow | Stn. 6 - Deep | | Stn. 5 - Shallow | Stn. 6 - Deep | |
| **Major Group** | **Sub-Group** | **Genus/Species** | **Aug. 4** | **Aug. 4** | **Aug. 5** | **Aug. 24** | **Aug. 24** | **Aug. 25** |
| AMPHIPODA | | *Gammarus lacustris* | | | + | | | + |
| CNIDARIA | Hydrozoa | *Hydra* sp. | | | + | | | + |
| DIPTERA | Chironomidae | Undetermined Adult | | + | | | | |
| | Chironominae | Undetermined | | | | | + | + |
| | | Undetermined Pupae | | + | | | | |
| | | Undet. Chironomini Pupae | + | | + | | | |
| | | Undet. Tanytarsini Juvenile | + | | + | | | |
| | | *Chironomus* sp. | | | + | | + | + |
| | | *Cryptochironomus* sp. | | | + | | | + |
| | | *Dicrotendipes* sp. | | | | | | + |
| | | *Glyptotendipes* sp. | + | | | | | |
| | | *Phaenopsectra* sp. | | + | + | + | | + |
| | | *Rheotanytarsus* sp. | + | + | + | | + | + |
| | | *Stempellinella* sp. | + | | | + | | + |
| | | *Stictochironomus* sp. | | | + | | | |
| | | *Tanytarsus* sp. | + | + | | + | | + |
| | | *Tanytarsus* sp. Larvae | | | + | | | |

**(continued)**

## Table 6.1-5
## Lake Benthos Identified from Boston Property Lakes, 1996[1]

| | | | Spyder Lake | | Stickleback Lake | Spyder Lake | | Stickleback Lake |
|---|---|---|---|---|---|---|---|---|
| | | | Stn. 5 - Shallow | Stn. 6 - Deep | | Stn. 5 - Shallow | Stn. 6 - Deep | |
| **Major Group** | **Sub-Group** | **Genus/Species** | **Aug. 4** | **Aug. 4** | **Aug. 5** | **Aug. 24** | **Aug. 24** | **Aug. 25** |
| | Orthocladiinae | Undetermined Juvenile | + | | + | | | + |
| | | Undetermined Pupae | + | | | | | |
| | | *Corynoneura* sp. | | | + | | | |
| | | *Cricotopus* sp. | | | + | | | + |
| | | *Eukiefferiella* sp. | | | + | + | | |
| | | *Heterotrissocladius* sp. | + | | | + | | |
| | | *Paracladius* sp. | + | + | | + | | |
| | Prodiamesinae | *Monodiamesa* sp. | + | + | | + | | + |
| | Tanypodinae | *Procladius* sp. | + | + | + | + | | + |
| HYDRACARINA | | Undetermined | + | + | + | + | | + |
| | Oxidae | *Frontipoda* ap. | + | | | + | | |
| MOLLUSCA | Bivalvia | *Pisidium* sp. | + | + | + | + | + | + |
| | | *Sphaerium* sp. | + | + | + | + | + | + |
| | Gastropoda | *Valvata sincera* | + | | + | + | | |
| NEMATODA | | Undetermined | + | + | + | + | + | + |
| OLIGOCHAETA | Enchytraeidae | Undetermined | + | + | | | | + |
| | Lumbriculidae | *Lumbriculus* sp. | | | | | | + |
| | Naidiae | *Nais* sp. | | | + | | | |
| | | *Chaetogaster* sp. | + | | + | | | + |

**(continued)**

## Table 6.1-5 (completed)
## Lake Benthos Identified from Boston Property Lakes, 1996[1]

| | | | Spyder Lake | | Stickleback Lake | Spyder Lake | | Stickleback Lake |
|---|---|---|---|---|---|---|---|---|
| | | | Stn. 5 - Shallow | Stn. 6 - Deep | | Stn. 5 - Shallow | Stn. 6 - Deep | |
| **Major Group** | **Sub-Group** | **Genus/Species** | **Aug. 4** | **Aug. 4** | **Aug. 5** | **Aug. 24** | **Aug. 24** | **Aug. 25** |
| | Tubificidae | Undetermined | | + | + | + | + | + |
| | | Undetermined juvenile | + | | | | | |
| OSTRACODA | | *Cypris* sp. | | | | | | + |
| | | Undetermined | | | | | + | + |
| | | Undetermined | | | + | | | |
| | | *Candona* sp. | + | | | | | + |
| PLECOPTERA | | Undetermined | | | | | | + |
| TRADIGRADA | | Undetermined | | | | | + | + |
| TRICHOPTERA | Limnephilidae | Undetermined Pupae | | | | | | + |
| | | *Clostoeca* sp. | | | | | | + |
| | | *Ecclisomyia* sp. Larvae | | | | | | + |
| | | *Grensia praeterita* | | | | + | | |
| TURBELLARIA | | Undetermined | | | | | | + |

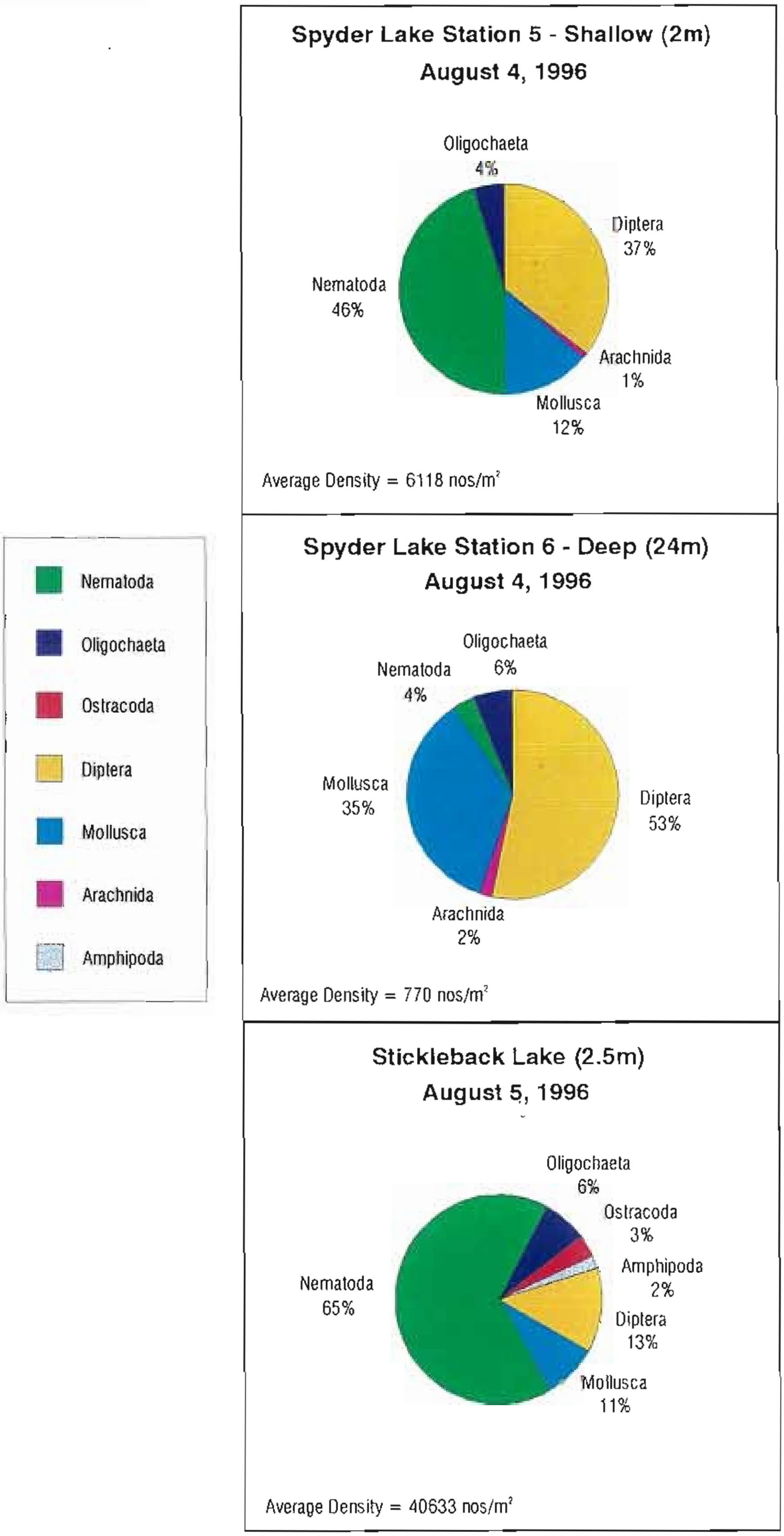
**1: + sign indicates taxa as present at sampling site.**

The Stickleback Lake benthic samples had the highest density in both summer and fall (Figures 6.1-5 and 6.1-6). Shallow summer samples from Spyder Lake had over six times the density of the samples from Stickleback Lake (40,633 and 6,118 individuals/$m^2$, respectively; Figure 6.1-5). Spyder Lake deep samples contained the least amount of organisms, with an average density of 770 individuals/$m^2$ in the summer and 2,029 individuals/$m^2$ in the fall. There were 25 genera identified from 12 major groups from the three sampling stations. Stickleback Lake contained the greatest number of genera in both the summer and the fall (S=14 and 20, respectively). The shallow station in Spyder Lake contained more genera than the deep station (Table 6.1-5). The shallower samples are expected to have greater densities and taxa richness due to the increased amount of light penetration, and hence an increased rate of production, at shallower depths.

In the summer samples the two shallow stations had similar taxonomic compositions, both being dominated by nematodes (Figure 6.1-5). Diptera was the second most abundant group; however, Stickleback Lake samples contained less diptera than Spyder Lake (13 and 37%, respectively). Both Stickleback and Spyder lakes had similar mollusc compositions (11 and 12%, respectively). The deep station at Spyder Lake was dominated by Diptera, with the majority of non-dipteran organisms belonging to the group Mollusca. The oligochaete community was fairly constant (between 4 to 6%) at all three stations.

In the fall samples the taxonomic composition changed (Figure 6.1-6). Spyder Lake shallow stations were dominated by molluscs, followed by dipterans and nematodes. Stickleback Lake samples were co-dominated by dipterans (49%) and nematodes (37%). Spyder Lake deep station samples were co-dominated by molluscs (44%) and oligochaetes (36%).

In both the summer and fall samples, the dipteran community in Stickleback Lake was more diverse than at the Spyder Lake stations (Table 6.1-6). In the summer, the communities of the two stations in Spyder Lake had similar diversity indices, but were less diverse than those from Stickleback Lake. In the fall, the deep stations samples were far less diverse than those from the shallow station (0.425 and 1.47, respectively). In general, all stations had more diverse dipteran communities in the summer compared to the fall.




# Taxonomic Composition of Lake Benthos Samples, Boston Property, Summer 1996

FIGURE 6.1-5

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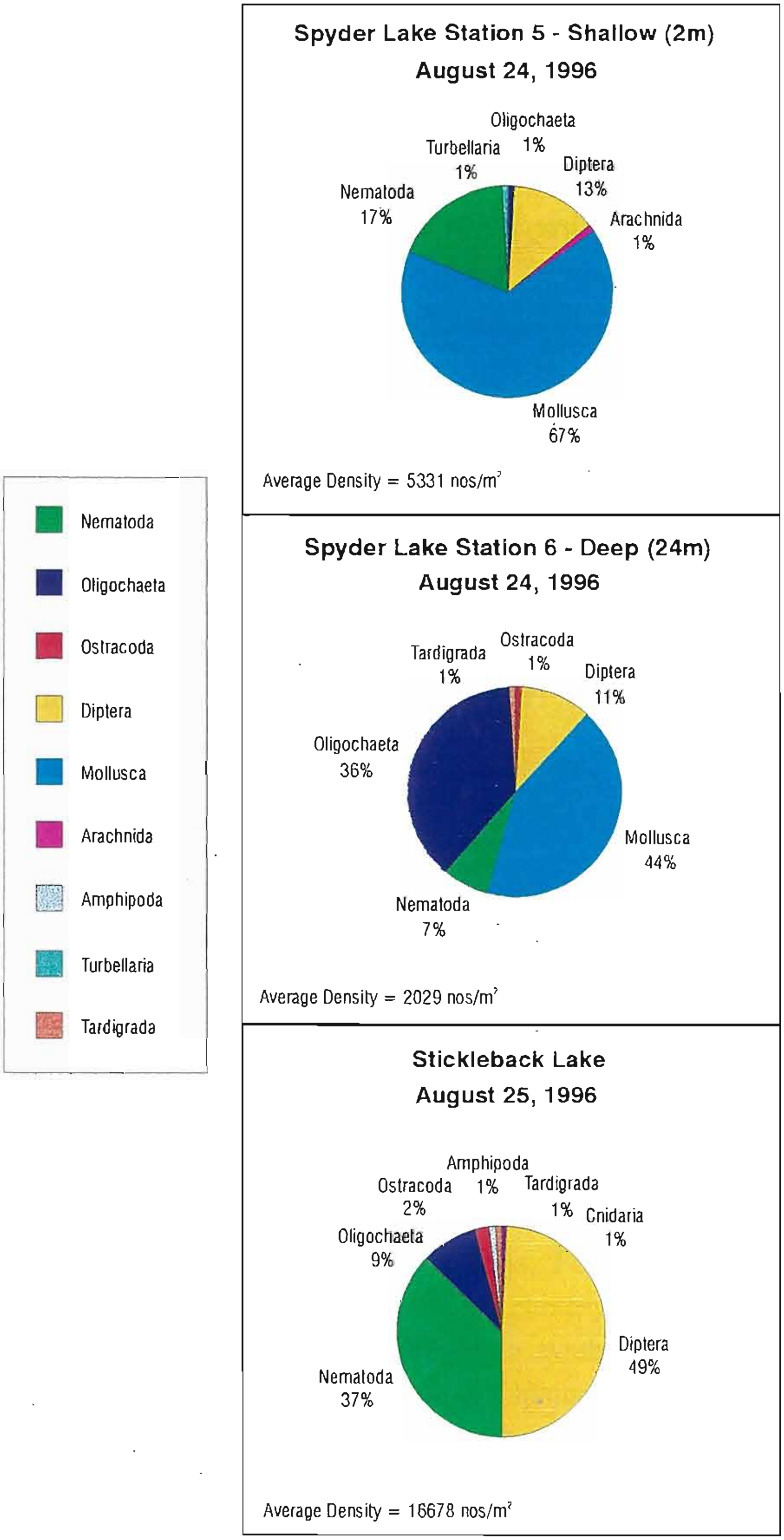


**Taxanomic Composition of Lake Benthos Samples, Boston Property, Fall 1996**

FIGURE 6.1-6

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**Table 6.1-6**
**Site Characteristics of Benthic Dipteran Communities for Boston Property Lakes, 1996**

| Sampling Site | Season | Richness (S) | S (90%) | Max. Dom. | Shannon Diversity Index (H') |
|---|---|---|---|---|---|
| Spyder Lake - Stn. 5 | Summer | 7 | 4 | 34.5 | 1.57 |
| Shallow | Fall | 8 | 5 | 42.3 | 1.48 |
| Spyder Lake - Stn. 6 | Summer | 6 | 4 | 39.2 | 1.54 |
| Deep | Fall | 2 | 2 | 84.9 | 0.43 |
| Stickleback Lake | Summer | 10 | 5 | 32.7 | 1.69 |
| | Fall | 10 | 4 | 33.7 | 1.52 |

In 1995, densities were much lower (18 and 479 individuals/$m^2$ for Spyder Lake shallow and Stickleback Lake, respectively). The two lakes had very similar compositions, which were co-dominated by dipterans and molluscs. Nematodes were present in Stickleback (11%) but not present in Spyder Lake in 1995.

### 6.1.2 Streams

The Trout and Stickleback outflow streams and the northeast and south inflow streams for Spyder Lake were sampled during the summer campaign for primary and secondary producers. The locations of the sampling sites are presented in Figure 6.1-1.

#### *6.1.2.1 Stream Primary Producers (Periphyton)*

The term periphyton refers to an assemblage of organisms living attached to a substrate submerged in water. This complex assemblage of organisms can include photosynthetic organisms, fungi, and bacteria. For the purposes of this report, the term periphyton will be used to denote the photosynthetic, autotrophic organisms (those organisms able to utilize sunlight to synthesize their own food) present within this assemblage, as they are the major primary producers of stream ecosystems. These organisms comprise the predominant food source for stream invertebrates, which in turn are a major food source for juvenile fish.

*Methods*

Stream periphyton samples were collected at three sites during the ice-free season: at two Spyder Lake inflows (Station 1 and Northeast Inflow) and at Stickleback Outflow (Figure 6.1-1). An attempt was made to use artificial substrate samplers at Stickleback and Trout outflows. However, due to drastic changes in water levels, no artificial substrate samplers were recovered. Therefore, instantaneous samples for periphyton were obtained either by using a modified syringe-brush or by scraping a known surface area of rock with a plastic spatula and ruler. Trout Outflow could not be sampled in late August due to strong currents and flooding, as no suitable rocks for sampling could be obtained. At the other sites, surface areas sampled were cleaned with a fine-bristled brush and rinsed using a wash bottle. The samples were transferred into 500 mL jars and preserved in Lugol's iodine solution. Genera, and where possible, species, were identified and enumerated by Fraser Environmental Services, in accordance with procedures described in reports for previous sample periods (Rescan 1995b).

For purposes of stream site comparisons, site characteristics were determined using the COMM program to genera as described previously (Appendix 6-1).

*Results and Discussion*

The taxonomic identification and enumeration of periphyton from all sample locations are given in Appendix 6-5. Table 6.1-7 presents the periphyton taxa composition and abundance of the three stream sites sampled. The South Inflow of Spyder Lake (Station 1) was dominated by cyanobacteria (Cyanophyta) and diatoms (Bacillariophyceae), with these taxonomic groups representing 56% and 41% of the total periphyton abundance, respectively (Table 6.1-7, Figure 6.1-7). The Northeast Inflow of Spyder Lake was dominated by cyanobacteria, but also had green algae (Chlorophyta) and diatoms present. Stickleback Inflow was dominated by cyanobacteria and diatoms, similar to the South Inflow of Spyder Lake (Figure 6.1-7). The South Inflow of Spyder Lake has the greatest cell density of any of the sites sampled.

**Table 6.1-7**
**Average Periphyton Taxa Composition for Boston Property Streams, August 1996**

| Phylum/Subphylum | % Composition<br>Spyder, South Inflow August 4, 1996 | Spyder, NE Inflow August 6, 1996 | Stickleback Outflow August 25, 1996 |
|---|---|---|---|
| Bacillariophyceae | 41 | 12 | 32 |
| Chlorophyta | 2 | 25 | 8 |
| Chrysophyta | 0 | 0 | 1 |
| Cyanophyta | 56 | 63 | 59 |
| Pyrrophyta | 1 | 0 | 0 |
| Ave. Cell Density (cells/cm$^2$) | $7.43 \times 10^5$ | $1.78 \times 10^5$ | $3.51 \times 10^5$ |

Table 6.1-8 presents the results of the COMM program site analysis. The South Inflow of Spyder Lake had the least diverse population, having a Diversity Index of 1.43. The genus responsible for 40% of the abundance was *Tabellaria*, a diatom genus. The Northeast Inflow of Spyder Lake and Stickleback Outflow were similar in their periphyton diversity, having Diversity Indices of 2.60 and 2.63 (Table 6.1-8). Both sites had cyanobacteria as their dominant genera.

**Table 6.1-8**
**Site Characteristics of Periphyton Assemblages for Boston Property Streams, August 1996**

| Stream Site | Sample Size | Density (cells/cm$^2$) | Richness (S) | S(90%) | Max. Dom. (%) | Max. Dom. Genus (numerically) | Diversity (H') |
|---|---|---|---|---|---|---|---|
| Spyder Lake, South Inflow August 4, 1996 | n = 1 | 743,198 | 16 | 4 | 39.8 | *Tabellaria* | 1.43 |
| Spyder Lake, NE Inflow August 6, 1996 | n = 2 | 178,045 | 30 | 14 | 25.8 | *Lyngbya* | 2.63 |
| Stickleback Outflow August 25, 1996 | n = 3 | 350,685 | 31 | 16 | 21.2 | *Anacystis* | 2.60 |

**S = the number of genera per site.**
**S(90%) = the number of genera contributing to 90% of the density.**
**Max. Dom. = the maximum dominance accounted for by a single genus.**
**H' = Shannon Diversity Index.**

Stickleback Outflow has been sampled in previous years (1993 to 1995). During early August in 1995, the periphyton assemblage at Stickleback Outflow was dominated by cyanobacteria (78%), with a total cell density of 11.9 x $10^5$ cells/$cm^2$ (Rescan 1995). Stickleback Outflow was sampled later in the season in 1996 (August 25), at which time 59% of the periphyton abundance was due to cyanobacteria. Cell densities were within a factor of three between years. In general, cyanobacteria are a major component of periphyton assemblages in the area, with diatoms and green algae also being abundant.

*6.1.2.2 Secondary Producers*

Secondary producers are defined as organisms that convert plant matter into animal tissue. The secondary producers in streams are generally benthic invertebrates, and are sampled using larval drift nets and *in situ* substrate samplers.

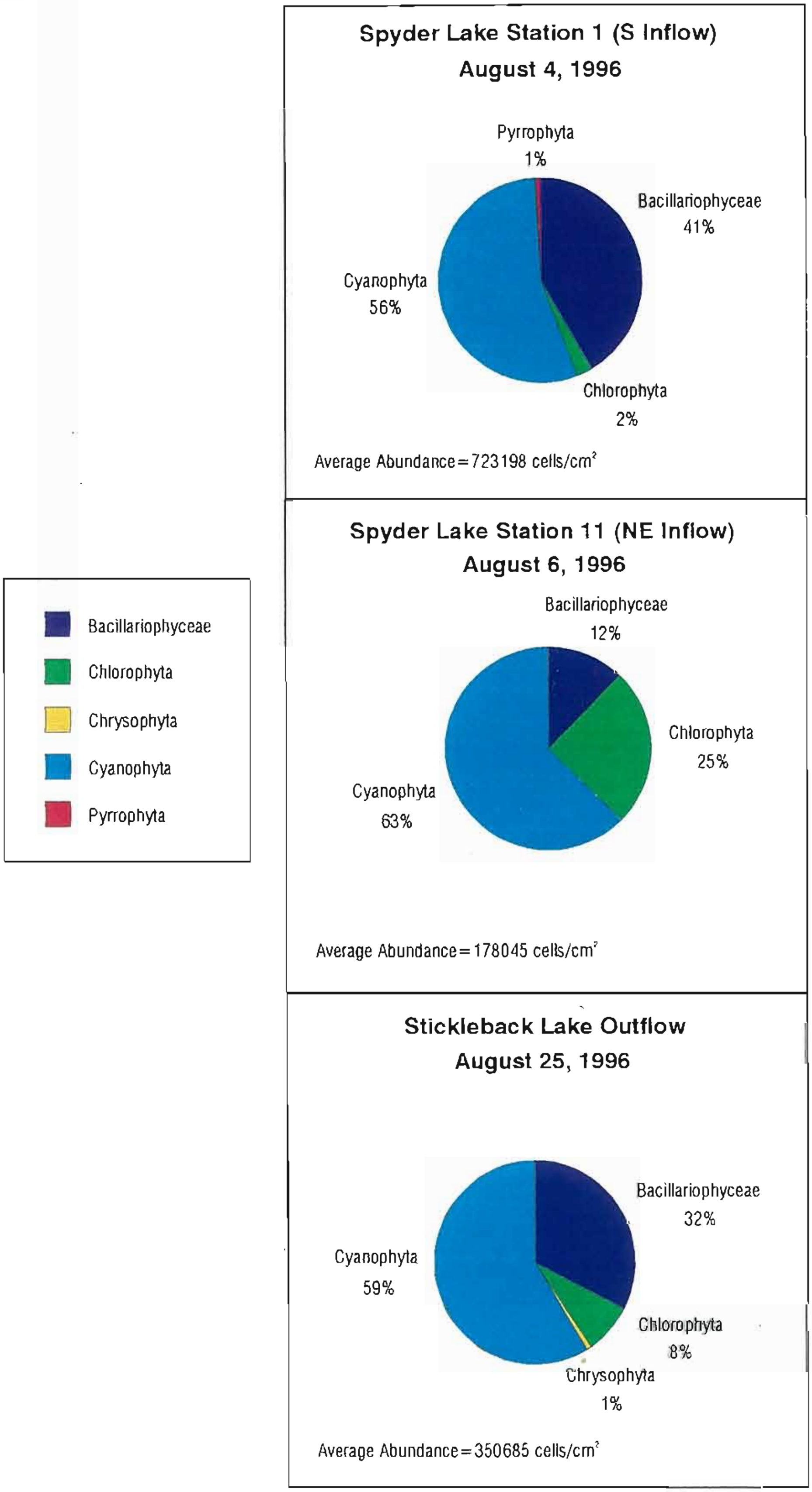
*Larval Drift*

Invertebrates can become dissociated from stream substrates either actively or passively. These invertebrates are then transported by stream currents and eventually colonize downstream habitat. Aquatic insects in pupal and adult life stages, fish, and terrestrial insects that have fallen onto the water surface are also collected in larval drift samples. Drifting invertebrates provide an important food supply for stream-living fish and therefore any notable decrease in larval drift densities may eventually affect fish populations.

- *Methods*

  Larval drift samples were collected from Stickleback and Trout outflow streams (Figure 6.1-1). Samples were collected in each stream using two drift-net samplers (0.14 $m^2$ frame), each consisting of a conical 500 µm or 1000 µm mesh net with a removable cod-end. Samplers were secured using rebar with net openings facing upstream in sufficient flow (Plate 6-2). The bottoms of the net frames were flush against the substrate and the upper edges of the frames remained above the water surface. The soak time in the five streams during the summer and fall periods was approximately 24 hours. At time of collection, samples were transferred from the cod-end of the sampler to a 500 mL jar and preserved in a final concentration of 10% formalin.

  Identification and enumeration of larval drift samples were conducted by Applied Technical Services (Saanichton, BC), a company that specializes in the

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# Periphyton Taxa Composition for Boston Property Streams August 1996

FIGURE 6.1-7

Rescan

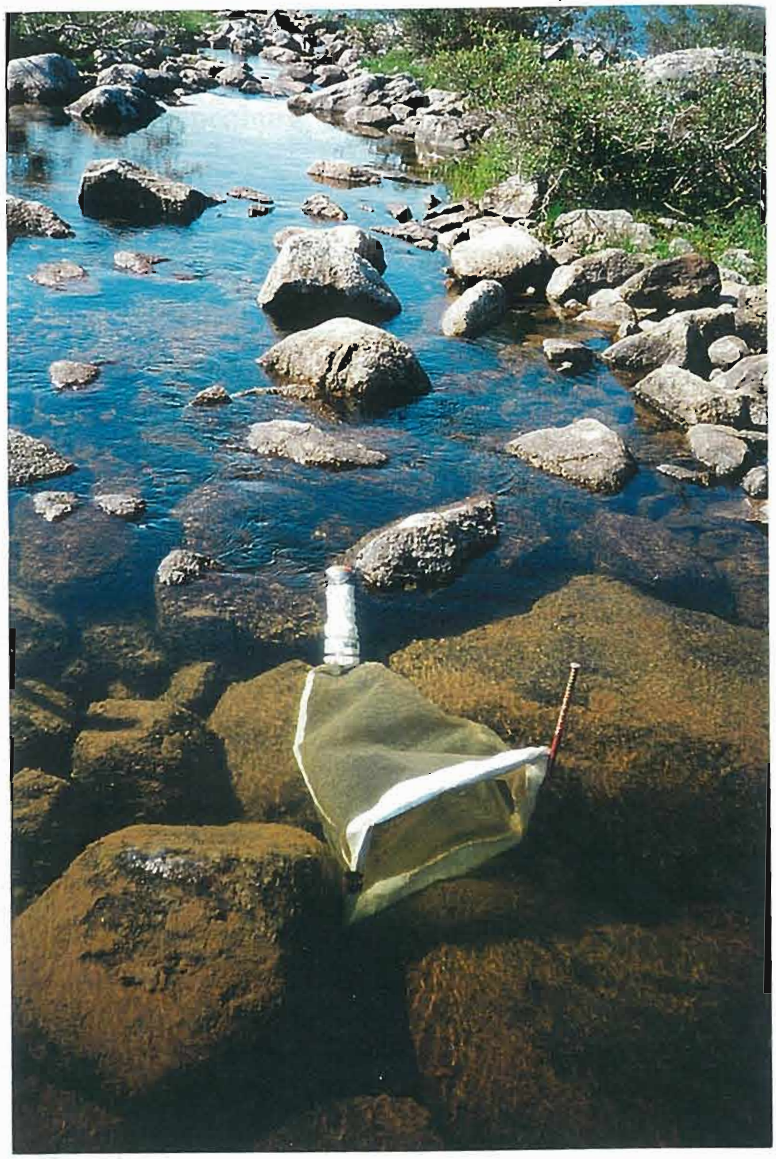


Plate 6-2: Larval drift net placed in flowing steam.

taxonomic identification of invertebrates. Methods of analysis were consistent with those of previous years (Rescan 1995). Organisms in certain groups were not identified down to the genus or species level and therefore only the dipteran community was used to calculate richness and diversity for each site using the COMM program (Piepenburg and Piatkowski 1993; see Section 6.1 and Appendix 6-1).

- *Results and Discussion*

The seasonal larval drift data collected in each stream are listed in Appendix 6-6. The list of organisms identified in stream larval drift samples is presented in Table 6.1-9. Pelagic zooplankton were not included in sample analysis.

The Trout Outflow samples contained ten times the number of organisms of the Stickleback Outflow samples (average density = 1,343 and 127 individuals per 24 hours, respectively; Figure 6.1-8). This may be a factor of the differences in stream flows, and therefore the amount of water flowing into the net over the 24 hour period. Eighteen genera in 13 major groups were identified from the two sites (Table 6.1-9). Trout Outflow contained 15 genera in 11 major groups while Stickleback Outflow contained nine genera in ten major groups. However, there were more higher order groups in the Stickleback samples as compared to the Trout Outflow samples.

The taxa composition in Stickleback Outflow was more varied than in Trout Outflow (Figure 6.1-8). In Trout Outflow samples, Diptera accounted for 84% of organisms, whereas in Stickleback Outflow, Diptera co-dominated with Arachnida and Trichoptera.

The dipteran community was more diverse in Trout Outflow than in Stickleback Outflow (Table 6.1-10). In Stickleback Outflow samples only one genus was present and therefore the H' was equal to zero. The Trout Outflow samples had a Shannon Diversity Index of 0.17.

## Table 6.1-9
## Larval Drift Organisms Identified from Boston Property, 1996[1]

| Group | Sub-Group/Genus | Stage[2] | Stickleback Lake Aug. 5, 1996 | Trout Lake Aug. 6, 1996 |
|---|---|---|---|---|
| CNIDARIA | *Hydra* | | + | |
| NEMATODA | Unidentified | | + | + |
| ANNELIDA | Oligochaeta | | | |
| | *Chaetogaster* | | + | + |
| | *Nais* | | | + |
| | Hirudinea | | | |
| | *Piscicola salmositica* | | | + |
| TARDIGRADA | Unidentified | | + | + |
| OSTRACODA | Candona | | + | + |
| | *Cypris* | | + | + |
| | *Cypria* | | + | + |
| AMPHIPODA | *Gammarus lacustris* | | + | |
| HYDRACARINA | Unidentified | | + | + |
| HEMIPTERA | Aphididae | A | | + |
| DIPTERA | Chironomidae | L* | + | + |
| | Tanypodinae | L* | | + |
| | Tanytarsini | L* | + | + |
| | *Dicrotendipes* | L | | + |
| | Orthocladiinae | L* | + | + |
| | Orthocladiinae | P | + | + |
| | *Corynoneura* | L | + | + |
| | *Cricotopus* | L | | + |
| | *Cricotopus* | P | | + |
| | Simulidae | | | |
| | *Simulium* | A | | + |
| TRICHOPTERA | Hydroptilidae | | | |
| | *Agraylea* | L | + | + |
| | Limnephilidae | | | |
| | *Grensia praeterita* | L | + | |
| HYMENOPTERA | Braconidae | A | | + |
| | Chalcoidea | A | | + |

**(continued)**

## Table 6.1-9 (completed)
## Larval Drift Organisms Identified from Boston Property, 1996[1]

| Group | Sub-Group/Genus | Stage[2] | Stickleback Lake Aug. 5, 1996 | Trout Lake Aug. 6, 1996 |
|---|---|---|---|---|
| COLEOPTERA | Dytiscidae | | | |
| | *Agabus* | A | | + |
| | *Hydaticus* | A | | + |
| | *Hydroporus* | A | | + |
| | Halplidae | | | |
| | *Haliplus* | L | | + |
| | Staphylinidae | A | | + |
| MOLLUSCA | *Valvata sincera* | | + | |

**1: + sign indicates taxa as present at sampling site.**
**2: L = larva**
**P = pupa**
**A = adult**
*** = small or damaged**

## Table 6.1-10
## Site Characteristics of Larval Drift Dipteran Communities for Stickleback Outflow, 1996

| Sampling Site | Richness | S(90%) | Max. Dom. | Shannon Diversity Index (H') |
|---|---|---|---|---|
| Stickleback Outflow | 1 | 1 | 100 | 0 |
| Trout Outflow | 4 | 1 | 96.9 | 0.17 |

*Stream Benthos*

Benthic invertebrates (benthos) are bottom-dwelling organisms that are important prey items for juvenile and adult fish living in streams. Changes in the diversity and density of benthos can be indicative of changes in water quality and bottom sediment disturbances. Decreases in the taxonomic diversity or biomass of the benthic community may affect fish populations.

- *Methods*

  Stream benthos were collected using artificial substrate samplers set in Stickleback Outflow (Figure 6.1-1).

Artificial substrate samplers were used to collect stream invertebrates. Hester-Dendy artificial substrate samplers consist of eight 0.064 $m^2$ plates stacked 0.5 cm apart (Plate 6-3a, b). The total area available for colonization of benthos is 0.448 $m^2$. Five Hester-Dendy samplers were set in the stream in July and collected in early August. The artificial substrate samplers were placed, exposed and collected in conditions as nearly identical as possible to reduce site to site variability. Prior to sampler removal, a sieve was placed on the downstream side of the sampler to prevent possible loss of organisms. Organisms were then gently brushed from the sampler, transferred to jars, and preserved in a final concentration of 10% formalin.

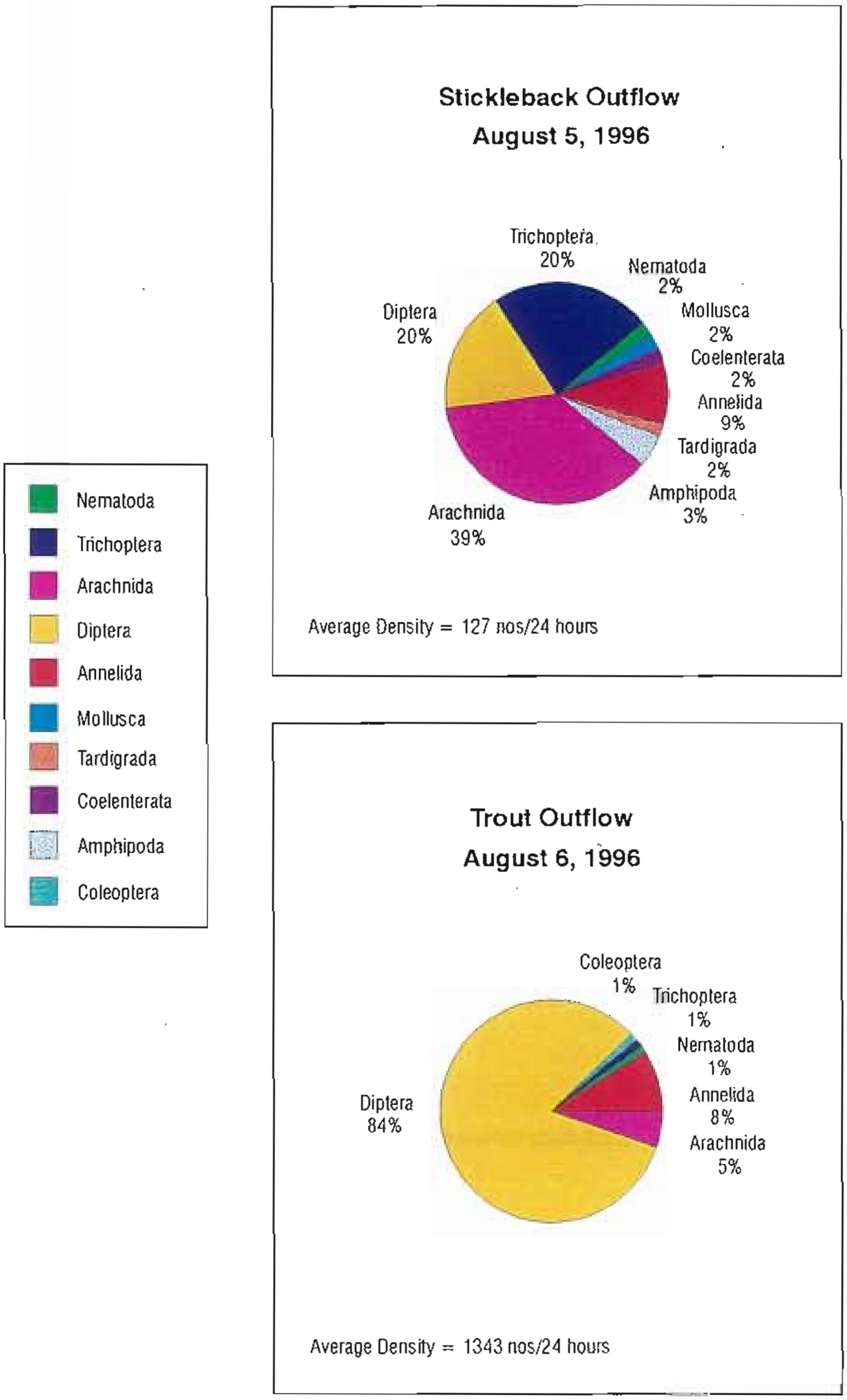
Genera, and where possible, species, were identified and enumerated by Biologica, (Victoria, BC) and analytical methods were consistent with those of previous years' work (Rescan 1995). Richness and diversity for the dipteran community at each site were calculated using the COMM program (Piepenburg and Piatkowski 1993) and are consistent with those discussed in Section 6.1 and Appendix 6-1.

The artificial substrates from Stickleback Outflow could not be located during the summer trip, so five additional samplers were set and retrieved during the fall sampling trip in late August.

- *Results and Discussion*

The data obtained from the Stickleback Outflow stream benthos samplers are listed in Appendix 6-7. A list of taxa that were found is given in Table 6.1-11.

The average density of organisms in the samples was 963 individuals/$m^2$ and contained 20 genera in 11 major groups. Stickleback Outflow benthos was dominated by Diptera at 79%, followed by Nematoda at 19% (Figure 6.1-9). The 1996 data cannot be compared to past years' data due to differences in sampling techniques. However, Hester-Dendy samplers are recommended for future surveys and will provide consistent data henceforth.

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# Taxonomic Composition and Abundance of Larval Drift Samples, Boston Property, Summer 1996

FIGURE 6.1-8

Rescan

Plate 6-3a: Hester-Dendy artificial substrate sampler placed in stream substrate.

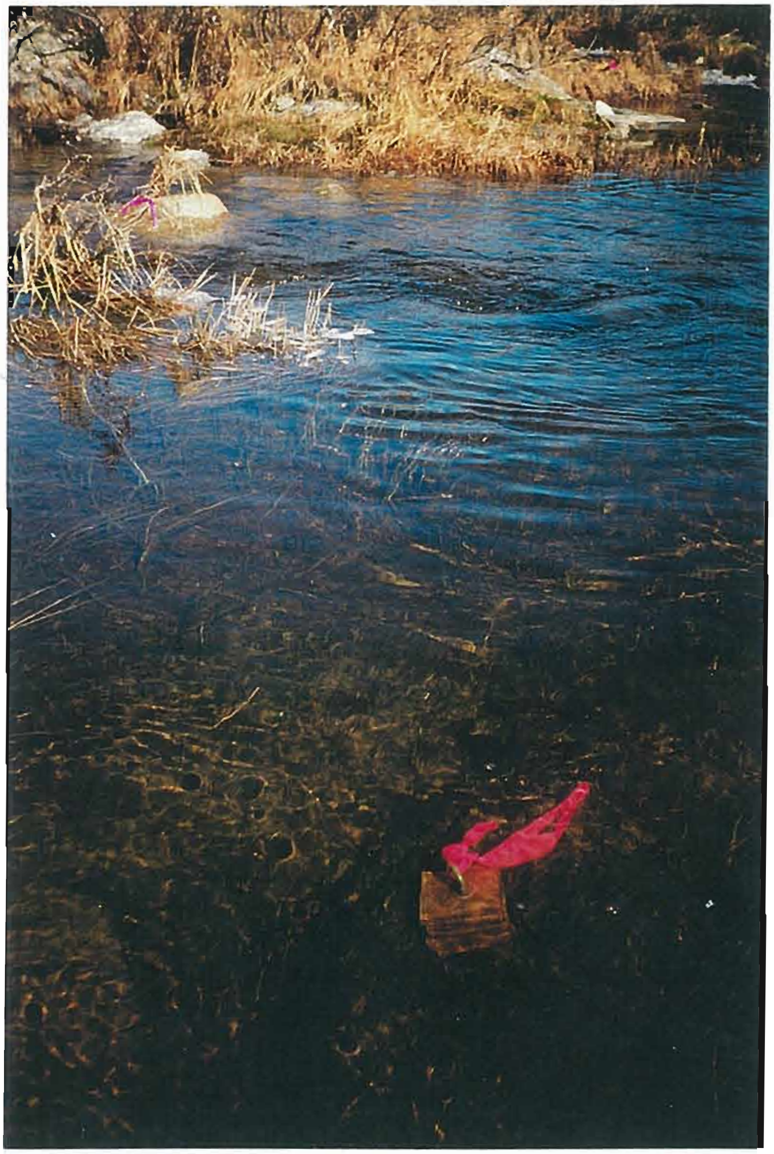
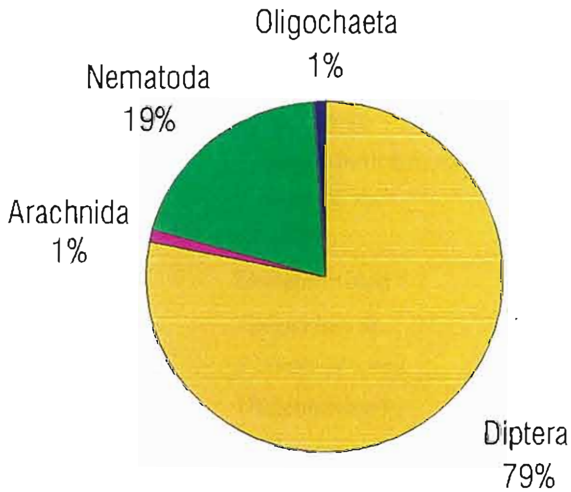


Plate 6-3b: Hester-Dendy artificial substrate sampler placed in flowing water.

**Stickleback Lake Outflow**
**August 25, 1996**




Average Density = 963 nos/$m^2$

FIGURE 6.1-9

**Taxonomic Composition of Stream Benthos Samples, Boston Property, August 1996**

BHP Rescan

**Table 6.1-11**
**Stream Benthos Identified from the Boston Property, 1996[1]**

| Major Group | Sub-Group | Genus/Species | Stickleback Outflow Aug. 25, 1996 Mean |
|---|---|---|---|
| AMPHIPODA | Gammaridae | *Gammarua lacustris* | + |
| CNIDARIA | Hydrozoa | *Hydra* sp. | + |
| DIPTERA | | Undetermined Adult | + |
| | | Undetermined Juvenile | + |
| | Chironominae | *Phaenopsectra* sp. | + |
| | | *Rheotanytarsus* sp. | + |
| | | *Stempellinella* sp. | + |
| | | *Tanytarsus* sp. larvae | + |
| | Orthocladiinae | *Cricotopus* sp. | + |
| | | *Eukiefferiella* sp. | + |
| | Simuliidae | *Simulium* sp. | + |
| | Tanypodinae | *Thienemannimyia* sp. | + |
| | Tipulidae | *Priuncera* sp. | + |
| | | *Tipula* sp. | + |
| HYDRACARINA | | Undetermined | + |
| MOLLUSCA | Bivalvia | *Sphaerium* sp. | + |
| | Gastropoda | *Valvata sincera* | + |
| NEMATODA | | Undetermined | + |
| OLIGOCHAETA | Enchytraeidae | Undetermined | + |
| | Lumbriculidae | *Lumbriculus variegatus* | + |
| | Naididae | *Nais* sp. | + |
| | | *Chaetogaster* sp. | + |
| | Tubificidae | Undetermined | + |
| OSTRACODA | | *Candona* sp. | + |
| PLECOPTERA | Nemouridae | *Podmosta* sp. | + |
| TRICHOPTERA | Limnephilidae | *Clostoeca* sp. | + |
| TURBELLARIA | | Undetermined | + |

**1: + sign indicates taxa as present at sampling site.**

## 6.2 Doris Lake Property

The Doris Lake Property lies near the northern end of the Hope Bay Belt area, and includes the marine region of Roberts Bay. Figure 6.2-1 presents the lakes and streams in the area that were sampled for primary and secondary producers during the 1996 field season.

### 6.2.1 Lakes

Six lakes in the Doris Lake Property area were sampled for primary and secondary producers during the fall sampling period. The lakes sampled included Patch, Ogama, Doris, Tail, Roberts and Windy lakes and are presented in Figure 6.2-1.

#### *6.2.1.1 Primary Producers (Phytoplankton)*

*Methods*

Samples for phytoplankton species identification and enumeration were taken from Patch, Ogama, Doris, Tail, Roberts, and Windy lakes at 0.5 m depth during late August of 1996 (Figure 6.2-1). All methods were the same as described in Section 6.1.1.1.

For purposes of lake comparisons, site characteristics for the six lakes were determined as described previously using the COMM program to the taxonomic level of genera (Appendix 6-1).

*Results and Discussion*

Phytoplankton taxa that were identified and enumerated for all six lakes are given in Appendix 6-2. Table 6.2-1 presents the percent taxa composition (to phylum/subphylum) and average cell density for all six lakes. The phytoplankton assemblages of Ogama, Doris, Roberts, and Windy lakes were strongly dominated by cyanobacteria (Table 6.2-1, Figure 6.2-2). Over 94% of the phytoplankton abundance for these four lakes was due to cyanobacterial organisms. Tail Lake, on the other hand, was strongly dominated by diatoms, with these organisms being responsible for 96% of the phytoplankton abundance (Table 6.2-1, Figure 6.2-2). Patch Lake had a phytoplankton assemblage consisting of diatoms, green algae, and cyanobacteria, and was the only lake exhibiting a mixed assemblage of taxa.

The cell abundance of primary producers was extremely variable in the six lakes sampled. Patch and Windy lakes had the lowest density of primary producers, while Doris Lake had the highest, with cell densities ranging from 0.22 to $62.30 \times 10^6$ cells/L (Table 6.2-1).

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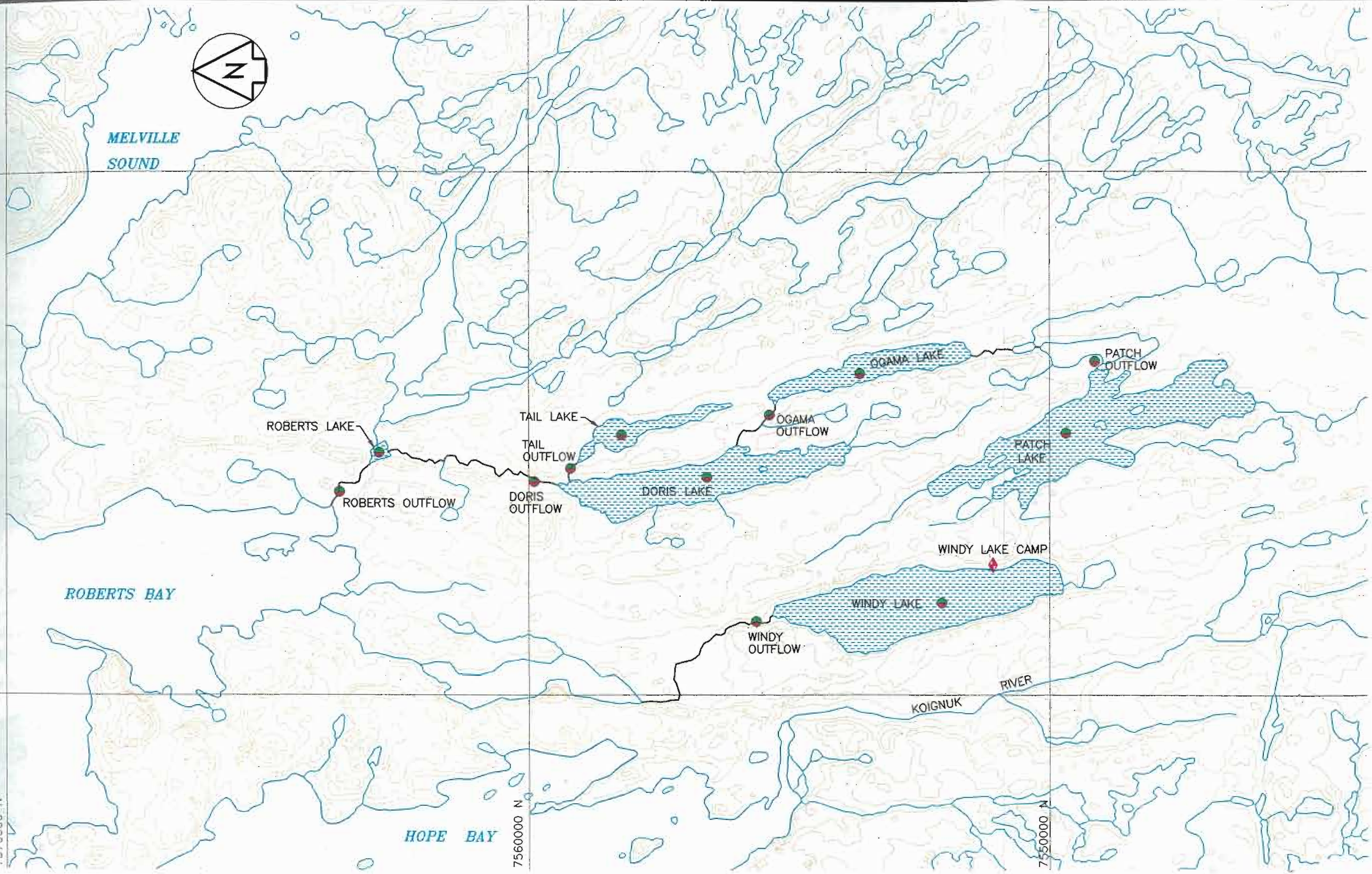


NOTE:
CONTOUR INTERVAL 20m

LEGEND:
PRIMARY PRODUCER SAMPLING STATION
SECONDARY PRODUCER SAMPLING STATION
CAMP SITE

0 2500m

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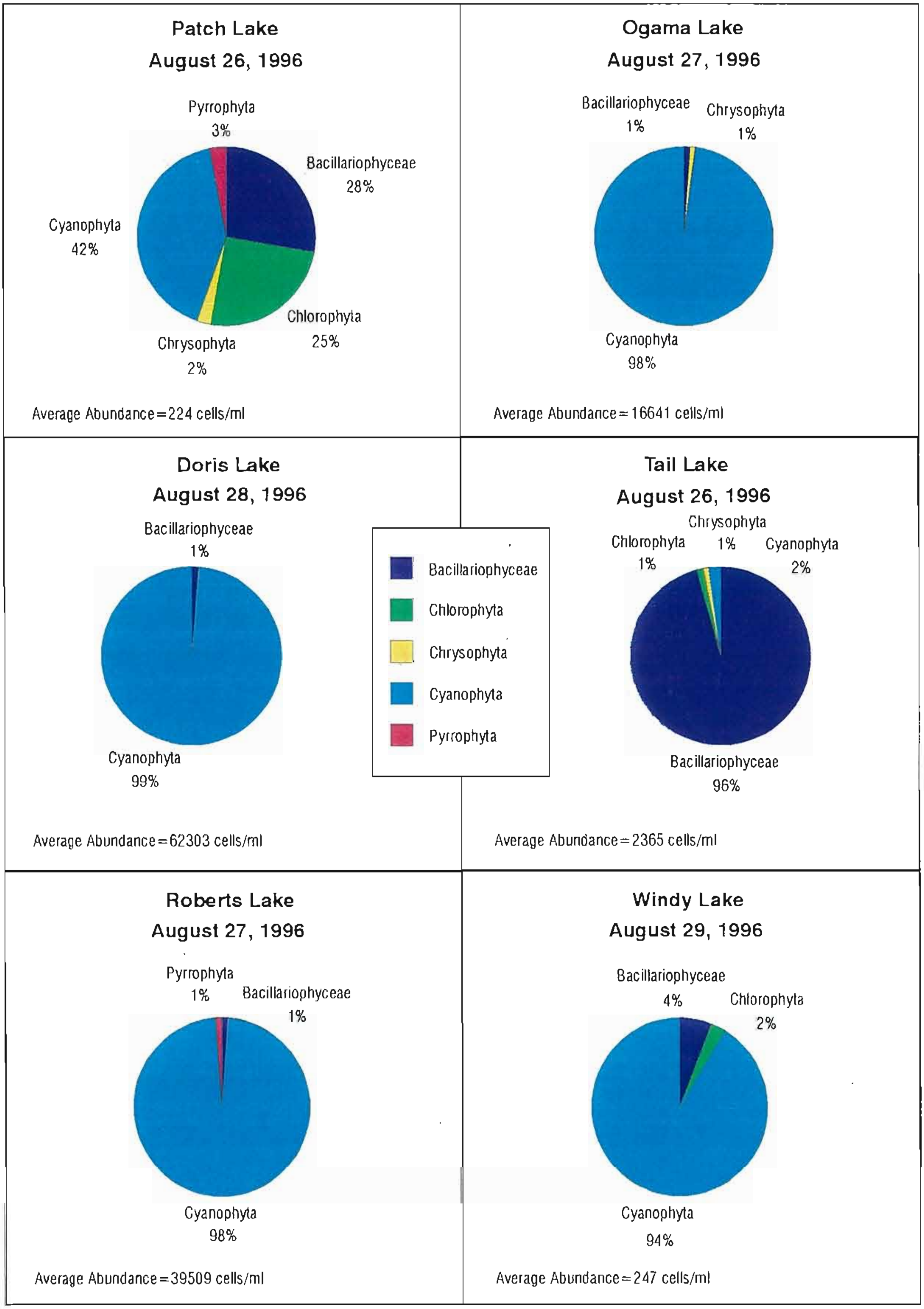
Aquatic Biology Sampling Stations
Doris Lake Property, 1996

Rescan

Fig 6.2-1

Source: Klohn-Crippen, 1995 fig3-11.dwg

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**Phytoplankton Taxa Composition for Doris Lake Property Lakes August 26-29, 1996**

FIGURE 6.2-2

Rescan

**Table 6.2-1**
**Phytoplankton Taxa Composition, Abundance, and Biomass for Doris Lake Property, August 1996**

| | % Composition | | | | | |
|---|---|---|---|---|---|---|
| **Phylum/Subphylum** | **Patch Aug. 26** | **Ogama Aug. 27** | **Doris Aug. 28** | **Tail Aug. 27** | **Roberts Aug. 27** | **Windy Aug. 29** |
| Bacillariophyceae | 28 | 1 | 1 | 96 | 1 | 4 |
| Chlorophyta | 25 | 0 | 0 | 1 | 0 | 2 |
| Chrysophyta | 2 | 1 | 0 | 1 | 0 | 0 |
| Cyanophyta | 42 | 98 | 99 | 2 | 98 | 94 |
| Pyrrophyta | 3 | 0 | 0 | 0 | 1 | 0 |
| Ave. Cell Density (cells/mL) | 224 | 16,641 | 62,303 | 2,365 | 39,509 | 247 |

Table 6.2-2 presents the results from the COMM program analysis. Ogama, Tail, and Doris lakes showed the least diversity, being dominated by single genera. However, Ogama and Doris lakes were dominated by cyanobacteria, while Tail Lake was dominated by diatoms. Diatoms are a superior food source for higher trophic levels than are cyanobacteria. Patch Lake showed the greatest diversity, having a Diversity Index of 2.25. The Diversity Indices ranged from 0.37 to 2.25 for the six lakes sampled.

In general, the waters of these lakes are poor in nitrogen (Appendix 5-2), favoring the growth of nitrogen-fixing organisms, which fulfill their nitrogen requirements from the atmosphere rather than the water. The small amounts of phosphorus present allow primary producers to grow. Nitrogen in the form of ammonium may be available for primary producers, especially later in the season, allowing other taxa to compete with the nitrogen-fixers.

### *6.2.1.2 Secondary Producers*

#### *Zooplankton*

- *Methods*

  The water column at the deepest point of six lakes was sampled during the early August field trips using the same methods as those described in

**Table 6.2-2**
**Site Characteristics of Phytoplankton Assemblages in Doris Lake Property Lakes, August 1996**

| Lake | Sample Size | Density (cells/L) | Richness (S) | S(90%) | Max. Dom. (%) | Max. Dom. Genus (numerically) | Diversity (H') |
|---|---|---|---|---|---|---|---|
| Patch<br>August 26, 1996 | n = 3 | 224 | 24 | 12 | 31.0 | *Lyngbya* | 2.25 |
| Ogama<br>August 27, 1996 | n = 3 | 16,641 | 13 | 1 | 93.3 | *Oscillatoria* | 0.37 |
| Doris<br>August 28, 1996 | n = 3 | 62,303 | 12 | 2 | 74.4 | *Oscillatoria* | 0.74 |
| Tail<br>August 27, 1996 | n = 3 | 2,365 | 14 | 1 | 91.9 | *Asterionella* | 0.44 |
| Roberts<br>August 27, 1996 | n = 3 | 39,509 | 17 | 3 | 60.8 | *Oscillatoria* | 1.07 |
| Windy<br>August 29, 1996 | n = 3 | 247 | 12 | 3 | 67.8 | *Oscillatoria* | 1.09 |

**S = the number of genera per site.**
**S(90%) = the number of genera contributing to 90% of the density.**
**Max. Dom. = the maximum dominance accounted for by a single genus.**
**H' = Shannon Diversity Index.**

Section 6.1.1. Genera richness and diversity were calculated using the COMM program (Piepenburg and Piatkowski 1993; Appendix 6-1).

- *Results and Discussion*

Lakes in the Doris Lake Property were sampled once during the summer sampling campaign. Zooplankton data are presented in Appendix 6-3. A list of the taxa that were present is given in Table 6.2-3.

Density was highest in Tail Lake (74,799 individuals/m$^3$) and lowest in Windy Lake (7,130 individuals/m$^3$; Figure 6.2-3), both of which had communities that were 98% Rotifera (Figure 6.2-3). Density in Ogama Lake was similar to Tail Lake (73,354 individuals/m$^3$) and Patch and Doris lakes contained similar intermediate densities of 13,953 and 11,693 individuals/m$^3$, respectively. A total of 15 genera was identified from the six lakes (Table 6.2-3). Roberts Lake contained the most genera (S=13; Table 6.2-4), followed by Tail Lake (S=12), Ogama Lake (S=9), Doris Lake (S=7), and Windy Lake (S=6). Patch Lake contained four genera, the lowest for the six lakes.

## Table 6.2-3
## Zooplankton Identified from the Doris Lake Property Lakes, 1996[1]

| Group/Genus | Stage[2] | Patch Lake Aug. 26 | Ogama Lake Aug. 27 | Doris Lake Aug. 28 | Tail Lake Aug. 27 | Roberts Lake Aug. 27 | Windy Lake Aug. 29 |
|---|---|---|---|---|---|---|---|
| ROTIFERA | | | | | | | |
| *Kellicottia longispina* | | + | + | + | + | + | + |
| *Keratella cochlearis* | | | | + | + | + | |
| *Keratella quadrata* | | | | | + | + | |
| *Conochilus unicornis* | colony[3] | | | + | + | + | |
| *Asplanchna* | | | | | + | + | + |
| *Lepadella* | | | | | | + | |
| CLADOCERA | | | | | | | |
| *Holopedium gibberum* | | | + | | + | + | |
| *Daphnia middendorffiana* | | | | | + | | |
| *Daphnia rosea* | | + | | | | | |
| *Daphnia longiremis* | | + | + | | + | + | + |
| *Bosmina longirostris* | | | + | + | + | + | + |
| *Chydorus sphaericus* | | + | + | + | + | + | |
| *Alona guttata* | | | + | | | | |
| COPEPODA | | | | | | | |
| Calanoida | | | | | | | |
| *Diaptomus pribilofensis* | M | | | | + | | |
| | F | | | | + | | |
| *Diaptomus ashlandi* | M | | | | | + | |
| *Limnocalanus macrurus* | M | + | | + | + | + | + |
| | F | + | | + | | + | + |
| | cop. V | | | | | | + |
| | IV | | | | | | + |
| | III | | | | | | + |
| | II | | | | | | + |
| *Epischura lacustris* | M | | + | | | | |
| | F | | + | | | | |
| Calanoid | nauplius | | + | | | + | + |
| Cyclopoida | | | | | | | |
| *Cyclops b. thomasi* | M | | + | | | + | |
| | F | | + | | | + | |

**(continued)**

## Table 6.2-3 (completed)
## Zooplankton Identified from the Doris Lake Property Lakes, 1996[1]

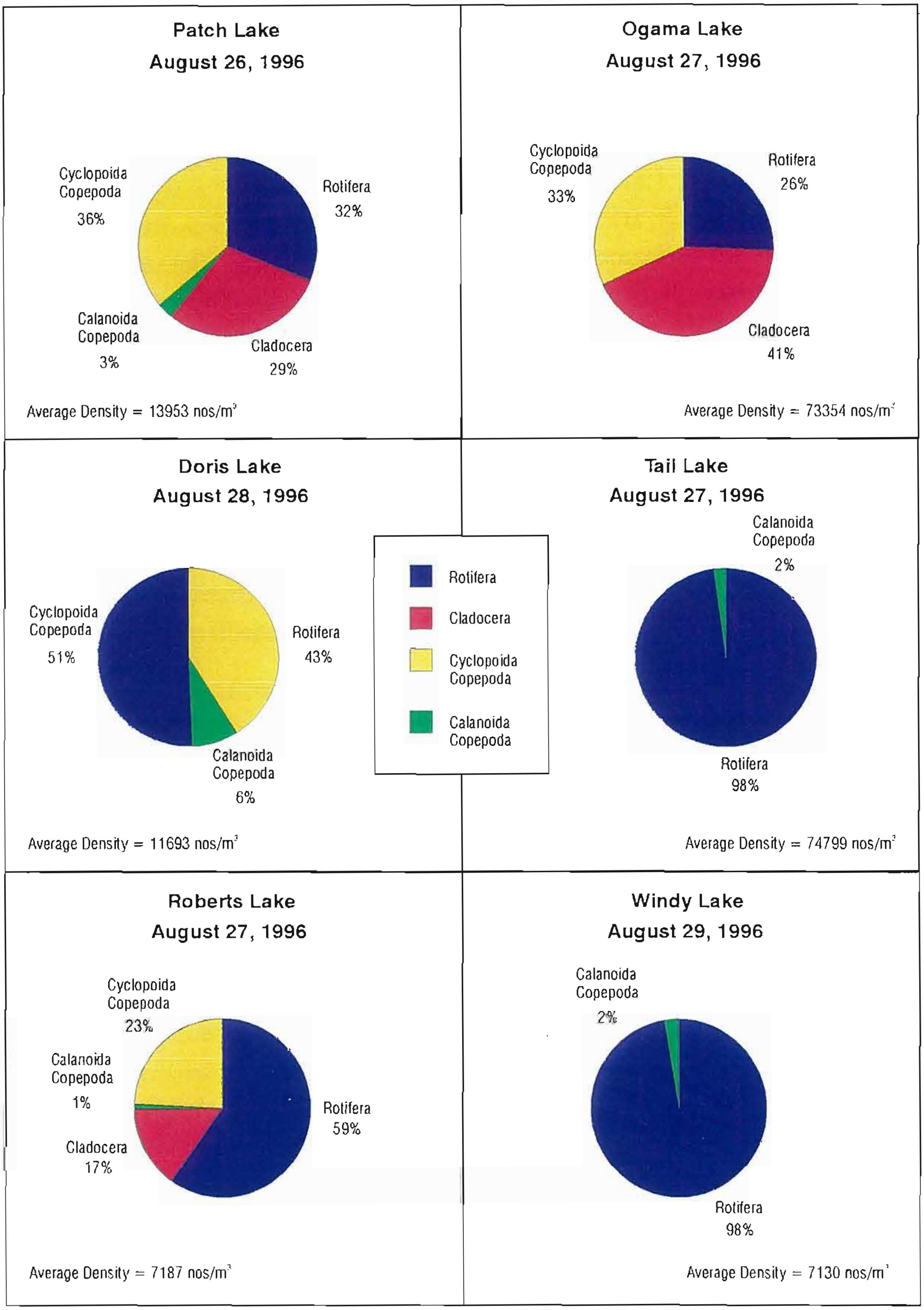
| Group/Genus | Stage[2] | Patch Lake Aug. 26 | Ogama Lake Aug. 27 | Doris Lake Aug. 28 | Tail Lake Aug. 27 | Roberts Lake Aug. 27 | Windy Lake Aug. 29 |
|---|---|---|---|---|---|---|---|
| *Cyclops scutifer* | M | | | + | + | | |
| | F | | | + | + | + | |
| Cyclopoida | cop. | + | + | + | + | + | + |
| Lichomolgidae (parasitic) | cop. | | | | | + | |
| | nauplius | | + | + | + | + | + |

**1: + sign indicates taxa as present at sampling site.**
**2: Conochilus numbers are estimates.**
**3: See Table 6.1-3.**

## Table 6.2-4
## Site Characteristics of Zooplankton Communities for Doris Lake Property, 1996

| Sampling Site | Richness | S(90%) | Max. Dom. | Shannon Diversity Index (H') |
|---|---|---|---|---|
| Doris Lake | 7 | 2 | 82.7 | 0.59 |
| Ogama Lake | 9 | 4 | 36.6 | 1.39 |
| Patch Lake | 4 | 2 | 49.9 | 0.86 |
| Roberts Lake | 13 | 5 | 61.9 | 1.37 |
| Tail Lake | 12 | 3 | 48 | 1.35 |
| Windy Lake | 6 | 1 | 98.3 | 0.09 |

Overall, Rotifera were the most common organisms. Rotifera dominated substantially in three lakes (Tail, Windy and Roberts lakes; 98%, 98% and 59%, respectively; Figure 6.2-3). Rotifers, copepods and cladocerans were of equal occurrence in Ogama and Patch lakes. Cyclopoids and rotifers co-dominated in Doris Lake. The overall dominance of Rotifera in taxa composition differs from that in similar studies in NWT lakes. Lakes in the Boston Property and in the Lac de Gras area were sampled using similar methods in 1996 and, with the exception of Trout Lake in the Boston area, showed an overall dominance of Cyclopoida (Section 6.1 of this report, Rescan 1996).




**Taxonomic Composition and Abundance of Zooplankton Samples, Doris Lake Property, Summer, 1996**

FIGURE 6.2-3

Diversity indices were calculated as outlined in Appendix 6.1 and the results are presented in Table 6.2-4. The Shannon diversity indices ranged from 0.09 in Windy Lake to 1.38 in Ogama Lake, indicating that Windy Lake had the least and Ogama Lake the most diversity. Diversity indices were very similar in Ogama, Roberts and Tail lakes (1.38, 1.37 and 1.35, respectively). The large difference in diversity indices in Tail Lake (H' = 1.35) and Windy Lake (H' = 0.094) indicates that although both lakes possessed the same taxa composition of 98% Rotifera, the rotifer community in Tail Lake was much more diverse than that in Windy Lake.

*Lake Benthos*

- *Methods*

Benthic invertebrate samples were taken at each of the six lakes during the summer sampling period using the methods outlined in Section 6.1.2. Genera richness and diversity were calculated for the dipteran communities using the COMM program (Piepenburg and Piatkowski 1993; Appendix 6-1).

- *Results and Discussion*

The data obtained from the lake benthos samples are listed in Appendix 6-4. A list of the taxa present in each lake is given in Table 6.2-5.

The density of organisms was greatest in Roberts Lake at 28,545 individuals/$m^2$. This was six times higher than in Ogama Lake, which had the next greatest density (4,800 individuals/$m^2$; Figure 6.2-4). Tail and Doris lakes had intermediate densities (3,526 and 2,059 individuals/$m^2$, respectively). Patch and Windy lakes had the lowest densities at 800 and 119 individuals/$m^2$, respectively. There were 23 genera identified from 11 major groups. Roberts and Tail lakes had the greatest number of genera (S=16 and 15, respectively) identified from the most amount of major groups (seven and nine, respectively). One organism was identified to the genus level from Doris Lake. Four major groups were identified in Doris Lake samples. Windy Lake contained five genera in only two major groups.

## Table 6.2-5
## Lake Benthos Data for Doris Lake Property Lakes, 1996[1]

| Major Group | Sub-Group | Genus/Species | Patch Lake Aug. 26 | Ogama Lake Aug. 23 | Doris Lake Aug. 28 | Tail Lake Aug. 27 | Roberts Lake Aug. 27 | Windy Lake Aug. 29 |
|---|---|---|---|---|---|---|---|---|
| AMPHIPODA | | *Gammarus lacustris* | | | | + | | |
| CNIDARIA | Hydrozoa | *Hydra* sp. | + | + | | + | + | |
| DIPTERA | | Undetermined Adult | + | | | | | |
| | Chironomidae | Undetermined pupae | | + | | | | |
| | | Undetermined Adult | | | + | | | |
| | | Undetermined Juvenile | | + | | + | + | |
| | Chironominae | Undet. Chironomini Pupae | | | + | | | |
| | | *Chironomus* sp. | | | + | | + | |
| | | *Chironomus* sp. Larvae | | | + | | | |
| | | *Chironomus* sp. Pupae | | | + | | | |
| | | *Phaenopsectra* sp. | + | + | | + | + | |
| | | *Rheotanytarsus* sp. | | + | | | + | |
| | | *Tanytarsus* sp. | + | + | | + | + | + |
| | Orthocladiinae | Undetermined | | | | | | + |
| | | *Abiskomyia* sp. | | | | | + | |
| | | *Cardiocladius* sp. | | | | + | | |
| | | *Corynoneura* sp. | | | | | + | |
| | | *Cricotopus* sp. | + | | | + | + | + |
| | | *Eukiefferiella* sp. | | | | + | | |
| | | *Phycoidella* sp. | | | | | | + |
| | Prodiamesinae | *Monodiamesa* sp. | + | + | | + | | + |
| | Tanypodinae | *Procladius* sp. | + | + | | + | + | + |
| | | *Thienemannimyia* sp. | + | | | | + | |
| EPHEMEROPTERA | Baetidae | *Baetis* sp. | | + | | | | |
| HOMOPTERA | Cicadellidae | Undetermined Adult | + | | | | | |
| HYDRACARINA | | Undetermined | | | + | + | + | |
| MOLLUSCA | Bivalvia | *Pisidium* sp. | | + | | + | + | |
| | | *Sphaerium* sp. | + | | | | + | |
| NEMATODA | | Undetermined | + | + | + | + | + | + |
| OLIGOCHAETA | Enchytraeidae | Undetermined | + | | | | | |
| | | *Lumbriculus variegatus* | | | | + | + | |
| | Naididae | *Chaetogaster* sp. | | | | + | + | |

**(continued)**

**Table 6.2-5 (completed)**
**Lake Benthos Data for Doris Lake Property Lakes, 1996[1]**

| Major Group | Sub-Group | Genus/Species | Patch Lake Aug. 26 | Ogama Lake Aug. 23 | Doris Lake Aug. 28 | Tail Lake Aug. 27 | Roberts Lake Aug. 27 | Windy Lake Aug. 29 |
|---|---|---|---|---|---|---|---|---|
| | Tubificidae | Undetermined | + | | | | + | |
| | | Undetermined Juvenile | | + | + | | | |
| OSTRACODA | | *Cypris* sp. | + | | | + | + | |
| | | Undetermined | | | | | + | |
| | | *Candona* sp. | + | | | + | + | |
| TRICHOPTERA | | *Grensia praeterita* | | | | + | | |

**1: + sign indicates taxa as present at sampling sites**

With the exception of Windy Lake, all lake benthic communities were dominated by Diptera (Figure 6.2-4). Nematodes were the second most abundant group of organisms. In Windy Lake, the taxonomic composition was opposite to that of the other lakes with 71% abundance of nematodes, followed by dipterans at 29%. There were no great differences between lake benthos data collected from the Doris Lake and Boston claim block areas.

The outcome of the COMM program analysis is presented in Table 6.2-6. According to the Shannon diversity indices, the most diverse dipteran community was found in Tail Lake, followed by Windy, Patch, Roberts and Ogama lakes. The dipteran community in Doris Lake contained only one dipteran genus and therefore was the least diverse.

### 6.2.2 Streams

The outflow streams of the six study lakes (Patch, Ogama, Doris, Tail, Roberts and Windy lakes) in the Doris Lake Property area were sampled for primary and secondary producers during the fall sampling period. The outflow streams sampled are presented in Figure 6.2-1.

**Table 6.2-6**
**Site Characteristics of Lake Benthic Dipteran Communities within the Doris Lake Property, 1996**

| Sampling Site | Season | Richness | S(90%) | Max. Dom. | Shannon Diversity Index (H') |
|---|---|---|---|---|---|
| Patch Outflow | Summer | 6 | 4 | 41.0 | 1.44 |
| Ogama Outflow | Summer | 5 | 3 | 46.3 | 1.18 |
| Doris Outflow | Summer | 1 | 1 | 100 | 0.00 |
| Tail Outflow | Summer | 7 | 5 | 27.8 | 1.67 |
| Roberts Outflow | Summer | 9 | 4 | 70.3 | 1.08 |
| Windy Outflow | Summer | 5 | 5 | 37.0 | 1.50 |

### *6.2.2.1 Primary Producers (Periphyton)*

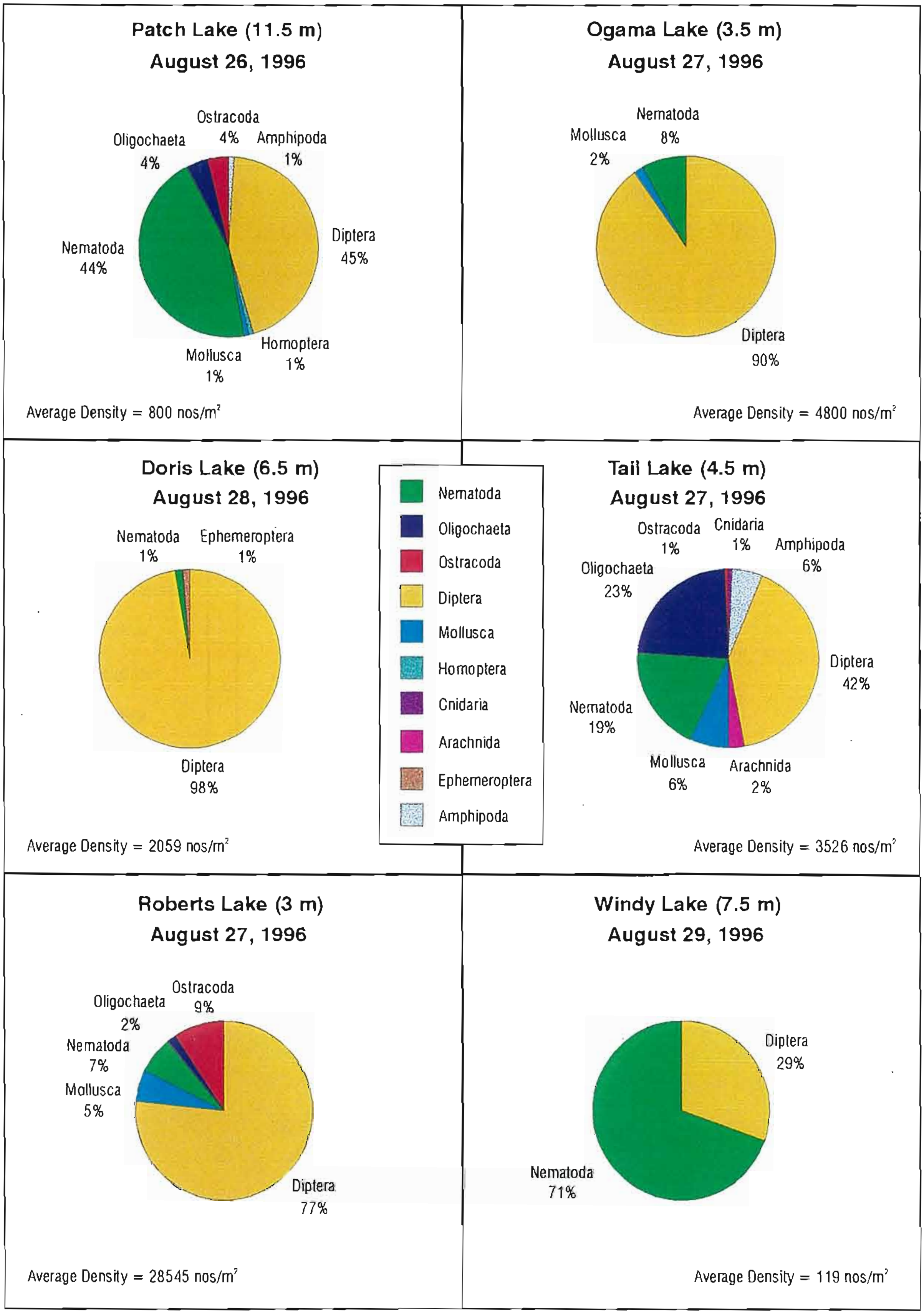
*Methods*

Stream periphyton samples were collected at five lake outflows during the ice-free season. Instantaneous samples for periphyton were collected at Patch, Ogama, Doris, Roberts, and Windy Lake outflows (Figure 6.2-1). No periphyton was visible at Tail Outflow, so no samples were taken at that site. Samples were obtained and processed as described in Section 6.1.2.1.

For purposes of stream site comparisons, site characteristics were determined using the COMM program to genera as described previously (Appendix 6-1).

*Results and Discussion*

The taxonomic identification and enumeration of periphyton from all sample locations are given in Appendix 6-5. Table 6.2-7 presents the periphyton taxa composition and abundance of the five stream sites sampled. Patch, Doris, Roberts, and Windy outflows were all dominated by cyanobacteria, representing 80 to 86% of the periphyton abundance (Table 6.2-7, Figure 6.2-5). Ogama Outflow periphyton consisted of roughly half diatoms and half cyanobacteria. Ogama Outflow was the only stream with a strong diatom component.

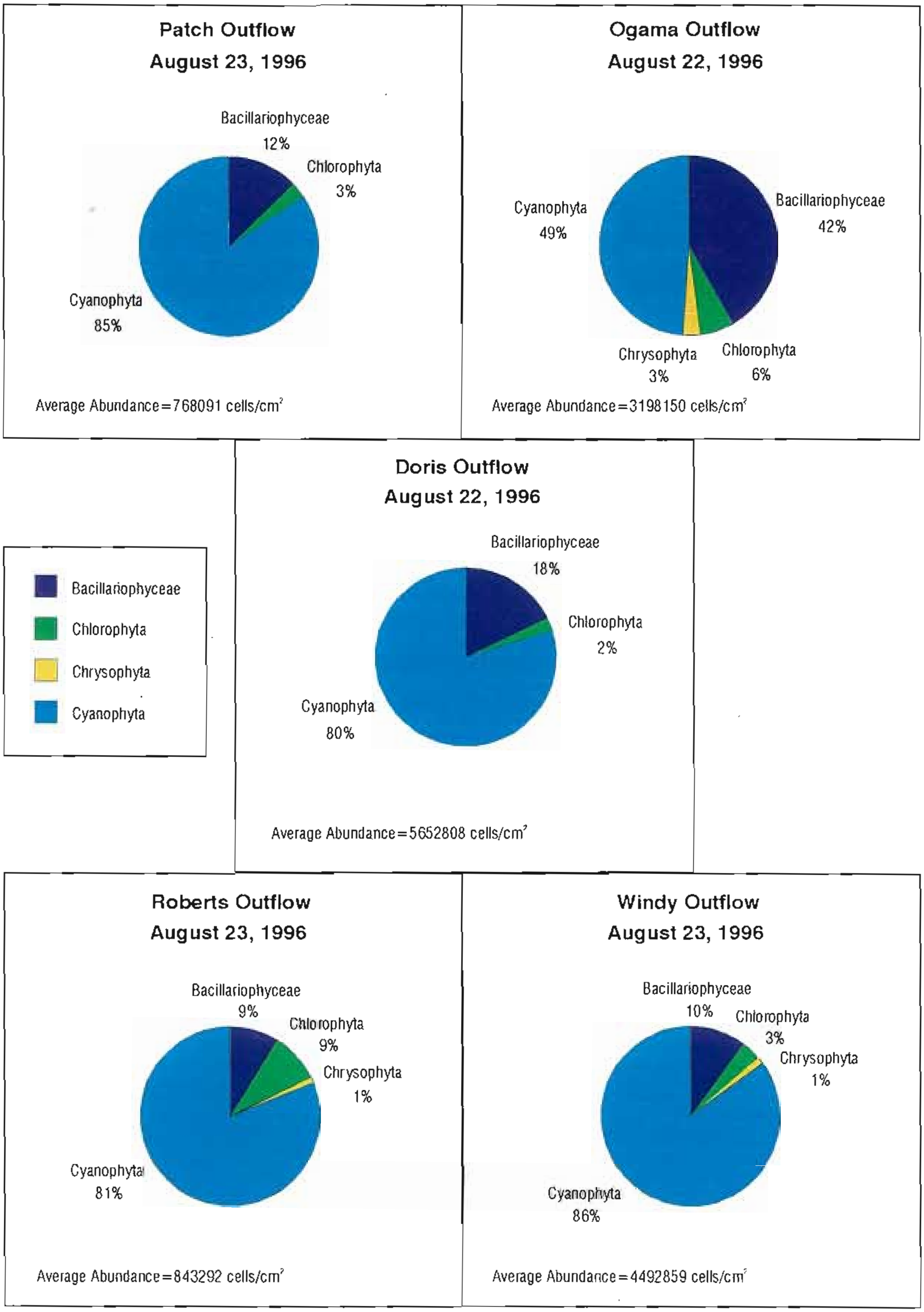



# Taxonomic Composition of Lake Benthic Samples, Doris Lake Property, Fall 1996

FIGURE 6.2-4

BHP

Rescan




BHP

**Periphyton Taxa Composition for Doris Lake Property Streams August 22-23, 1996**

FIGURE 6.2-5

Rescan

**Table 6.2-7**
**Average Periphyton Taxa Composition for**
**Doris Lake Property Streams, August 1996**

| | % Composition | | | | |
|---|---|---|---|---|---|
| **Phylum/ Subphylum** | **Patch Outflow Aug. 23** | **Ogama Outflow Aug. 22** | **Doris Outflow Aug. 22** | **Roberts Outflow Aug. 23** | **Windy Outflow Aug. 23** |
| Bacillariophyceae | 12 | 42 | 18 | 9 | 10 |
| Chlorophyta | 3 | 6 | 2 | 9 | 3 |
| Chrysophyta | 0 | 3 | 0 | 1 | 1 |
| Cyanophyta | 85 | 49 | 80 | 81 | 86 |
| Pyrrophyta | 0 | 0 | 0 | 0 | 0 |
| Ave. Cell Density (cells/cm$^2$) | $7.68 \times 10^5$ | $31.98 \times 10^5$ | $56.53 \times 10^5$ | $8.43 \times 10^5$ | $44.92 \times 10^5$ |

Patch Outflow had the lowest periphyton abundance of the five streams, with a cell density of $7.68 \times 10^5$ cells/cm$^2$. Patch Lake also had the lowest phytoplankton abundance of the six lakes sampled (Table 6.2-1). Doris Outflow had the highest abundance of periphyton, with a cell density of $56.53 \times 10^5$ cells/cm$^2$. Again, Doris Lake had the highest phytoplankton abundance of the six lakes sampled (Table 6.2-1). Both Doris Lake and Doris Outflow were dominated by the genus *Oscillatoria*, which are fillamentous nitrogen-fixing cyanobacteria.

Table 6.2-8 presents the results of the COMM program site analysis. All streams had fairly diverse periphyton assemblages, with no single genus being responsible for more than 53% of the periphyton abundance. Ogama Outflow showed the greatest diversity, with a Diversity Index of 2.63. The range of Diversity Indices for all five stream sites ranged from 1.49 to 2.63.

#### *6.2.2.2 Secondary Producers*

*Stream Benthos*

- *Methods*

  Stream benthos were collected from all six outflow streams in the Doris Lake Property area (Figure 6.1-1). Samplers could not be located at Doris Outflow

**Table 6.2-8**
**Site Characteristics of Periphyton Assemblages for Doris Lake Property Streams, August 1996**

| Stream Site | Sample Size | Density ($cells/cm^2$) | Richness (S) | S(90%) | Max. Dom. (%) | Max. Dom. Genus | Diversity (H') |
|---|---|---|---|---|---|---|---|
| Patch Outflow Aug. 23, 1996 | n = 3 | 768,091 | 23 | 8 | 53.1 | *Anabaena* | 1.74 |
| Ogama Outflow Aug. 22, 1996 | n = 3 | 3,198,150 | 33 | 16 | 26.7 | *Oscillatoria* | 2.63 |
| Doris Outflow Aug. 22, 1996 | n = 3 | 5,652,808 | 28 | 14 | 25.1 | *Oscillatoria* | 2.58 |
| Roberts Outflow Aug. 23, 1996 | n = 3 | 843,292 | 15 | 10 | 28.3 | *Oscillatoria* | 2.32 |
| Windy Outflow Aug. 23, 1996 | n = 3 | 4,492,859 | 27 | 8 | 67.4 | *Gloeotrichia* | 1.49 |

**S = the number of genera per site.**
**S(90%) = the number of genera contributing to 90% of the density.**
**Max. Dom. = the maximum dominance accounted for by a single genus.**
**H' = Shannon Diversity Index.**

during the summer sampling period; an additional five samplers were set and retrieved in the fall. The methods for setting and retrieving Hester-Dendy artificial substrate samplers are outlined in Section 6.1.2. Genera richness and diversity were calculated for the dipteran communities using the COMM program (Piepenburg and Piatkowski 1993; Appendix 6-1).

- *Results and Discussion*

Raw stream benthos data are presented in Appendix 6-7. The organisms identified from the stream benthos samples are listed in Table 6.2-9.

The highest average density (23,194 individuals/$m^2$) was found in the Ogama Outflow samples, over six times greater than the second largest density in Windy Outflow (Figure 6.2-6). Patch, Doris and Tail outflows had intermediate densities. Roberts Outflow contained an average of 85 individuals/$m^2$. There were 37 genera identified from 16 major groups (Table 6.2-9). The number of genera ranged from ten in Roberts Outflow to 24 in Ogama Outflow. Patch, Tail and Windy outflows all contained the same number of genera (S=19).

## Table 6.2-9
## Stream Benthos Identified From Doris Lake Property, 1996[1]

| Major Group | Sub-Group | Genus/Species | Patch Outflow Aug. 3 | Ogama Outflow Aug. 2 | Tail Outflow Aug. 2 | Doris Outflow Aug. 25 | Roberts Outflow Aug. 3 | Windy Outflow Aug. 1 |
|---|---|---|---|---|---|---|---|---|
| AMPHIPODA | Eusiridae | *Pseudacanthus estuarius* | + | | | | | |
| CNIDARIA | Hydrozoa | *Hydra* sp. | + | + | + | + | + | + |
| COLEOPTERA | Dytiscidae | *Hydaticus* sp. | | + | | | | |
| | Staphylinidae | Undetermined | + | | | | | |
| COLLEMBOLA | Isotomidae | *Isotoma* sp. | | | + | | | |
| | | *Isotomurus palustris* | + | + | | | | |
| | | *Isotomurus* sp. | | + | | | | |
| | Poduridae | *Hypogastrura* sp. | | | + | | | |
| | | *Podura aquatica* | | + | + | | | |
| | Sminthuridae | *Bourletiella spinata* | | + | + | | | |
| | | *Sminthurides* sp. | | + | | | | |
| DIPTERA | | Undetermined Adult | | | + | | | |
| | Chironomidae | Undetermined Pupae | | | + | + | + | |
| | | Undetermined Adult | + | + | + | | | + |
| | | Undetermined Juvenile | | | + | + | + | + |
| | Chironominae | Undetermined Pupae | | | + | | | |
| | | Undet. Chironomini Pupae | + | | | | | |
| | | Undet. Tanytarsini Pupae | | + | | | | |
| | | Undet. Tanytarsini Juvenile | | + | | | | |
| | | *Rheotanytarsus* sp. | + | + | + | + | | + |
| | | *Stempellinella* sp. | | | | | | + |
| | | *Tanytarsus* sp. | + | + | + | + | | + |
| | Diamesinae | *Diamesa* sp. | | + | | + | | |
| | Empididae | Undetermined Pupae | | | + | | | + |
| | | *Chelifera* sp. | + | | | | | + |
| | | *Clinocera* sp. | | | | | | + |

**(continued)**

## Table 6.2-9
## Stream Benthos Identified From Doris Lake Property, 1996[1]

| Major Group | Sub-Group | Genus/Species | Patch Outflow Aug. 3 | Ogama Outflow Aug. 2 | Tail Outflow Aug. 2 | Doris Outflow Aug. 25 | Roberts Outflow Aug. 3 | Windy Outflow Aug. 1 |
|---|---|---|---|---|---|---|---|---|
| | Orthocladiinae | Undetermined Adult | + | | | | | |
| | | Undetermined Juvenile | + | + | | | | |
| | | Undetermined Pupae | + | + | | | | |
| | | *Corynoneura* sp. | + | + | + | | + | + |
| | | *Cricotopus* sp. | + | + | + | + | + | + |
| | | *Eukiefferiella* sp. | + | + | + | + | | + |
| | | *Euryhapsis* sp. | | + | | | | |
| | | *Heterotanytarsus* sp. | | | + | | | |
| | | *Thienemanniella* sp. | | | | | | + |
| | Simuliidae | Undetermined Adult | | | | | | + |
| | | *Simulium* sp. Pupae | + | | + | + | | + |
| | | *Simulium* sp. Larvae | + | | + | | | + |
| | | *Simulium* sp. | | + | | | | |
| | Tanypodinae | *Procladius* sp. | | + | + | | + | |
| | | *Thienemannimyia* sp. | + | + | + | + | + | + |
| | Tipulidae | *Hexatoma* sp. | + | | | | | |
| | | *Tipula* sp. | | + | | | + | |
| | Tabanidae | *Tabnus* sp. | | | | + | | |
| EPHEMEROPTERA | Baetidae | *Baetis* sp. | | + | + | | | + |
| | Ephemerellidae | *Ephemerella* sp. | + | + | | | | + |
| HOMOPTERA | *Aphididae | Undetermined Adult | + | | | + | | |
| | *Cicadellidae | Undetermined Adult | | | + | | | |
| HYDRACARINA | | Undetermined | + | + | + | + | + | + |
| ISOPODA | Idoteidae | *Saduria* sp. | + | | | | | |
| NEMATODA | | Undetermined | + | + | + | + | + | + |
| OLIGOCHAETA | Lumbriculidae | Undetermined | | | + | | | |
| | | *Lumbriculus variegatus* | | + | | | | |
| | Naididae | *Nais* sp. | + | + | + | | + | + |
| | | *Chaetogaster* sp. | + | + | + | | + | + |
| | Tubificidae | Undetermined | | | + | + | | + |
| | | Undetermined Juvenile | + | + | | | | |

(continued)

## Table 6.2-9 (completed)
## Stream Benthos Identified From Doris Lake Property, 1996[1]

| Major Group | Sub-Group | Genus/Species | Patch Outflow Aug. 3 | Ogama Outflow Aug. 2 | Tail Outflow Aug. 2 | Doris Outflow Aug. 25 | Roberts Outflow Aug. 3 | Windy Outflow Aug. 1 |
|---|---|---|---|---|---|---|---|---|
| OSTRACODA | | *Cypris* sp. | + | + | | | | |
| | | Undetermined | + | | | | | + |
| | | *Candona* sp. | + | + | + | + | + | + |
| PLECOPTERA | Nemouridae | *Podmosta* sp. | + | | + | + | + | + |
| TARDIGRADA | | Undetermined | + | + | + | + | | + |
| THYSANOPTERA | | Undetermined Adult | | + | | | | |
| | | Undetermined Nymph | | | + | | | |
| TURBELLARIA | | Undetermined | | | | | | + |

**1: + sign indicates taxa as present at sampling site**

Diptera were the dominating organisms in all outflow samples, with the exception of Roberts Outflow, which was co-dominated by Cnidaria, Diptera, Plecoptera and Oligochaeta (Figure 6.2-6). The increase in the number of organisms contributing to the taxonomic composition tends to increase with decreasing density, and therefore a community like Roberts Outflow may appear more diverse than it actually is.

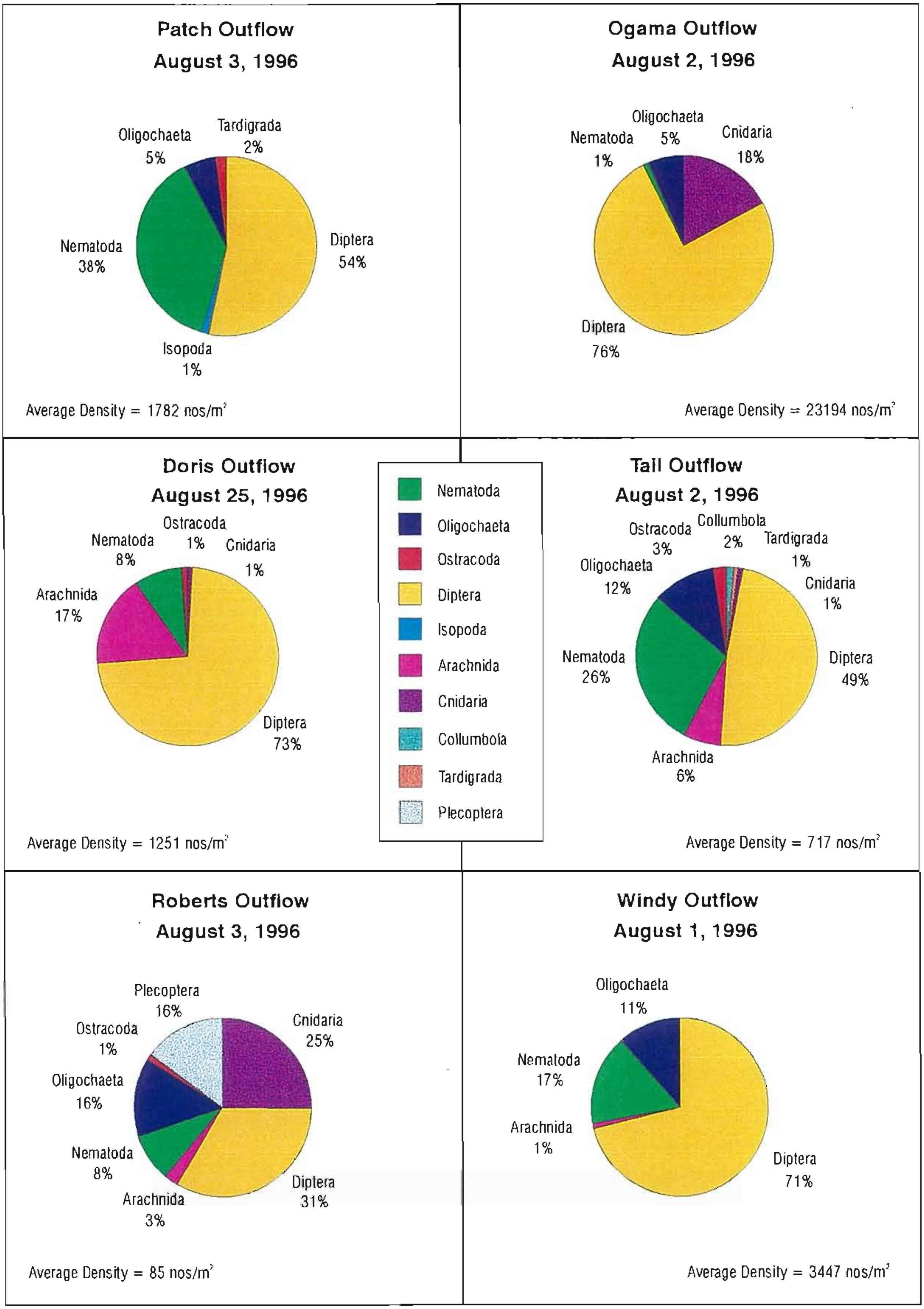
The dipteran community in Roberts Outflow was the most diverse according to the Shannon Diversity Indices (H' = 1.48; Table 6.2-10). The order of the diversity was as follows:

Roberts Outflow > Windy Outflow = Tail Outflow > Patch Outflow > Doris Outflow > Ogama Outflow.

With the exception of Roberts Outflow, the streams in the Doris Lake area had similar taxonomic composition and abundance to Stickleback Outflow in the Boston area (Section 6.1.2.2).

## Table 6.2-10
## Site Characteristics of Benthic Dipteran Communities for Outflow Streams within the Doris Lake Property, 1996

| Sampling Site | Season | Richness | S(90%) | Max. Dom. | Shannon Diversity Index (H') |
|---|---|---|---|---|---|
| Patch Outflow | Summer | 7 | 3 | 45.3 | 1.15 |
| Ogama Outflow | Summer | 10 | 2 | 60.3 | 0.85 |
| Doris Outflow | Fall | 8 | 3 | 69.1 | 1.02 |
| Tail Outflow | Summer | 9 | 5 | 57.4 | 1.38 |
| Roberts Outflow | Summer | 5 | 5 | 42.9 | 1.48 |
| Windy Outflow | Summer | 9 | 4 | 42.3 | 1.40 |




# Taxonomic Composition of Stream Benthos Samples, Doris Lake Property, August 1996

FIGURE 6.2-6

BHP

Rescan

# 7. Fisheries

# 7. FISHERIES

## 7.1 Introduction

The fish sampling component of the 1996 field program continued work previously conducted at the Boston Property, and expanded fisheries studies to the Doris Lake Property and proposed winter trail route. The 1996 fish study was directed at accomplishing three tasks including:

- an aerial survey of all inflow and outflow creeks of the Doris Property lakes, the Boston Property lakes and the proposed winter trail;
- a description of all inflow and outflow creeks that are deemed suitable fish habitat; and
- an examination of the biological characteristics of fish species in both streams and lakes.

## 7.2 Sampling Sites and Methods

Previous field seasons focused on Trout, Stickleback and Spyder lakes (all found within the Boston Property; Rescan 1994, 1995) and Doris, Tail, Patch and Windy lakes (all found within the Doris Lake Property; Klohn-Crippen 1995). In 1996, sampling efforts were extended to include all associated inflow and outflow streams on both properties. The water courses that intersected the proposed winter trail were also examined.

### 7.2.1 Aerial Survey

Aerial surveys of the entire Hope Bay Belt were conducted in order to determine the overall importance of inflow and outflow streams of lakes as fish habitat. First, streams were labelled as either ephemeral or permanent, and examples of streams deemed extremely poor fish habitat were photographed for reference. All other streams were photographed, given an identification number and measured for approximate length using GPS waypoints at the headwaters and outflows.

### 7.2.2 Stream Survey

#### *7.2.2.1 Fish Habitat*

Fish habitat was characterized by several factors:

- average velocity (m/s);
- percent runs/riffles/pools;
- bank vegetation;
- stream bank and stream substrate composition; and
- mean stream wetted width.

For each stream, habitat was classified in at least three 100 m sections. Average velocity was measured using the timed float method. Mean stream width was determined by taking an average of five wetted width measurements. The remaining habitat characteristics were estimated visually.

#### *7.2.2.2 Fish Biology*

From the aerial survey, several inflow and outflow streams were selected as potentially important for fish habitat. These streams were examined for species presence/absence and described using Department of Fisheries and Oceans (DFO) stream survey parameters.

Species presence/absence was determined by sampling each stream using an electrofisher. A team of one biologist and one technician surveyed three 100 m sections of each stream (when possible), using a Smith Root 15A gas-powered electrofisher. Special attention was given to the regulation of voltage to ensure that fish were not harmed - a voltmeter was used to test the amount of voltage distributed into the water. Relevant machine data was collected at each site (amperage, voltage, water temperature and duration). All collected fish were identified to species, measured for fork length (nearest 1.0 mm) and then released. While population estimates were not the primary intent of this exercise, sampling efforts (electrofishing duration and catch size) were used to calculate catch per unit effort (CPUE). Minnow traps were not used as they were found to be relatively ineffective for species other than ninespine stickleback (*Pungitius pungitius*; Rescan, 1995).

### 7.2.3 Lake Fish Species Survey

The Boston Property lakes, Spyder and Trout, were examined in 1996 as part of an ongoing collection of baseline data. In the anticipation of a bulk sampling project on the Doris Property for 1997, potentially affected lakes (Doris, Ogama, Patch, Tail and Windy) were examined in more detail in 1996 than in the reconnaissance survey by Klohn-Crippen in 1995.

Lakes were sampled in early August, using a system of experimental gillnets. Each sampling station consisted of two nets set perpendicular to shore and parallel to each other. One net consisted of 1.91, 2.54 and 3.81 cm mesh, while the second net consisted of 5.08, 6.35, 8.89 and 12.70 cm mesh. The first and second gillnets had total lengths of 45.7 and 61.0 m, respectively. Fish mortality was minimized by setting gillnets for a maximum of eight hours and checking each net hourly. At each sample site, a pair of GPS coordinates was obtained, surface water temperature was measured and gillnet set and lift times were recorded. Seining was conducted on Windy Lake in June and throughout the Doris Property study lakes in early August. A 15.2 m beach seine (2 mm mesh) was used.

All live fish captured were individually identified to species and measured for fork length (nearest 1.0 mm). Notes were made as to which gillnet panel fish were caught in. For the dead catch, each individual was identified to species and sex, measured for fork length, total weight (nearest 50 grams), gonad weight (nearest 1.0 g) and maturity. Maturity was determined using an index described in Bond and Erickson (1985). A left pectoral fin and/or a saggital otoloith was removed for aging. Eggs were not removed for fecundity estimates as no gravid females were captured. A section of dorsal muscle tissue and the entire liver were removed from each fish for trace metal analysis. Tissues were stored in clean labelled whirl pack bags and subsequently frozen. Tissue analysis was carried out using procedures adapted from *Recommended Guidelines for Measuring Metals in Puget Sound Marine Water, Sediment, and Tissue Samples* prepared for the United States Environmental Protection Agency (EPA) and the Puget Sound Water Quality Authority (1995). Tissues are first dessicated gravimetrically by drying the sample for 12 hours at 103°C. Tissue samples are homogenized either mechanically or manually prior to digestion. The hotplate digestion involves the use of nitric acid followed by repeated additions of hydrogen peroxide. Instrumental analysis is by atomic absorption spectrophotometry (EPA Method 7000) and/or inductively coupled plasma - optical emission spectrophotometry (EPA Method 6010).

## 7.3 Sampling Results

### 7.3.1 Aerial Survey

Results of the aerial survey are presented in Table 7.3-1. Note the creeks that have been designated as suitable fish habitat. Creeks labelled “run off” were considered to be poor fish habitat (Plate 7-1). Figures 7.3-1 and 7.3-2 illustrate the location of each site listed in Table 7.3-1. The site numbers as well as coordinates illustrate how points were used in the estimation of creek length (in km). Approximate length was not estimated for ephemeral creeks.

### 7.3.2 Stream Habitat Survey

#### *7.3.2.1 Doris Property*

Results of the stream habitat survey are provided in Appendix 7-1. The streams surveyed included Doris Outflow, Windy Outflow, Ogama Outflow and Ogama Inflow. Doris Outflow begins as an outflow from the northern end of Doris Lake, flowing through Roberts Lake before terminating at Roberts Bay (Plate 7-2). A set of falls near Doris Lake acts as a physical barrier, preventing certain species, such as lake trout (*Salvelinus namaycush*) and lake whitefish (*Coregonus clupeaformis*), from moving into Doris Lake (Plate 7-3). Therefore, fish populations found in Doris Lake are resident and isolated from populations in the lower reaches of the Doris Outflow.

Windy Outflow is a shallow low-flow stream that begins as an outflow on the northern end of Windy Lake and terminates at Hope Bay. This creek offers little spawning habitat, but may be important for feeding. Unlike Doris Outflow, Windy Outflow has a continuous connection with Hope Bay, possibly allowing access for anadromous species to Windy Lake.

## Table 7.3-1
## Summary of Inflow and Outflow Creeks Examined, Hope Bay Belt, 1996

| Stream | Site | Length | Coordinates | | Comments |
|---|---|---|---|---|---|
| | WP01 | <500 m | 68°02.944' | 106°37.622' | |
| Windy Outflow | WP02 | | 68°06.142' | 106°37.677' | |
| Windy Outflow | WP03 | 2.78 km | 68°07.355' | 106°41.025' | |
| Doris Outflow | WP04 | | 68°08.422' | 106°35.184' | |
| Doris Outflow | WP05 | 3.25 km | 68°10.144' | 106°34.410' | |
| Doris Outflow | WP06 | 4.26 km | 68°10.697' | 106°35.953' | |
| Doris Outflow | WP07 | < 500 m | 68°08.292' | 106°35.044' | |
| Ogama Outflow | WP08 | | 68°06.570' | 106°34.020' | |
| Ogama Outflow | WP09 | 1.06 km | 68°06.180' | 106°32.898' | |
| | WP10 | | 68°05.470' | 106°34.008' | run off |
| | WP11 | 2.42 km | 68°04.170' | 106°32.927' | |
| Ogama Inflow | WP12 | | 68°04.186' | 106°31.423' | |
| Ogama Inflow | WP13 | 4.87 km | 68°01.697' | 106°29.343' | |
| | WP14 | | 68°04.556' | 106°35.115' | run off |
| | WP15 | | 68°03.584' | 106°35.597' | run off |
| | WP16 | | 68°02.428' | 106°34.008' | run off |
| | WP17 | | 68°02.744' | 106°31.507' | run off |
| | WP18 | | 68°01.211' | 106°32.530' | run off |
| | WP19 | | 68°02.634' | 106°37.238' | run off |
| | WP20 | | 68°07.024' | 106°35.618' | run off |
| | WP21 | | 68°07.392' | 106°35.468' | run off |
| | WP22 | | 68°04.337' | 106°37.238' | run off |
| Boulder Creek | WR01 | | 67°54.726' | 106°35.831' | |
| Boulder Creek | WR02 | 12.4 km | 67°54.962' | 106°36.432' | |
| | BP01 | 0.7 km | 67°40.433' | 106°20.620' | run off |
| Trout Outflow | BP02 | | 67°38.893' | 106°21.769' | |
| | BP03 | 3.93 km | 67°37.809' | 106°20.812' | |
| NE Spyder Inflow | BP04 | | 67°41.385' | 106°19.837' | also site F9 and F10 |
| | BP05 | | 67°40.174' | 106°19.822' | run off |
| | BP06 | | 67°40.496' | 106°20.648' | run off |
| | BP07 | | 67°40.138' | 106°20.523' | run off |
| | BP08 | | 67°39.582' | 106°20.376' | run off |
| | BP12 | | 67°37.809' | 106°20.812' | run off |
| | BP13 | | 67°38.211' | 106°22.630' | run off |
| | BP14 | | 67°38.574' | 106°23.225' | run off |

Ogama Outflow is a short stream that flows from Ogama Lake to Doris Lake. This creek has a slow flow rate, numerous large deep pools and shallow runs. Ogama Outflow does not appear to contain suitable spawning habitat, but may serve as a feeding and rearing habitat, especially for lake trout.

Ogama Inflow is a narrow high-flow stream that connects a chain of lakes draining into Ogama Lake. In the sections surveyed, this creek was relatively shallow and contained a few pools and back eddies; however, since this creek does connect a series of lakes, it is important as both fish habitat and a migration route between habitats.

#### *7.3.2.2 Proposed Winter Trail Route*

Boulder Creek is a wide, long (approximately 13 km) stream that intersects the proposed winter trail route (Figure 7.3-2, inset). This creek, which drains a series of lakes, terminates at the Koignuk River. At its head, Boulder Creek is slow moving with a mud/cobble substrate, but becomes faster with a rocky substrate near its confluence with the Koignuk River (Plate 7-4). The rock/gravel sections near this confluence provide suitable habitat for arctic grayling (*Thymallus arcticus*) and trout spawning.

The Koignuk River extends from a chain of lakes west of Spyder Lake. The river converges with the outflow of Spyder Lake and continues toward its terminus at Hope Bay. The Koignuk is a fast running river with a predominantly rock/cobble substrate interspersed with numerous gravel bars (excellent spawning habitat) and two major falls. These falls may not act as a migration barrier to species such as arctic grayling, but could possibly prevent upstream migrations of arctic char (*Salvelinus alpinus*) and anadromous coregonids (*e.g.*, arctic cisco, *Coregonus autumnalis*). As a result, it is unlikely that anadromous forms of species such as arctic char inhabit Spyder Lake. Instead, if present, resident (landlocked) forms of such species may occur.

#### *7.3.2.3 Boston Property*

The streams surveyed on the Boston Property include NE Spyder Inflow, Trout Outflow and the Spyder River. NE Spyder Inflow is a relatively long stream,

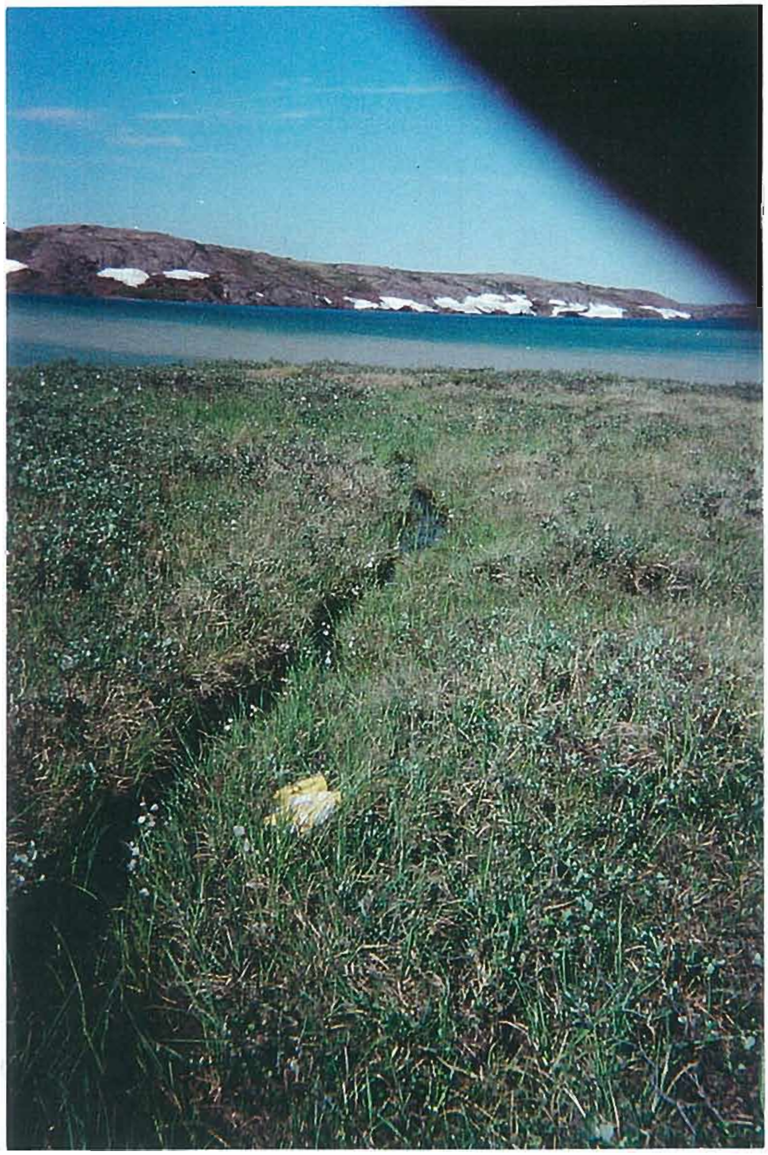
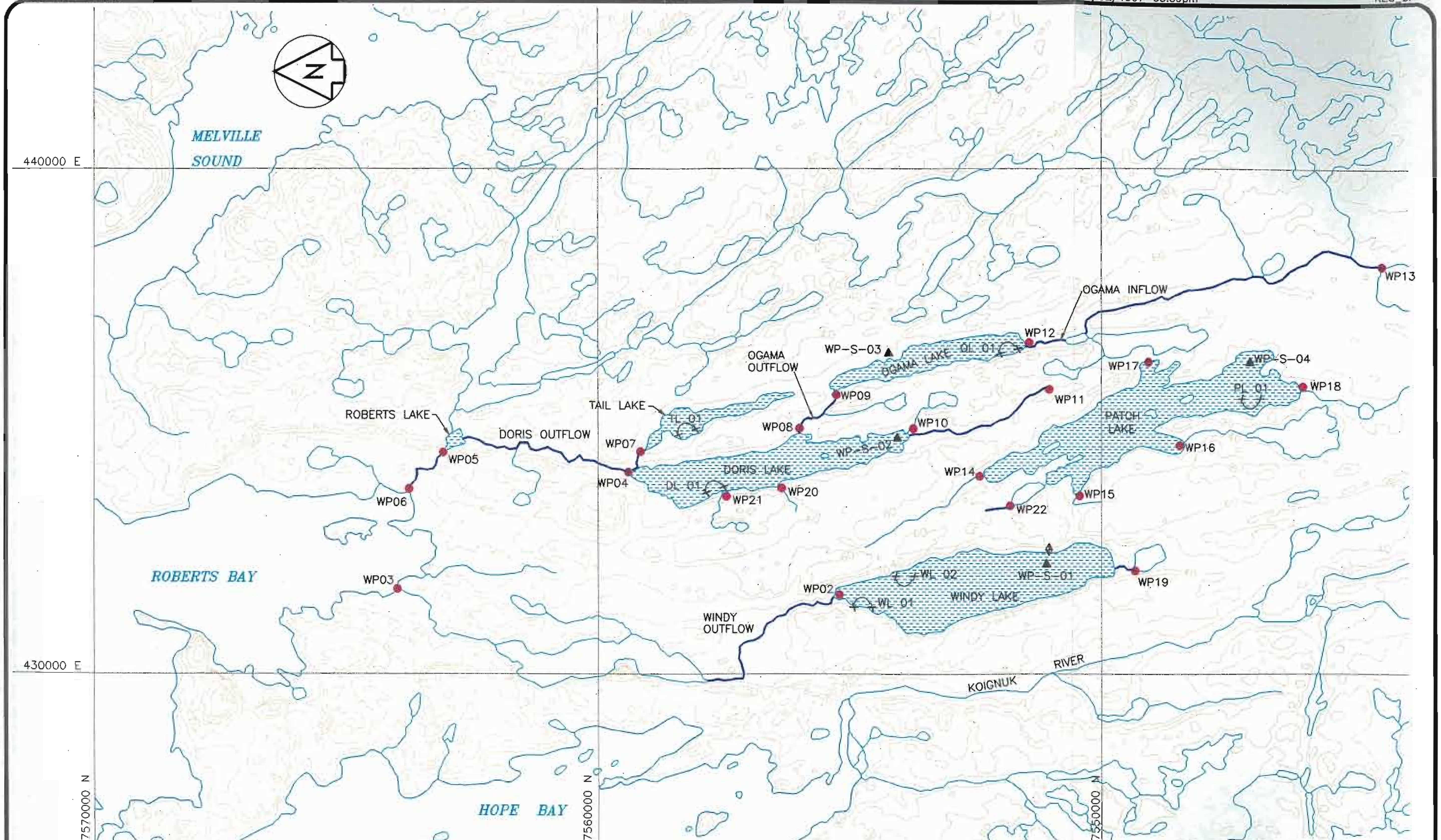


Plate 7-1: This photograph illustrates a typical ephemeral (run-off) stream, here shown flowing into Patch Lake. Numerous such streams are found throughout the Hope Bay Belt Area.

Cad No. a2159s | Scale: 1:75 000 | Job No. 526-5 | 13/02/1997-03:39pm | RES BF




NOTE:
CONTOUR INTERVAL 20m

LEGEND:
- AERIAL SURVEY SITES
- SEINE SITES
- GILLNET SITES OF OUTFLOW
- CAMP SITE

0 2500m

BHP

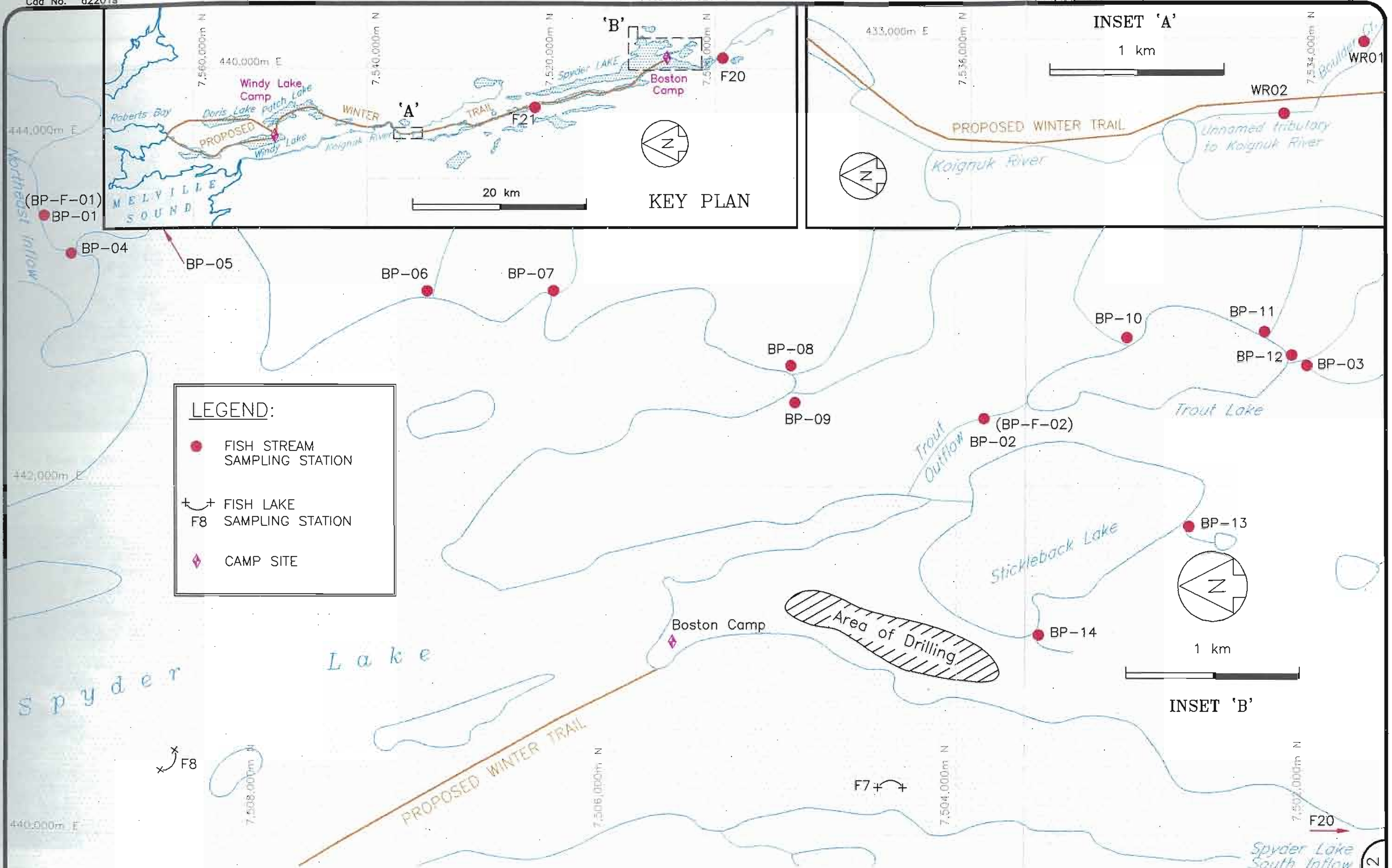
# Fisheries Sampling Stations
# Doris Lake Property, 1996

Rescan

Fig 7.3-1

Source: Klohn-Crippen, 1995 fig3-11.dwg

Cad No. a2201s | Scale: Scale: 1:21 000 | Job No. 526-5 | 18/03/1997-02:57pm RES_BF




BHP

Fisheries Sampling Stations
Boston Property, 1996

Rescan

Fig 7.3-2

Plate 7-2: The Doris Outflow terminus, here shown flowing into Roberts Bay.

Plate 7-3: The Doris Outflow falls located immediately downstream from Doris Lake. These falls may act as a migration barrier for many species of fish, especially the coregonids.

Plate 7-4: Boulder Creek near the Boulder Creek-Koignuk River confluence.

extending from a chain of lakes east of Spyder Lake then draining into the northeast portion of Spyder Lake (Plate 7-5). This stream is also referred to as the Northeast Inflow of Spyder Lake. NE Spyder Inflow consists almost exclusively of a rock/cobble bottom (with small sections of cobble/gravel), clear water and a moderate water flow. Second to Spyder River, NE Spyder Inflow is the largest stream connected to Spyder Lake. As a result, it is especially important as a spawning habitat for lake trout and arctic grayling.

The Spyder River terminates as a southern inflow into Spyder Lake. At this confluence, the substrate of the river is extremely rocky, especially in autumn low water levels (Plate 7-6). As a consequence, it is doubtful that these sections are important as spawning grounds.

Trout Outflow is a small fast flowing stream, connecting Trout Lake to Spyder Lake. The creek substrate consists almost entirely of rock and cobble, with some gravel sections. There are no pools, but the creek does widen considerably at its confluence with Spyder Lake. Trout Outflow is deep enough to allow fish to move between Trout and Spyder lakes, but has limited potential for spawning habitat.

### 7.3.3 Fish Biology Stream Surveys

Appendix 7-2 summarizes the electrofishing results for all survey creeks. Lake trout, lake whitefish and ninespine stickleback (not shown) were present in the survey streams, with lake trout and ninespine stickleback dominating the catch. Due to time constraints and large catch sizes, actual counts of ninespine sticklebacks were not conducted. Unlike 1995, arctic grayling were not found in creeks during the 1996 field season. However, lake trout young-of-the-year (y-o-y) less than 50 mm captured in the Spyder River and NE Spyder Inflow may have been misidentified y-o-y arctic grayling, due to difficulty in identifying fish in early life stages. To prevent uncertain identifications in the future, y-o-y will be identified using species keys or samples will be preserved in 10% buffered formalin for later identification. Of the creeks examined, NE Spyder Inflow, Boulder Creek and the Koignuk River had the highest CPUEs of y-o-y fish. As a result, it would appear that streams on the Boston Property are more productive than creeks found on the Doris Property. This is supported by the contrast in size of the creeks between properties, with the Boston creeks being much larger.

However, seasonal and sampling bias may also contribute to the observed differences.

### 7.3.4 Fish Biology Lake Surveys

Results of the lake surveys conducted in the Hope Bay Belt are not compared by property, due to the low sample sizes from Spyder and Trout lakes. As a consequence, results for biological characters, except for length, are pooled from all lakes and presented by fish species. Mean fork length for each species in each lake is presented in Table 7.3-2. The raw data are presented by lake and by species in Appendix 7-3.

**Table 7.3-2**
**Mean Fork Length (mm) ± Standard Deviations of Fish Species Caught in the Hope Bay Belt Study Lakes (1996)**

| Sample Site | Arctic Grayling | Cisco | Lake Trout | Lake Whitefish |
|---|---|---|---|---|
| Windy Lake | ___ | ___ | $\bar{x}$ = 472 ± 117.5, n=19 | $\bar{x}$ = 409 ± 14.1, n=2 |
| Patch Lake | ___ | $\bar{x}$ = 235 ± 68.5, n=6 | $\bar{x}$ = 556 ± 133.8 , n=13 | $\bar{x}$ = 475 ± 26.6, n=3 |
| Ogama Lake | ___ | $\bar{x}$ = 539 ± 155.9, n=4 | $\bar{x}$ = 291 ± 59.0, n=5 | $\bar{x}$ = 342 ± 51.4, n=23 |
| Tail Lake | ___ | ___ | $\bar{x}$ = 562 ± 149.0, n=21 | ___ |
| Doris Lake | ___ | $\bar{x}$ = 262.4 ± 32.7, n=18 | $\bar{x}$ = 699 ± 228.1, n=3 | $\bar{x}$ = 412.2 ± 57.4, n=19 |
| Spyder Lake | ___ | ___ | $\bar{x}$ = 623.5 ± 153.4, n=10 | $\bar{x}$ = 521 ± 0, n=1 |
| Trout Lake | $\bar{x}$ = 289.3 ± 82.1, n=4 | ___ | ___ | ___ |

#### *7.3.4.1 Catch Distribution*

Figure 7.3-3 summarizes the distribution of absolute catch for three species and seven mesh sizes. Catch per unit effort (CPUE) for all four fish species observed in large and small mesh nets are presented in Tables 7.3-3 and 7.3-4, respectively.

Of the four species captured in the 1996 field season, lake trout were the most prevalent. Lake trout were captured in every lake except Trout Lake and were present in every mesh size, with the highest catch in small mesh nets placed in Windy Lake. Also, cisco (*Coregonus artedii*) showed up in the catch for the first time during the 1996 field season, probably due to the range of mesh sizes used.

Plate 7-5: This photograph of NE Spyder Inflow shows the many riffle and pool sections that are important for fish spawning. This picture was taken near the terminus at Spyder Lake.

Plate 7-6: The Spyder River near its inflow to the southern tip of Spyder Lake. Note the extremely low water levels which are typical during autumn.

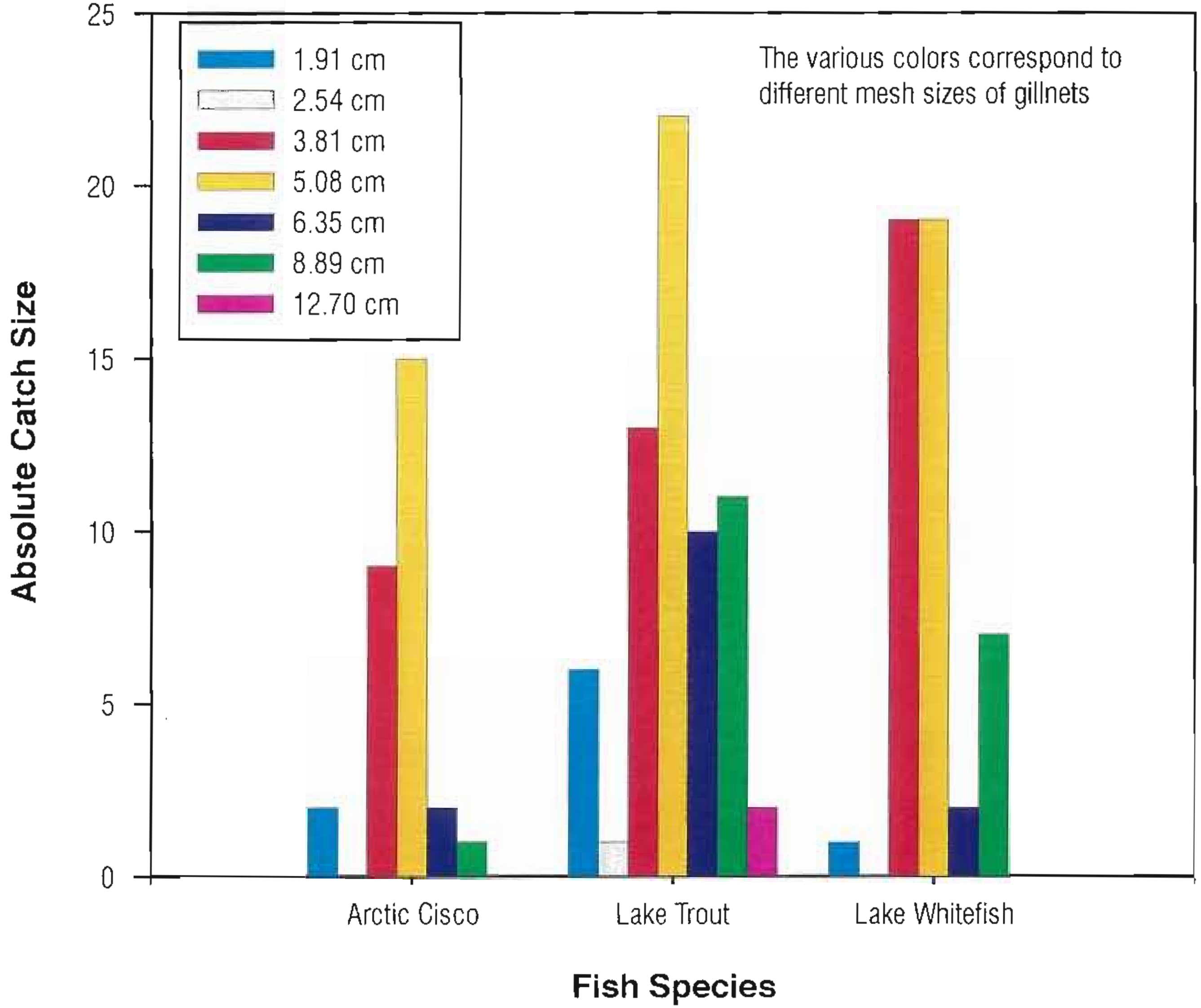



FIGURE 7.3-3

BHP

**Catch Distribution of Three Species Captured in Multimesh Gillnets in Lakes at the Hope Bay Belt Study Area, 1996**

Rescan

**Table 7.3-3**
**Catch per Unit Effort (CPUE)**
**for Large Mesh Nets (fish/45.7 metres/hour) for**
**Fish Species Caught in the Hope Bay Belt Study Lakes (1996)**

| Sample Site | Arctic Grayling | Cisco | Lake Trout | Lake Whitefish |
|---|---|---|---|---|
| Windy Lake (WP-01) | ___ | ___ | 1.00 | ___ |
| Windy Lake (WP-02) | ___ | | 0.67 | ___ |
| Patch Lake | ___ | 0.30 | 0.76 | 0.30 |
| Ogama Lake | ___ | ___ | 0.21 | 1.26 |
| Tail Lake | ___ | ___ | 0.72 | ___ |
| Doris Lake | ___ | 0.15 | 0.15 | 0.15 |
| Spyder Lake (F7) | ___ | ___ | 0.46 | ___ |
| Spyder Lake (F8) | ___ | ___ | 0.13 | 0.13 |
| Trout Lake | 0.53 | ___ | ___ | ___ |

**Table 7.3-4**
**Catch per Unit Effort (CPUE)**
**for Small Mesh Nets (fish/61.0 metres/hour) for**
**Fish Species Caught in the Hope Bay Belt Study Lakes (1996)**

| Sample Site | Arctic Grayling | Cisco | Lake Trout | Lake Whitefish |
|---|---|---|---|---|
| Windy Lake (WP-01) | ___ | ___ | 0.49 | ___ |
| Windy Lake (WP-02) | ___ | | 2.04 | 0.45 |
| Patch Lake | ___ | 0.62 | 1.38 | 0.15 |
| Ogama Lake | ___ | 0.95 | 0.19 | 4.00 |
| Tail Lake | ___ | ___ | 1.57 | ___ |
| Doris Lake | ___ | 2.72 | 0.48 | 3.04 |
| Spyder Lake (F7) | ___ | ___ | 0.32 | ___ |
| Spyder Lake (F8) | ___ | ___ | 0.65 | 0.13 |
| Trout Lake | 0.53 | ___ | ___ | ___ |

Lake whitefish had the highest CPUE in small mesh nets placed in Ogama Lake, while cisco had the highest CPUE in small mesh nets placed in Doris Lake. Arctic grayling were the least prevalent, occurring only in the Trout Lake catch.

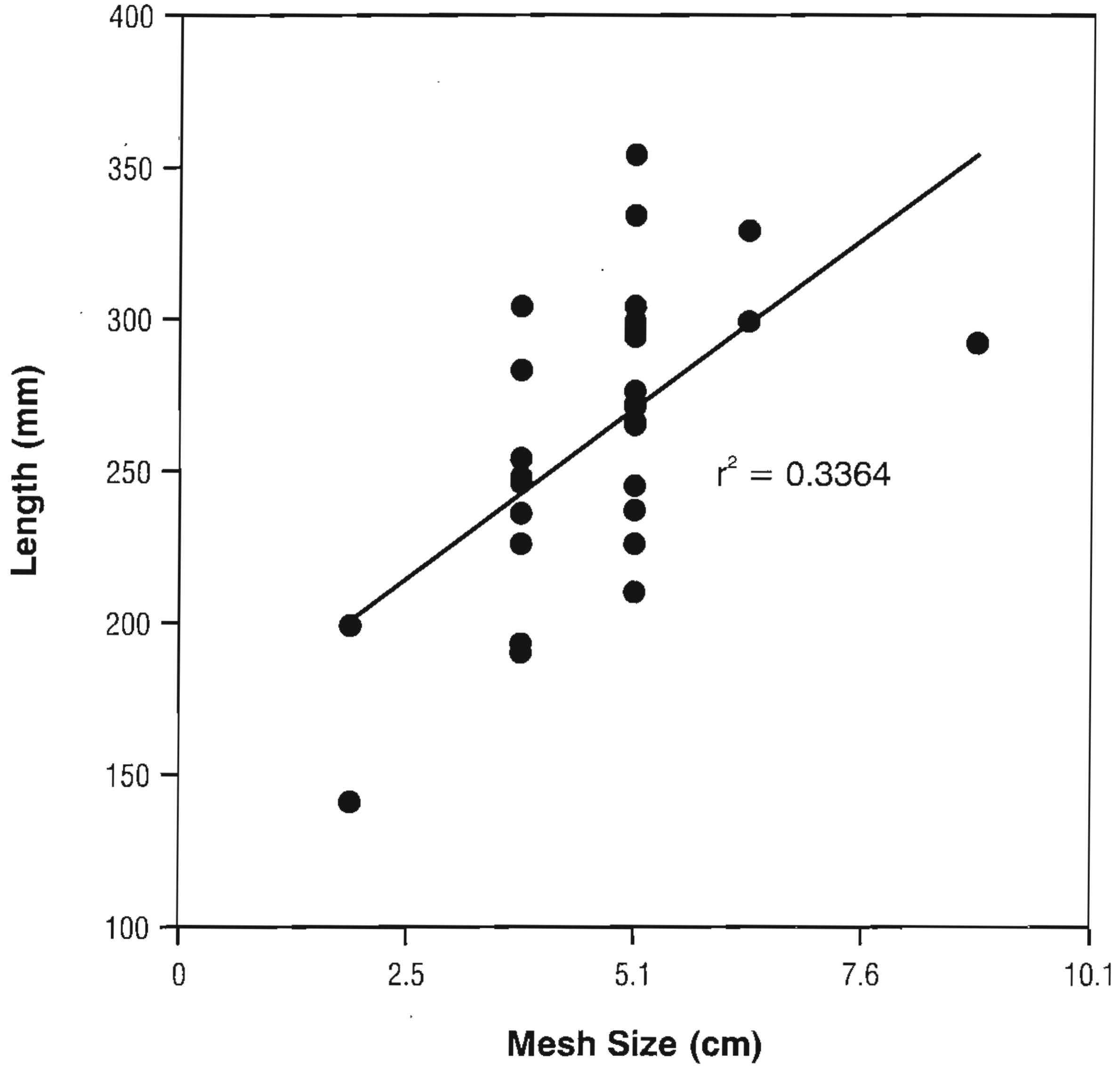
In general, mesh size did appear to have an affect on the size or species of fish captured. Figures 7.3-4 to 7.3-6 illustrate the relationship between gillnet mesh size and fork length of three species captured. Table 7.3-5 presents, by mesh size, lake trout or lake whitefish obtained. Johnson (1976, 1983) confirms that gillnet size selectivity is poor at best, but stresses that multiple mesh sizes should be used to ensure that all size classes are captured. Therefore, this data could be interpreted as the actual distribution of fish size (and age) present in a particular lake.

**Table 7.3-5**
**Mean Size (length in mm) ± Standard Deviations of Fish Species Caught in Each Gillnet Mesh Size for 1996**

| Mesh Size | Arctic Grayling | Lake Cisco | Lake Trout | Lake Whitefish |
|---|---|---|---|---|
| 1.91 cm | ___ | $\bar{x}$ = 170 ± 41.0, df=2 | $\bar{x}$ = 615 ± 98.5, df=6 | $\bar{x}$ = 392 ± 0, df=1 |
| 2.54 cm | ___ | ___ | $\bar{x}$ = 633 ± 0, df=1 | ___ |
| 3.81 cm | $\bar{x}$ = 234 ± 14.1, df=2 | $\bar{x}$ = 242 ± 37.3, df=9 | $\bar{x}$ = 129 ± 35.7, df=13 | $\bar{x}$ = 380 ± 56.7, df=19 |
| 5.08 cm | $\bar{x}$ = 345 ± 88.4, df=2 | $\bar{x}$ = 276 ± 38.8, df=15 | $\bar{x}$ = 562 ± 149.0, df=22 | $\bar{x}$ = 388.7 ± 79.1, df=19 |
| 6.35 cm | ___ | $\bar{x}$ = 314 ± 21.2, df=2 | $\bar{x}$ = 536 ± 96.6, df=10 | $\bar{x}$ = 317 ± 13.4, df=2 |
| 8.89 cm | ___ | ___ | $\bar{x}$ = 545 ± 170.7, df=11 | $\bar{x}$ = 405 ± 76.6, df=7 |
| 12.70 cm | ___ | ___ | $\bar{x}$ = 562 ± 156.3, df=2 | ___ |

### *7.3.4.2 Size Distribution*

Size (fork length and weight) distributions and means for three species are presented for all lakes in Figures 7.3-7 and 7.3-8. Mean fork lengths of four fish species are presented by study lake in Table 7.3-2 and by gillnet mesh size in Table 7.3-5. In all species, (particularly in lake trout) the majority of fish captured comprised the smaller size classes, but length frequency appeared to be normally distributed. This does not preclude the possibility that such bimodality does not occur in each lake. However, small sample sizes did not allow for such an analysis. The two coregonid species present, cisco and lake whitefish, do not overlap in size distribution. This lack of size overlap suggests that these two species partition the available resources and environment. Similar observations have been noted in lake whitefish - least cisco interactions, where lake whitefish were found to be benthic feeders, while cisco were pelagic feeders (Lindsey, 1981). Interpretation of weight frequency distributions is less clear, due to small




***Note:*** *Data from all study lakes were pooled.*

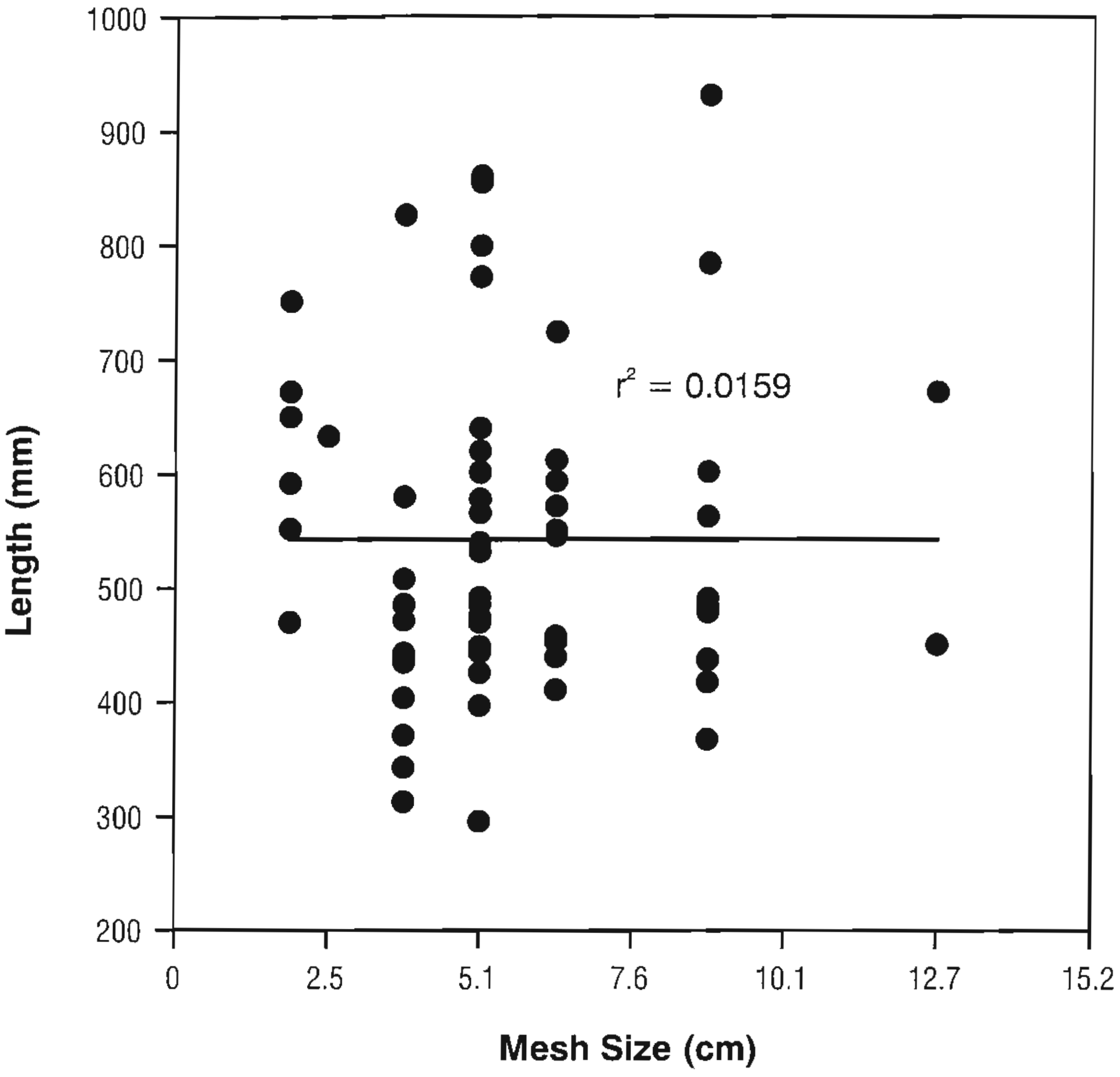
*Despite the poor relationship, catch length does increase with mesh size.*

BHP

**Relationship Between Gillnet Mesh Size and Fork Length of Cisco Captured**

FIGURE 7.3-4

Rescan




**Note:** *In contrast to cisco lake trout length did not increase with larger mesh sizes.*

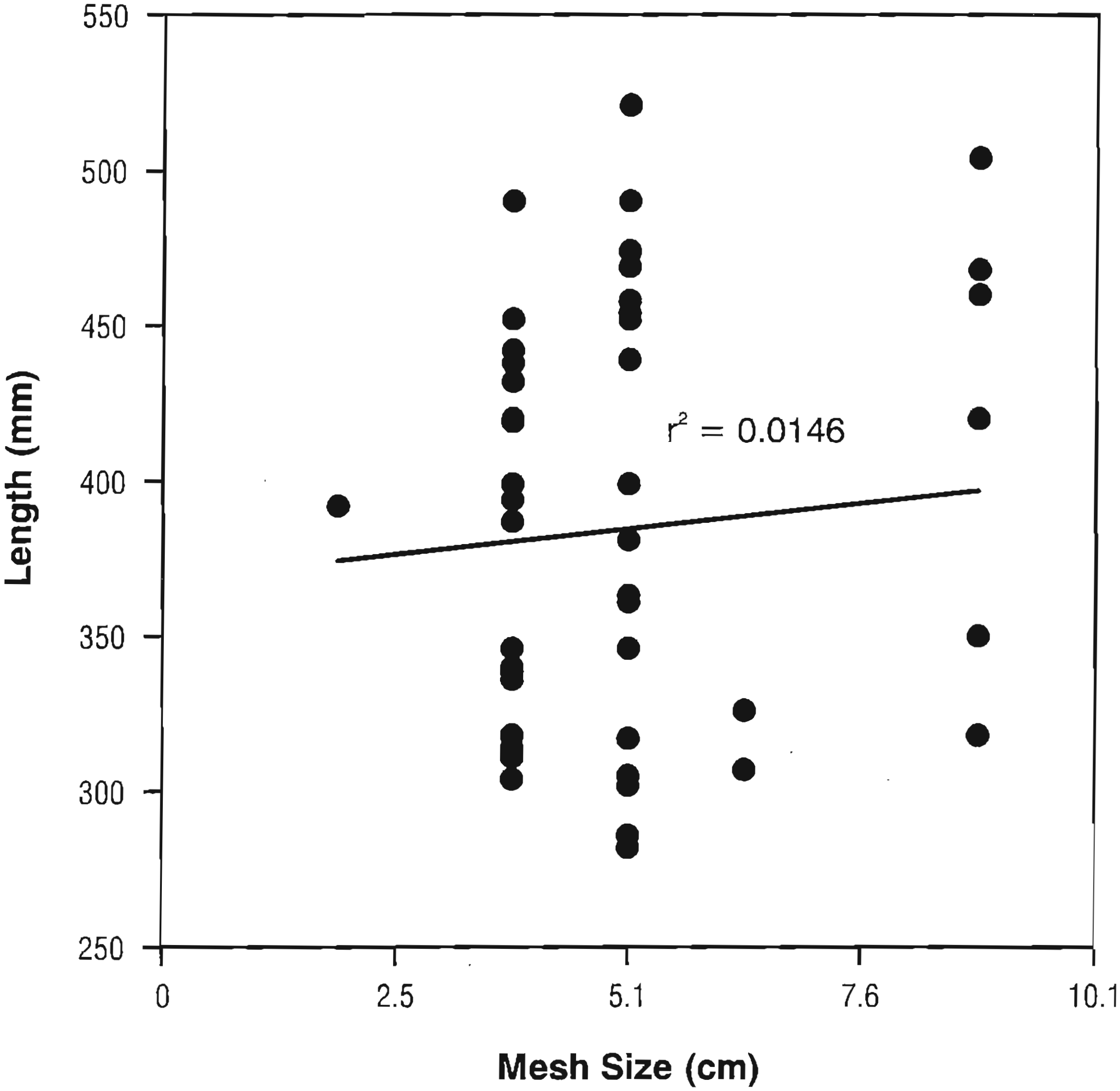
*Data from all study lakes has been pooled.*

# Relationship Between Gillnet Mesh Size and Lake Trout Fork Length

FIGURE 7.3-5

BHP

Rescan




***Note:*** *No significant relationship between gillnet mesh size and fish length is observed.*

*Data from all study lakes has been pooled.*

BHP

**Relationship Between Gillnet Mesh Size and Lake Whitefish Fork Length**

FIGURE 7.3-6

Rescan

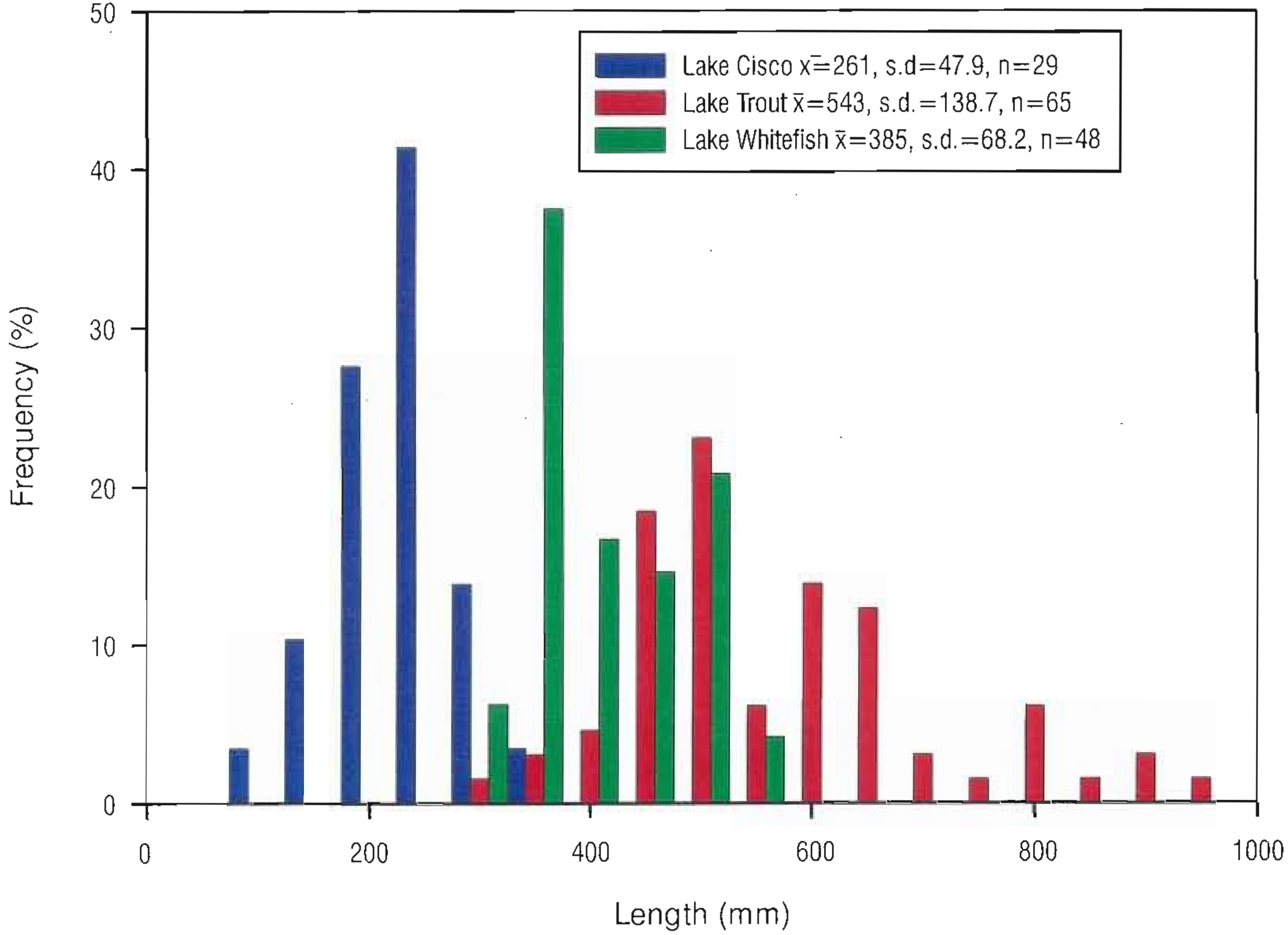



FIGURE 7.3-7

BHP

**Length Distribution of Three Fish Species Sampled in the Hope Bay Belt Study Area, 1996**

Rescan

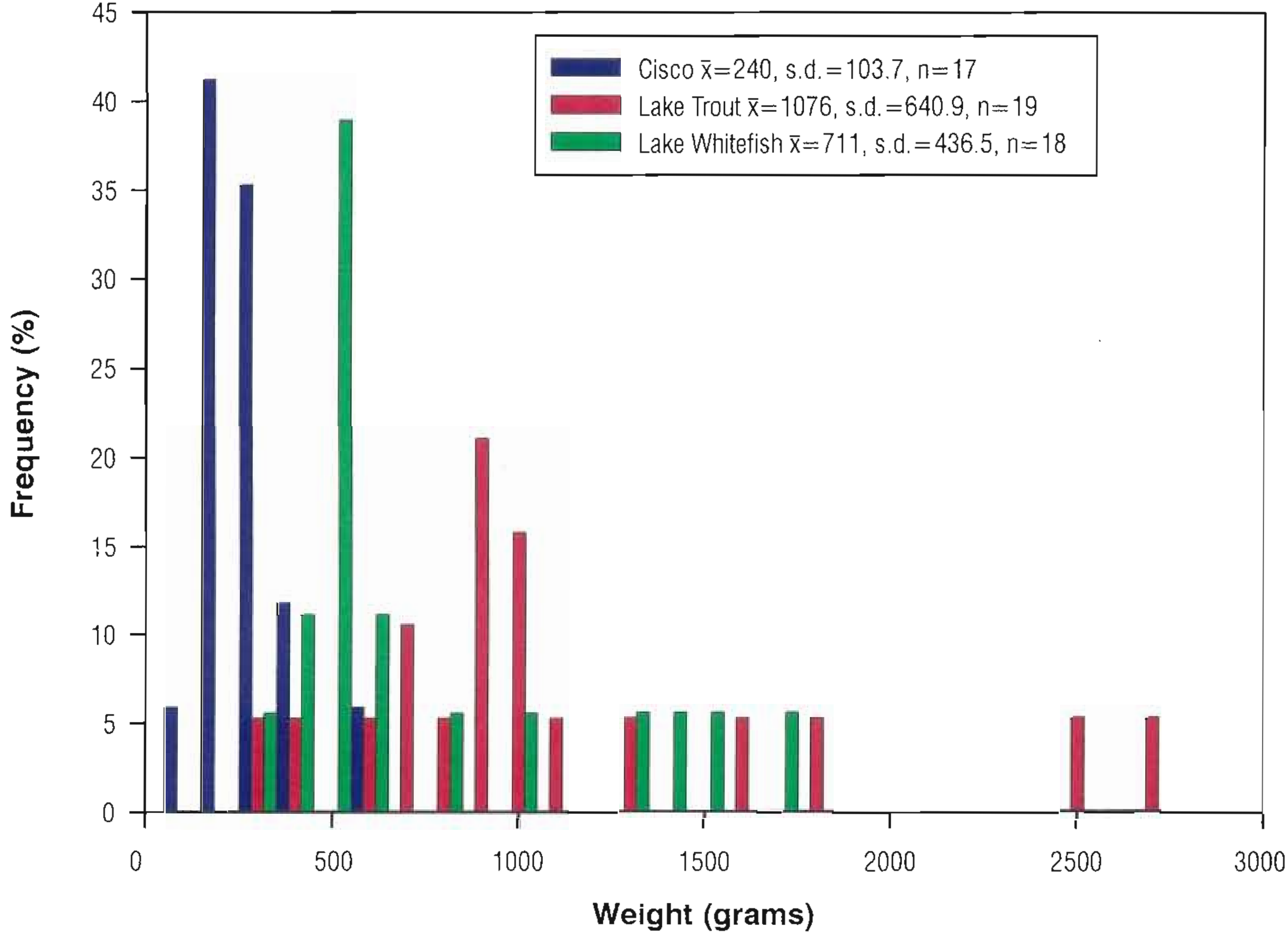



FIGURE 7.3-8

BHP

**Weight Distribution of Three Fish Species Sampled in the Hope Bay Belt Study Area, 1996**

Rescan

sample sizes. Lake whitefish and arctic cisco weight and length distributions do exhibit the same pattern of segregation as in length.

*7.3.4.3 Age, Condition and Maturity*

Figures 7.3-9 to 7.3-11 illustrate the relationship between size (fork length) and age in three fish species. Regression analysis demonstrated a strong linear fit (low variability) in lake whitefish and a poor fit in lake trout (high amount of unexplained variation). In all species, especially in the coregonids, the greatest growth is observed before the age of maturity (approximately ten years). This accelerated growth is observed in the cisco length data (Figure 7.3-9). The ranges of age observed were 7 to 21 years, 6 to 39 years and 5 to 29 years in cisco, lake whitefish and lake trout, respectively.

Condition factors (K) distribution and means are presented in Figure 7.3-12. Mean condition factors were around 1.0 in all species, indicating healthy fish. However, K values did vary greatly in lake trout, and to a lesser extent in cisco and lake whitefish. Overall, condition factors were found to decrease with increasing age. This degradation in health is documented to occur in coregonids (Dabrowski 1985). A decline in condition with increasing age was most pronounced in cisco and less evident in lake whitefish. However, it should be noted that all species examined were in early stages of gonad development for the oncoming spawning season (late September-October). If food is limiting, then gonad development requires the use of energy stored in the form of lipids and muscle tissue. As a result, a fish that is in poor health could appear to be healthy, as condition factor is calculated using fish total weight and length. This is especially true for female fish, which invest a great deal of energy into egg production (Dabrowski 1985). Ideally, condition factor is best used as an indicator of health when only male fish are examined well before spawning. Unfortunately, limited sample sizes of the current data do not allow for such an analysis.

Figures 7.3-13 to 7.3-15 illustrate the relationship between gonadosomatic index (GSI) and age. The gonadosomatic index is a measure of an individual's reproductive effort and when traced over time can indicate the onset of spawning. In general, females of a species usually have a higher GSI than males, but this difference is most pronounced during spawning. In the three species examined, GSI values for both sexes overlap, especially in lake trout. Two immature individuals were observed in the lake trout sample (five and six years) and the cisco sample (eight and nine years). These values are consistent with the known age of maturity in each species (Scott and Crossman 1973). Gonadosomatic indices were observed to vary considerably among individuals of a particular age class. Coregonids and lake trout exposed to the harsh environment of arctic ecosystems are believed to spawn every other year (Dabrowski 1985). The variation in GSI values observed in the current data seem to support this odd year spawning behavior.

### *7.3.4.4 Trace Metal Analysis*

The objective of consumption guidelines is basically to protect humans from the harmful intake of toxic materials. In the absence of industrial sources of heavy metals in the Hope Bay Belt only parent materials in the watersheds are considered responsible for the background values detected in fish, which are very low.

Due to low sample sizes, trace metals were examined in liver and dorsal muscle tissue composites. A composite for each tissue was done for each species and each lake. Individual samples were used for Spyder, Trout and Ogama lakes. Results of the trace metal analysis on a dry weight basis are presented in Appendix 7-4.

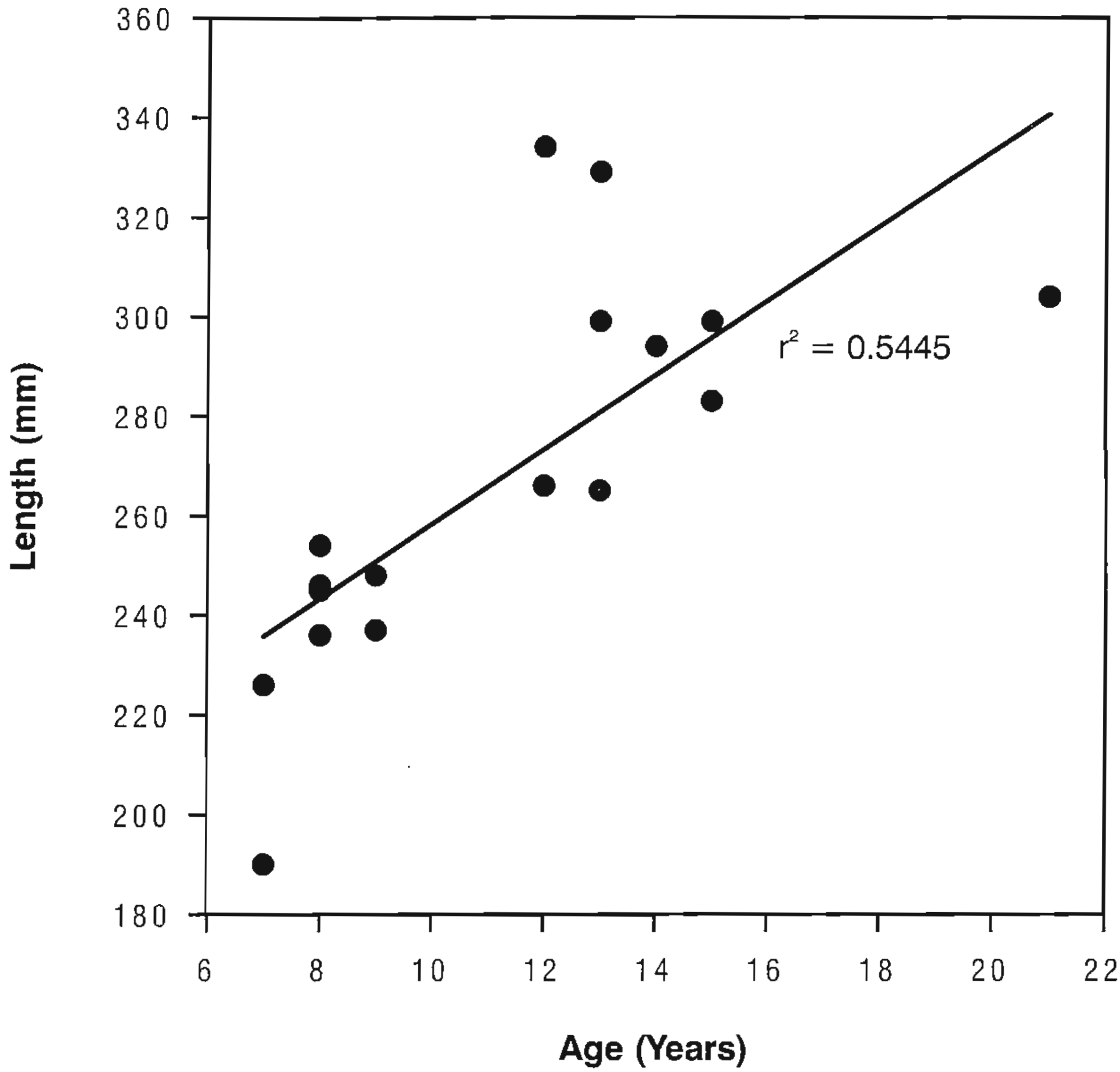
Mercury is the only trace metal for which consumption guidelines, set by Health and Welfare Canada are enforced. The maximum allowable level of mercury in fish tissue is 0.5 mg/kg wet weight (CCREM 1993). To allow a comparison of dry and wet weight values, the Hope Bay Belt data were converted to wet weight values by multiplying dry basis results by 0.2. All mercury values observed fell below the acceptable limit of 0.5 mg/kg.

Other metals for which guidelines have been written include arsenic, lead and zinc. Table 7.3-6 places selected Hope Bay Belt results in perspective *vis a vis* other reported background levels in Canadian fish and existing guidelines. A compilation of other background metal levels in 14 species of fish from the non-pristine lower Fraser River is given in Appendix 7-5.

# Table 7.3-6
## Metal Consumption Guidelines and Concentrations in Fish from Hope Bay Belt and Representative Canadian Location

| Element | Canadian Guideline[1] | Representative Canadian Background[1] ppm wet wt. | Hope Bay Belt Lake Trout ppm wet wt. |
|---|---|---|---|
| Arsenic | 3.5 | 02.-0.47 | <0.05 |
| Cadmium | N/A | <0.1 | <0.02 |
| Copper | N/A | 0.5 | 0.047 |
| Lead | 0.5 | <2.7 | <0.05 |
| Zinc | 100 | <48 | 0.624 |
| Mercury | 0.5 | <0.5 | 0.045 |

**1: Source Rescan 1990.**
**N/A - not available.**



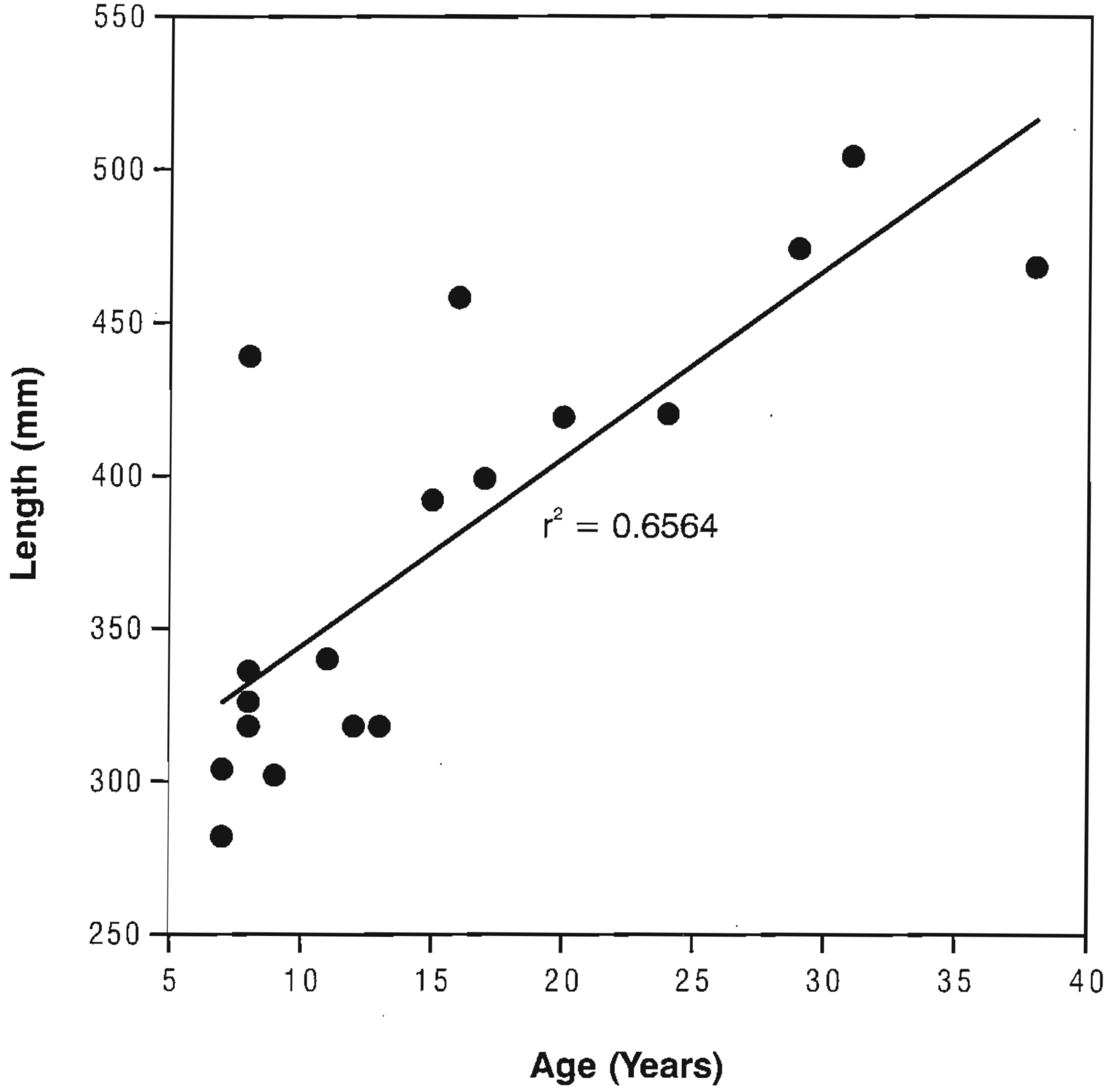

***Note:*** *Data from all study lakes were pooled*

FIGURE 7.3-9

BHP

**Size (Length) at Age for Cisco**

Rescan



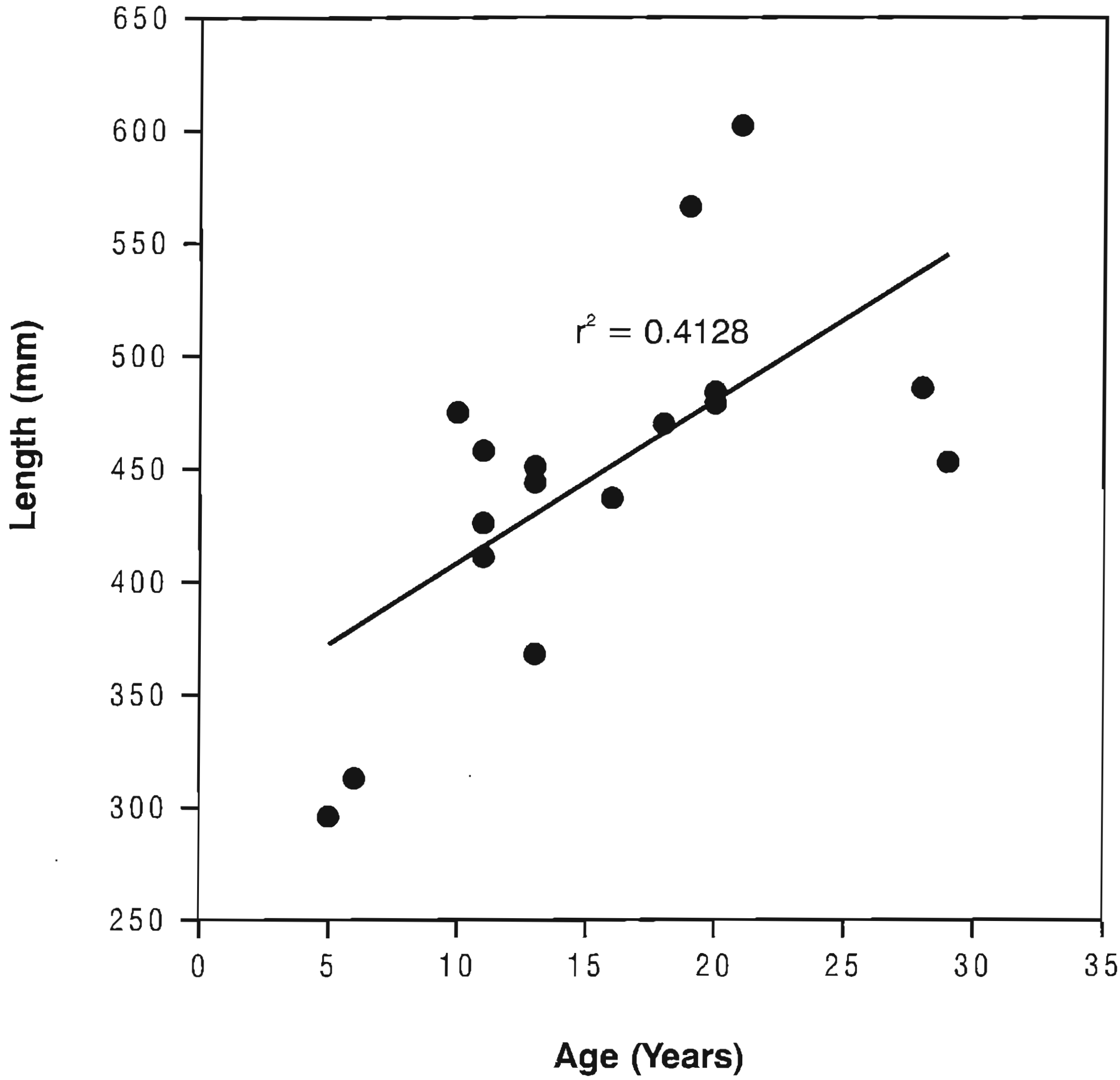

***Note:*** *Data from all study lakes were pooled*

FIGURE 7.3-10

BHP

**Size (Length) at Age for Lake Whitefish**

Rescan



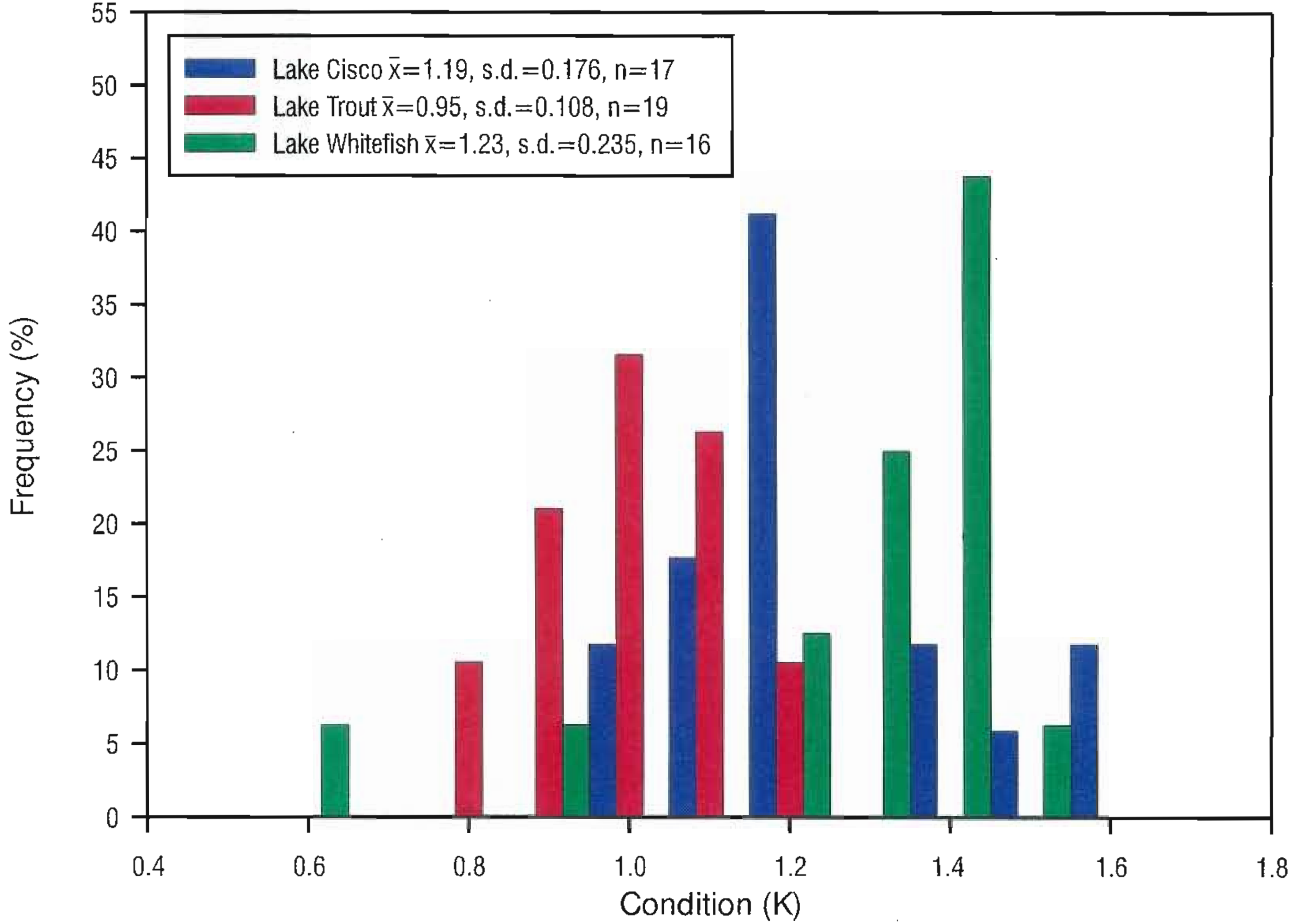

***Note:*** *Data from all study lakes were pooled*

FIGURE 7.3-11

BHP

**Size (Length) at Age for Lake Trout**

Rescan

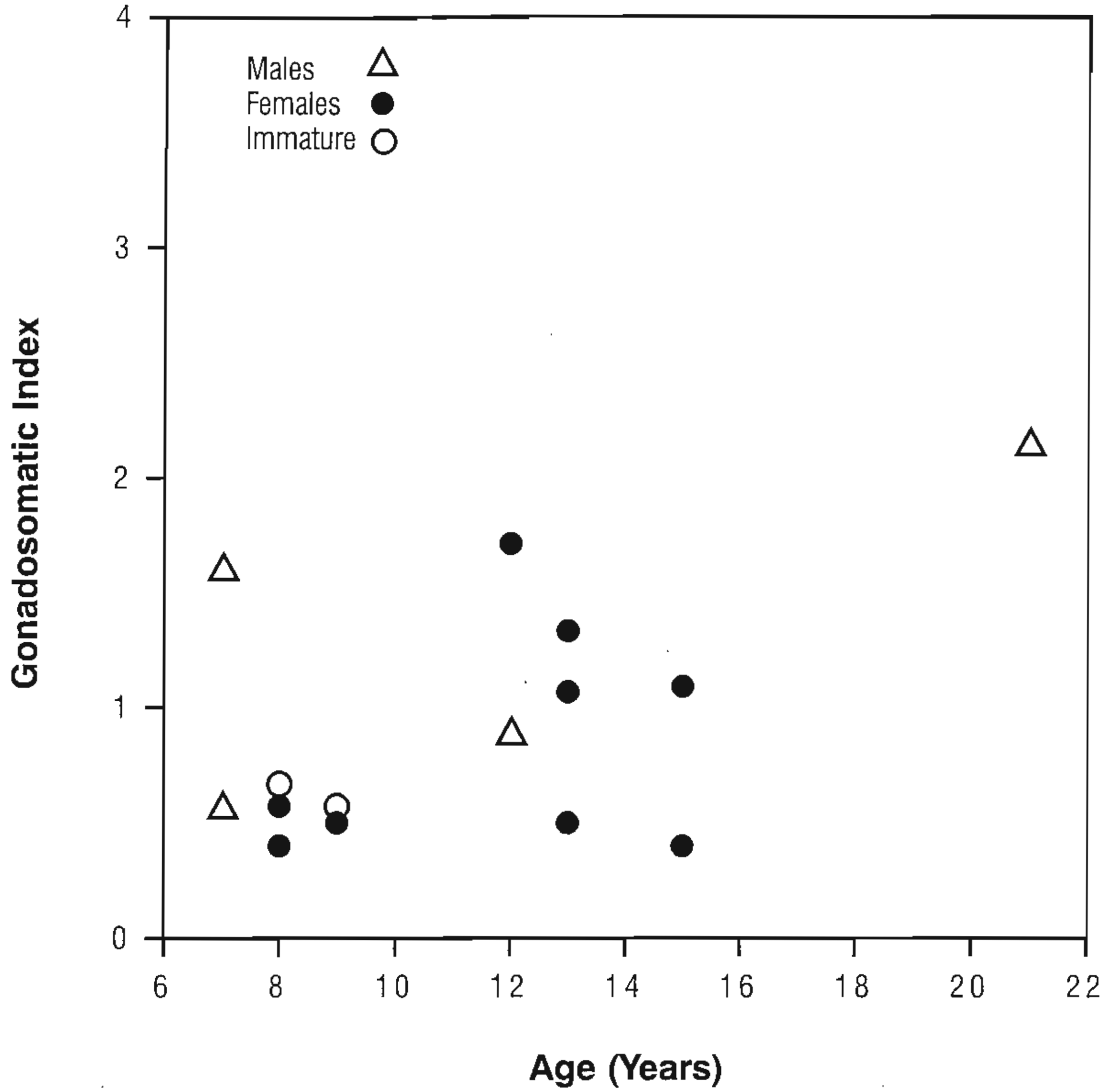



***Note:*** *Data from all study lakes were pooled*

FIGURE 7.3-12

**Distribution of Condition (K) for Three Fish Species Sampled in the Hope Bay Belt Study Area, 1996**

BHP Rescan




**Note:** *Higher GSI indicates gonad development for the oncoming spawning season (late September to November, Scott and Crossman, 1973) Individuals usually mature between six to eight years.*

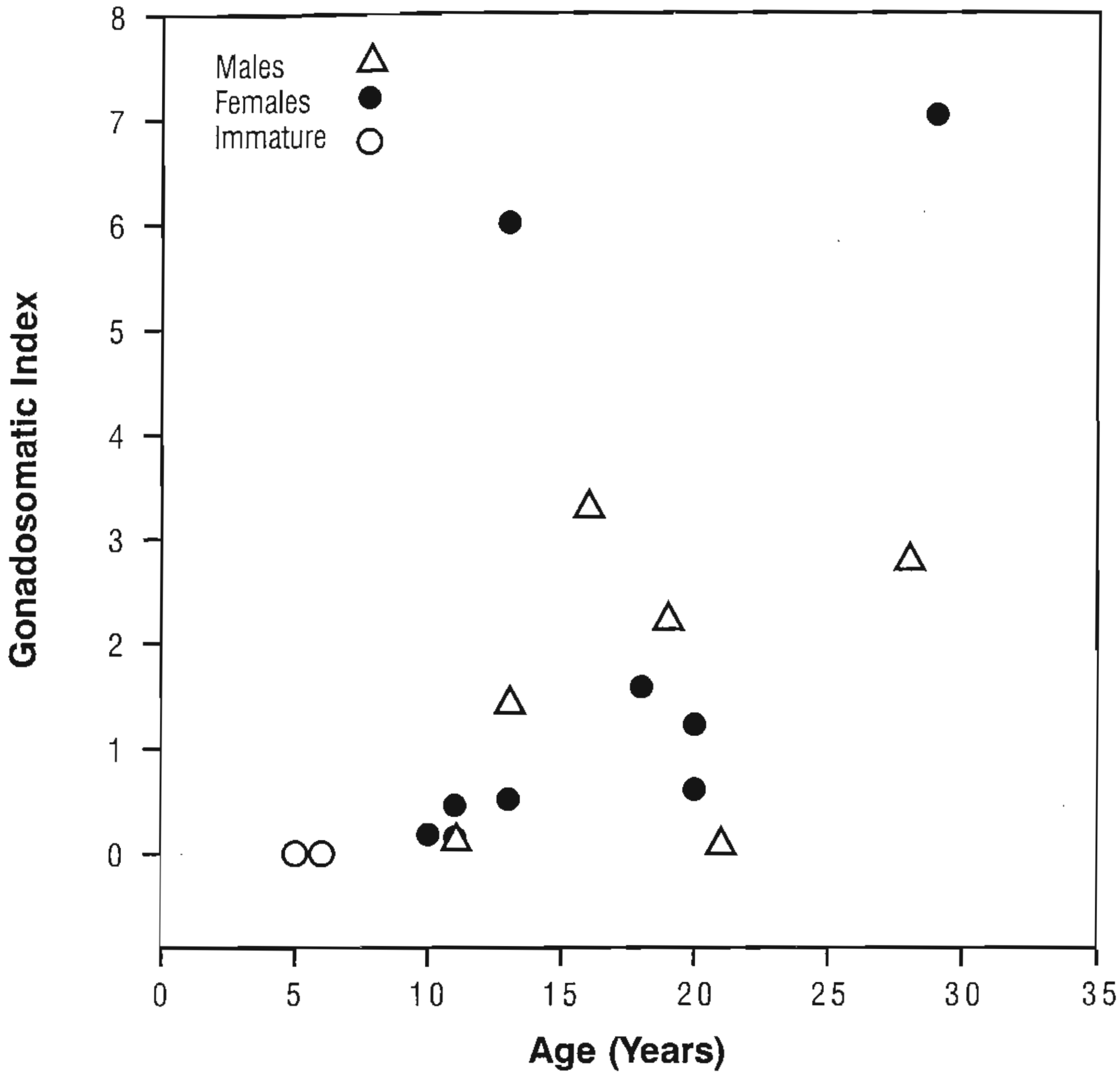
*Data from all study lakes were pooled*

FIGURE 7.3-13

BHP

**Relationship Between Cisco Age and GSI**

Rescan




**Note:** *Spawning typically occurs between September and October in northern areas. Age at maturity is reached as late as 13 years in the Northwest Territories (Scott and Crossman, 1973)*

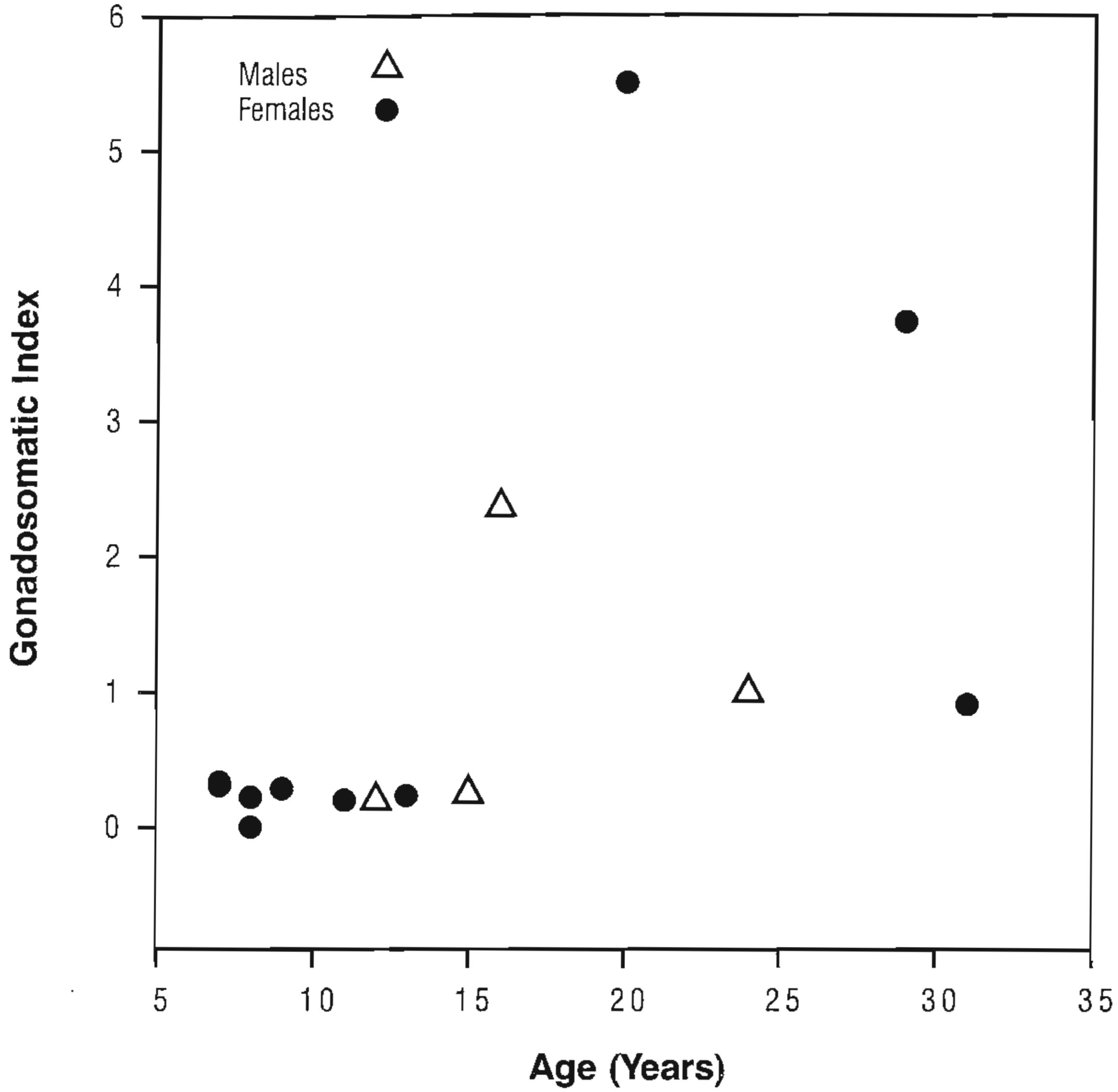
*Data from all study lakes were pooled*

FIGURE 7.3-14

BHP

**Relationship Between Lake Trout Age and GSI**

Rescan




**Note:** *Lake Whitefish typically spawn September and October, maturing between 6 and 8 years.*

*Data from all study lakes were pooled*

FIGURE 7.3-15

BHP

# Relationship between Lake Whitefish Length and GSI

Rescan

# 8. Terrestrial Ecosystem Mapping

# 8. TERRESTRIAL ECOSYSTEM MAPPING

This section describes the concepts, protocols and objectives of ecosystem mapping using a multidisciplinary approach, and rationalizes the methods used for field sampling. The results of field work completed in 1996 and field sampling remaining to be completed in 1997 are summarized. A digitally-based ecosystem map will be produced by November 31, 1997.

## 8.1 Background Information

Terrestrial ecosystem mapping is a method of stratifying the landscape into polygons that delineate ecosystems. The term “ecosystem” has a range of interpretations from the broad and theoretical (sum-total of the biotic and abiotic elements in an area - Fosberg 1967) to the more restrictive and practical (a segment of land relatively uniform in its biotic and abiotic components, structure and function - Sukachev and Dylis 1964). This latter interpretation more commonly forms the basis for management-oriented land classification.

Ecosystem classification generally concentrates on identifying and characterizing those abiotic and biotic components such as vegetation, soil, and terrain which integrate other components, reflect ecosystem function best, and are most conveniently studied (Meidinger and Pojar 1991). Ecosystems are thus commonly described by the vegetation communities and the soil types on which they persist.

## 8.2 Objectives

Within the context of this multidisciplinary study, the overall objective of mapping the terrestrial ecosystems is to provide a baseline map and database of the ecosystems within the Hope Bay Belt study area. This information can then be used to:

- guide resource management decisions;
- monitor changes to ecosystems over time;
- interpret wildlife values of specific areas;

- identify compensation and/or mitigation opportunities associated with development activities; and
- aid in the identification of sensitive and/or rare ecosystems.

Specific objectives are:

- to identify and characterize the vegetation communities (ecosystem units);
- to identify any broad regional differences within the study area; and
- map terrain and ecosystem units.

## 8.3 Study Area

A map of the study area is presented in Figure 8.3-1. The study area is composed of four sub-areas. At the north end is the proposed barge landing area in Roberts Bay measuring 6 $km^2$. To the southeast is the Doris Lake study area centred around the north tip of Doris Lake and measuring 16 $km^2$. To the extreme south is the Spyder Lake study area centred around Boston Camp and measuring 24 $km^2$. Connecting each of these is the two kilometre wide strip centred on the proposed winter trail alignment.

## 8.4 Methods

Terrestrial Ecosystem Mapping of the Hope Bay Belt follows as closely as possible the standard methodology of TEM in British Columbia (see Ecosystems Working Group 1995, 1996); however, three important factors specific to the project required that standard methodology be modified. These factors relate to differences in ecological land classification between NWT and BC, the lack of a set of identified ecosystems in Hope Bay, and the lack of large-scale aerial photography available prior to commencement of field work.

### 8.4.1 Ecological Land Classification

Lands of the Northwest Territories have been classified according to Canada's national land classification system (Ecological Stratification Working Group 1996). There are seven levels in this hierarchical system which describe and delineate ecologically distinctive areas based on incremental similarities in biotic and abiotic elements (*i.e.*, climate, terrain, soils, flora and fauna). Within this

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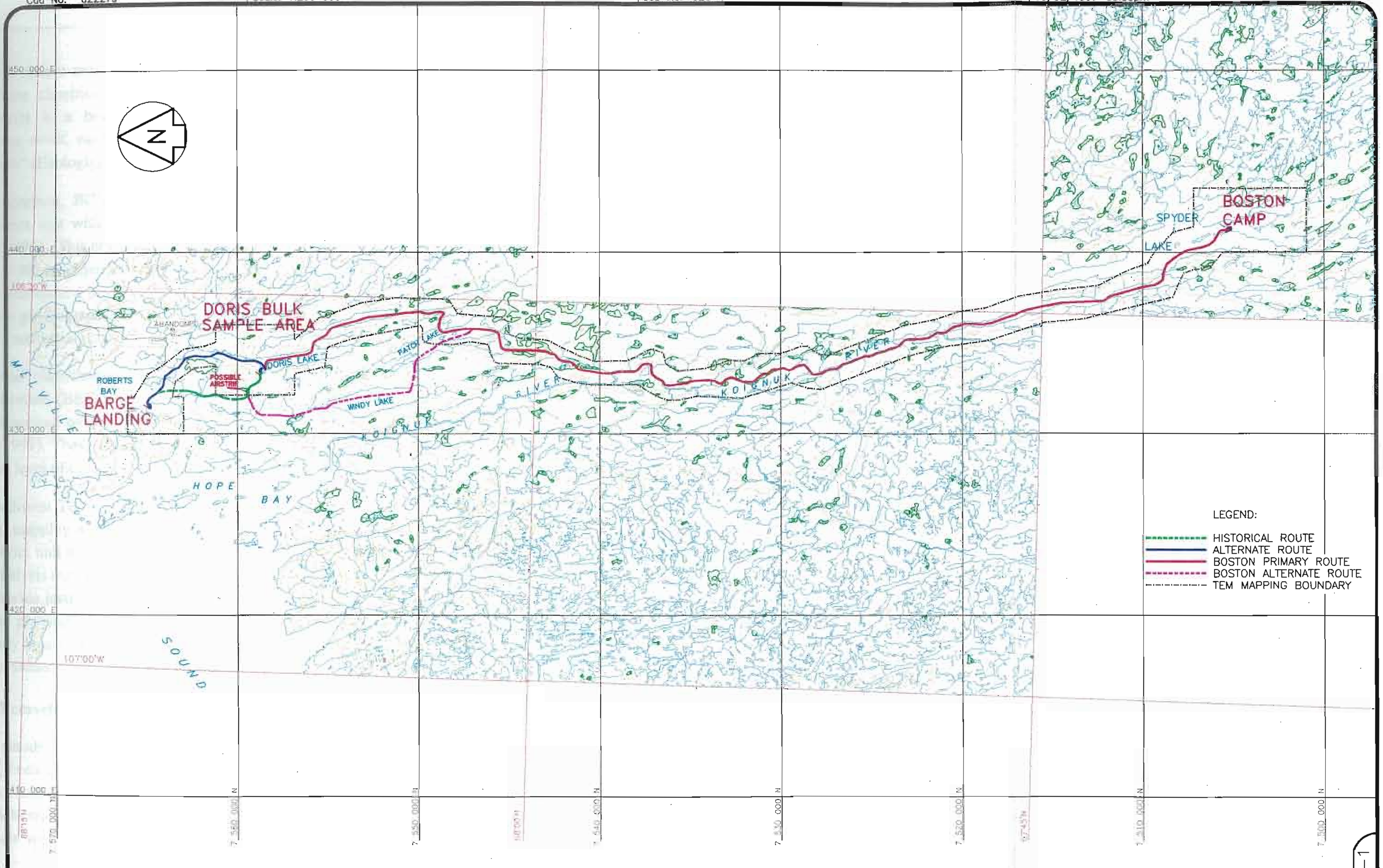


BHP

Terrain Ecosystem Mapping Areas – 1996

Rescan

Fig 8.3-1

national system much of Canada (including the Hope Bay Belt study area) has only been classified down to the third broadest level: the Ecodistrict. An Ecodistrict is a broad region characterized by “distinctive assemblages of landform, relief, surficial geological material, soil, water bodies, vegetation and land uses” (Ecological Stratification Working Group 1996).

In comparison, BC’s Ecosection is the provincial equivalent to the national Ecodistrict unit with only minor differences (Ecological Stratification Working Group 1996). This provincial classification system (Demarchi 1988 and Demarchi *et al.* 1990) stratifies the landscape at five successively smaller scales based on macroclimatic and physiographic differences. The Ecosection, defined as an area of minor physiographic and macroclimatic variation, is the broadest unit employed in BC’s terrestrial ecosystem mapping methodology.

A second classification system employed in BC is Biogeoclimatic Ecosystem Classification (BEC) and is the framework within which ecosystem units have been described over much of the province’s forested landscape (Meidinger and Pojar, 1991). These ecosystem units are also utilized in TEM and form the most detailed level of ecological classification.

As Northwest Territory lands are not managed under the framework of the BEC system, mapping will be based on a two-level classification hierarchy: the national Ecodistrict unit and the local ecosystem units (to be identified during the study). Data analysis may identify regional differences within the study area which may in turn provide justification for stratifying the study area. The analysis will examine whether physiographic differences between the northern and southern portions of the study area as discussed by Bird and Bird (1961) result in regional differences in ecosystems.

### 8.4.2 Ecosystem Unit Identification

The methods and protocols for conducting TEM are dependent on ecosystem units having been identified and described based on edaphic conditions (soil moisture and nutrients) and vegetation communities. As the ecosystems within the Hope Bay Belt study area are not described at a sub-regional level, field sampling protocols were developed to facilitate their description as well as to map them according to the standards developed by the Ecosystems Working Group (1995, 1996).

Preliminary ecosystem units have been identified based on the results of the 1996 field season sampling program (see section 8.5); however, tabular analysis of the data has yet to be completed. It should be stressed, therefore, that the sequence of preliminary ecosystem units discussed below may be modified upon completion of the analysis and subsequent sampling in 1997.

### 8.4.3 Aerial Photography

TEM standards require the study area to be stratified prior to commencing field activities. This is normally done by delineating bioterrain polygons on large-scale (1:15,000) aerial photos and developing a working legend based on bioterrain criteria to help identify sampling locations. Prestratification of bioterrain units on large-scale photographs was not conducted prior to the 1996 field season as photographs were not yet available.

### 8.4.4 1996 Field Sampling

Plots were located systematically across the study area according to an initial plan refined by an initial reconnaissance of the study area on July 28, 1996. In order to identify the complete range of prospective ecosystem types, sample plots were established on different terrain types, surficial materials, and mesoslope positions. These physical features strongly influence soil moisture and nutrient regimes and consequently, the vegetation communities that are sustained. The various combinations of moisture and nutrient regimes that are largely the product of physical features are manifested in distinct vegetation communities. Terminology used to describe moisture and nutrient regimes is presented in Appendix 8-1.

Landform and surficial materials were identified using small-scale (1:60,000) aerial photographs (1:15, 000 scale photos were unavailable), and from a helicopter or on the ground during the field sampling. Once a sampling site had been chosen, a 10 x 10 m plot was placed in an area uniform in vegetation, terrain and soils. Transitional areas were generally avoided and field crews attempted to obtain at least six samples for each vegetation community encountered.

Sampling was conducted in accordance with the methods of Luttmerding *et al.* (1990), the Ecosystems Working Group (1995, 1996) and Mitchell *et al.* (1989). Standard ecosystem field forms were filled out at each sampling location. Site-specific information recorded onto field cards included slope, aspect, mesoslope position, surface shape, moisture and nutrient regimes, terrain class and surface substrate composition. Soils were classified according to the Canadian system of soil classification (Agriculture Canada Expert Committee on Soil Survey 1987). Soils data included soil profile descriptions, numerous genetic horizon characteristics, drainage class, rooting depth, presence or absence of seepage water, depth to (and type of) root restricting layer, and humus form type.

Plant species were identified and given a unique six letter code. Percent cover and physiognomic form (herb, shrub, moss or lichen) were also recorded. Voucher specimens of all plant species were collected. Species that could not be positively identified on site were identified later with the aid of taxonomic keys (Porsild and Cody 1980, Hulten 1968). A collection of mosses encountered was sent to a specialist on arctic mosses for identification (LaFarge-England 1996). Representative photographs of the soil pit and vegetation community were taken at each sampling location.

TEM recognizes two types of plot sampling. Detailed plots are the most comprehensive and are the type required for tabular analysis to describe ecosystems. Visual plots are less detailed and are used to confirm bioterrain pretyping and ecosystem assignment. They may be conducted either on the ground or from the air. Sampling in 1996 concentrated on the collection of detailed plot information.

Sample data will be entered into a vegetation tabulation program as part of the ecosystem analysis. Analysis will indicate vegetation and environment data correlations and provide ecosystem descriptions. Replications of six or more plots per vegetation community are preferred to strengthen the reliability of the ecosystem descriptions, however uncommon communities may be described using fewer plots.

## 8.5 Results

A total of 173 sample plots was established in the summer of 1996. Distribution between plot types was; 127 detailed plots and 49 visual plots. We identified eighteen vegetation communities representing preliminary ecosystems. By convention, ecosystem names tend to reflect the dominant vegetation species of the community. For simplicity and convenience during sampling, preliminary names as they appear here reflect the dominant species and/or specific physical conditions common to all plots assigned to the given preliminary ecosystem.

Eighteen preliminary communities were identified:

- *Eriophorum* tussock meadow;
- Wet *Eriophorum* meadow;
- Wet sedge meadow;
- Mounded dwarf shrub;
- *Dryas*-dwarf shrub;
- Dry *Carex*-lichen;
- Dwarf shrub-sheath;
- *Betula-Ledum-Eriophorum;*
- *Eriophorum-Salix-Betula*;
- *Betula*-moss;
- Low bench floodplain;
- High bench floodplain;
- Intertidal;
- *Betula-Ledum*-lichen;
- Low shrub boulder field;
- Riparian willow;
- Sparsely vegetated; and
- Dry willow.

The following descriptions outline typical site characteristics and unique or diagnostic species assemblages that distinguish the communities.

### 8.5.1 *Eriophorum* Tussock Meadow

This community is typically found in gently-sloping (<5%) or level valley positions and is characterized by a high vegetation cover (>40%) of sheathed cottongrass *(Eriophorum vaginatum)* in tussock form. Tussocks typically measure between 15 and 40 cm in diameter and range in height from 5 to 25 cm.

Soils are typically fine-textured gleysolic or brunisolic static cryosols. Textures vary between silt loam, silty clay, and silty clay loam. The depth to permafrost layer is variable but does not appear to exceed 40 cm. Soil drainage varies from moderate in gentle, mid-valley positions to very poor in valley bottoms. Soil moisture is typically subhygric to hygric. A water table may or may not be present. Surficial materials are either marine or marine-washed glacial till (see Plate 8.5-1).

### 8.5.2 Wet *Eriophorum* Meadow

This community is typically found in depressional or level valley bottom positions and is characterized by a preponderance of cottongrass (*Eriophorum* spp.) and sedges (*Carex* spp.) which (in total) have a cover greater than 75%. Tussocks are absent or scarce and the water table is typically present at or near the surface.

Soils are typically fine-textured gleysolic or brunisolic turbic or static cryosols. Soil textures vary between silt loam, silty clay, and silty clay loam. The active layer is variable but generally deeper than that within the *Eriophorum* tussock meadow community. Soil drainage is poor to very poor. Soil moisture is typically subhydric and the nutrient regime poor to rich. Surficial materials are either marine or marine washed glacial till (see Plate 8.5-2).

### 8.5.3 Wet Sedge Meadow

This community is typically found in depressional or level valley-bottom positions and characterized by a high cover (> 40%) of *Carex aquatilis* var. *stans* and at least 75% total sedge species coverage. Cottongrass tussocks and shrubs are lacking or rare and isolated.

Soil class is variable between turbic, static and orthic cryosols. Soil textures are fine (silt loam, silty clay loam silty clay and clay). Soils are subhydric to hydric. Seasonal and prolonged inundation occurs if located near the shore of a lake or pond.

Water table is present at or near the surface restricting the effective rooting depth generally to between five and ten centimetres (see Plate 8.5-3).

### 8.5.4 Mounded Dwarf Shrub

The diagnostic feature of the mounded dwarf shrub community is the presence of frost boils. These frost boils exhibit variable amounts of exposed (unvegetated) soil depending on the intensity of soil-churning activity. Dwarf shrub species are relatively abundant and comprise at least 25% cover. Frost boils can measure up to one metre in diameter and exhibit centre profiles of dense, structureless and dry (submesic) soils. The movement of soil materials associated with the formation of frost boils results in the accumulation of organic materials in the trenches between boils.

Soil moisture regime is subxeric to mesic. Soil nutrient regime is poor to rich. Marine shell fragments are occasionally found at the surface of frost boils and within the soil pedon. Surficial materials are variable and include moderately coarse glacial till to fine (clay loam) marine sediments. Soils are typically static or turbic cryosols (see Plate 8.5-4).

### 8.5.5 *Dryas*-dwarf Shrub

The *Dryas*-dwarf shrub community is characterized by a high cover (>40%) of mountain avens *(Dryas integrifolia)*. Dwarf shrubs generally comprise greater than 10% cover. Slope profiles are generally convex.

Typically this community is found on rock outcrops where a thin layer of glacial till or marine-washed till overlays bedrock or weathered bedrock. Slopes vary from gentle to steep and typical soils are regosols and brunisols in which permafrost is present at depths greater than two metres. Static cryosols are occasionally present. Soil textures are typically coarse. Soil moisture regimes are

Plate 8.5-1: *Eriphorum* tussock meadow.

Plate 8.5-2: Wet *Eriphorum* meadow.

Plate 8.5-3: Wet sedge meadow.

Plate 8.5-4: Mounded dwarf shrub.

dry (xeric to sub-mesic). Soil nutrient regimes are poor to medium; poor sites typically occur on shallow sandy/gravely soils (see Plate 8.5-5).

### 8.5.6 Dry *Carex*-lichen

This community type is common throughout the arctic on rock outcrops and rapidly-drained gravely deposits (eskers, old marine beach ridges). The occurrence of *Carex rupestris* at greater than 50% cover is diagnostic of this community. Associate species typically include *Dryas integrifolia* at covers of greater than 10% and crustose lichens at covers greater than 20%.

Soils are typically coarse-textured, well-drained regosols or brunisols. This community is found on gravely ridge crests and gently sloped or level areas where the soils are formed on glacial till or glaciofluvial deposits. Glacial till deposits are typically found overlying rock outcrops. Soil moisture is typically submesic and the nutrient regime medium. Coarse fragment content is variable depending on the origin of the surficial materials (see Plate 8.5-6).

### 8.5.7 Dwarf Shrub-Heath

The dwarf shrub-heath community is characterized by a shrub cover of greater than 20% with at least 5% scrub birch *(Betula glandulosa)*. There is also at least a 10% cover of mountain heather *(Cassiope tetragona)*; late snow-lie areas may sustain very high cover (>50%).

This community is typically associated with coarse glacial or marine-washed glacial till deposited on, or adjacent to, rock outcrops. Slopes vary between gentle and moderate (4 to 32%). Relative soil moisture and nutrient regimes are typically submesic to mesic, and poor to rich, respectively. Coarse-textured (loam, loamy sand) or skeletal soils predominate. Soils are typically either brunisols or cryosols (see Plate 8.5-7).

### 8.5.8 *Betula-Ledum-Eriophorum*

This community is characterized by the prevalence of northern Labrador tea (*Ledum decumbens*) in association with tussock-forming cottongrass (*E. vaginatum*) and dwarf birch at low to moderate (1 to 25%) cover. Other common species include lingonberry and bilberry (*Vaccinium vitis-idaea, V. uligonosum*).

Typical site characteristics include level or gentle slopes (<7%). Soils are generally fine-textured marine sediments (silt loams or silty clay loams). Coarse fragments are absent, and drainage is imperfect. The active layer averages a thickness of approximately 30 cm. Soils are typically gleysolic static cryosols (see Plate 8.5-8).

### 8.5.9 *Eriophorum-Salix-Betula*

This community is one of the most wide-spread in the area. It is found on level ground or slopes less than 5%. The dominant plant species is the tussock forming sheathed cotton-grass *(E. vaginatum)*, which is found at high cover (40 to 70%). Associate species are scrub birch *(B. glandulosum)* and several willow species, particularly *Salix lanceolata*.

Typically, the soils are gleysolic static cryosols with silty clay loam textures. Occasionally, turbic cryosols are found. The active layer varies in depth from 30 to 55 cm and seepage may or may not be present at time of sampling. Origin of the sediments is marine (see Plate 8.5-9).

### 8.5.10 *Betula*-moss

The *Betula* moss community is readily identified from aerial photographs due to the relatively dark tones created by high total cover of scrub birch (> 50%) and bryophytes (>60%).

Soil textures are variable but generally sandy loam to loamy sand with few coarse fragments. The active layer ranges in depth from 30 to 70 cm. Seepage water is present and is often found at the permafrost boundary. Soil moisture regimes range from submesic to subhygric and the nutrient regime is generally poor. Soils are static cryosols derived from marine sediments or washed till (see Plate 8.5-10).

Plate 8.5-5: *Dryas* dwarf shrub.

Plate 8.5-6: Dry *Carex* lichen.

Plate 8.5-7: Dwarf shrub heath.

Plate 8.5-8: *Betula Ledum Eriophorum*.

Plate 8.5-9: *Eriophorum Salix Betula.*

Plate 8.5-10: *Betula* moss.

### 8.5.11 Low Bench Floodplain

Low bench floodplain communities are mostly found along the Koignuk River and other large watercourses within the study area at elevations of less than 0.3 m above average low water level. It is characterized by a lack of shrub cover. The two dominant herbaceous species include *Hippurus vulgaris* and *Dupontia fischeri* ssp. *psilosantha.*

This community is found on level mesoslope positions which are subject to prolonged inundation from the adjacent watercourses. Soil textures are stratified with typically sandy fluvial deposits overlying finer marine silts and clays. Drainage is imperfect to very poor in the active layer that averages 80 to 90 cm. Exposed mineral soil forms a significant portion of the ground cover, as fluvial sediments are deposited annually (see Plate 8.5-11).

### 8.5.12 High Bench Floodplain

High bench floodplain communities are limited in occurrence to fluvial benches at elevations of between 0.3 and 1 m above the average summer water level. This community is subject to periodic inundation associated with high flows from adjacent water courses. This is a shrub-dominated community with willow species *(Salix* spp.*)* reaching one metre in height. The herb layer cover is variable ranging from 6 to 55% depending on the inundation frequency and sediment deposition patterns.

High bench sites are generally gently-sloping moderately well drained sites with sandy loam fluvial soils. The soil moisture regime is typically mesic and the nutrient regime rich. Soils are static or turbic cryosols with an active layer ranging in depth from 44 to 75 cm (see Plate 8.5-12).

### 8.5.13 Intertidal

Plant communities and soil formation processes are strongly influenced by the proximity to the marine environment (salt-spray, tidal inundation). The plant species in foreshore communities are typically absent from inland communities. Goosegrass (*Puccinelia phryganodes*) and *Stellaria humifusa* occur in nearly monospecific communities in tidally inundated areas. Infrequently inundated (by tides) areas are dominated by *Carex subspatheca* with lesser amounts of *Potentilla* *egedii* and scurvy grass (*Cochlearia officianalis*). Backshore communities are often associated with sandy deposits and are characterized by an abundance of *Elymus*, *Potentilla* spp. and prickly saxifrage (*Saxifraga tricuspidata*). Shrubs are conspicuously absent (or sparse) within these communities.

Soils are typically poorly-drained (or saturated) gleysols in the lower zone and gleysolic static cryosols in the upper zone. Permafrost depth was found to be greater than soil pit depth (>0.6 m). Soils are formed on marine sediments and soil textures include marine S and LS. Soil moisture ranges from hydric in foreshore areas to submesic in backshore areas. The nutrient regime is medium in foreshore communities; decaying tidally-deposited detritus is a significant nutrient source. The sandy soils in backshore communities are typically nutrient-poor (see Plate 8.5-13).

### 8.5.14 *Betula-Ledum*-lichen

This community appears to be quite limited in its extent and is generally restricted to the crests or upper slopes of drumlinoid ridges in the Spyder Lake area. It is a community dominated by crustose lichens (15 to 40%), northern labrador tea (~ 25%), and dwarf birch (10 to 15%) growing under nutrient-poor, submesic conditions.

Soils are typically well-drained sandy to sandy loam till. Slopes are typically very gentle to level (0 to 2%). The active layer is relatively deep and soils are either brunisols or regosols (see Plate 8.5-14).

### 8.5.15 Low Shrub Boulder Field

This crustose lichen dominated community grows on dry nutrient-poor sites. Crustose lichens average between 30 and 75% cover. Boulders and smaller bare rocks (5 to 20%) are typically found scattered throughout the site. Low shrubs form a moderate cover of 30 to 45%. Scrub birch is the dominant shrub. The herb layer is present at low coverages averaging 5%.

This community is found on well-drained sands, sandy loams and loamy sands originating as till or washed till deposits. Coarse fragment content averages 20 to 40%. Soils are typically brunisols or regosols (see Plate 8.5-15).

Plate 8.5-11: Low bench floodplains.

Plate 8.5-12: High bench floodplains.

Plate 8.5-13: Intertidal.

Plate 8.5-14: *Betula Ledum* lichen.

Plate 8.5-15: Low shrub boulder field.

### 8.5.16 Riparian Willow

This community is found immediately adjacent to small watercourses, lakes and ponds where it is subject to prolonged flooding. This results in a high cover of sedge and willow species. *Salix alaxensis* and *Salix lanceolata* comprise the dominant willow species.

Soils are fine-to-medium-textured marine or fluvial deposits (silt loams and silty clay loams). Drainage is poor and the water table is present at or near the surface throughout the growing season. Relative soil moisture varies between subhygric and subhydric. Nutrient status is medium to rich. Soils are typically gleysolic or brunisolic static cryosol (see Plate 8.5-16).

### 8.5.17 Sparsely Vegetated

This community type is common but generally not extensive. It is distinguished by a high proportion of unvegetated rock and/or mineral soil (>40%). The vegetation is sparsely distributed and includes a variety of plant species, depending on the site conditions. Crustose lichens are generally the most abundant.

Soils are rapidly-drained skeletal, sandy or gravely regosols. The depth to permafrost is likely greater than one metre; soil pit excavation was impeded by the high proportion of coarse fragments (see Plate 8.5-17).

### 8.5.18 Dry Willow

The dry willow community occurs on moderately-well to well drained upper or mid valley slope positions where slopes average approximately 10%. *Salix lanceolata* and (*S. glauca*) form the dominant vegetation cover in these sub-mesic to mesic communities. Herb coverage averages approximately 5 to 15% and mosses and lichens only 5 to 10%.

This community often complexes with moister communities where the landscape undulates. Moister ecosystems such as the *Betula-Ledum-Eriophorum* community are characteristically found in the adjacent gentle U-shaped valleys. Soil textures are moderate to fine (silt loam to silty clay loam). Seepage is generally present at the permafrost interface which ranges between 25 and 45 cm. Soils are typically turbic cryosols (see Plate 8.5-18).

## 8.6 Discussion

The vegetation communities described here have been preliminarily identified based on field observations and generalizations deduced from the field cards. Definitive ecosystem descriptions will be made upon analysis of the field data using a vegetation tabulation program and subsequent sampling in 1997. It is anticipated that some of these preliminary ecosystems may be amalgamated.

Plate 8.5-16: Riparian willow.

Plate 8.5-17: Sparsely vegetated.

Plate 8.5-18: Dry willow community.

# 9. Wildlife Resources

# 9. WILDLIFE RESOURCES

## 9.1 Terrestrial Mammals And Avifauna

Recent interest in mineral resources in the Hope Bay Belt has encouraged attempts to describe more completely faunal resources of the area. Only with a thorough view of wildlife community composition and structure, combined with an understanding of wildlife-habitat relationships, can efforts to mitigate industrial effects and to conserve populations and habitat be undertaken. The current project was established to begin to address these issues. Specific objectives were to identify species which used the area, to assess their relative abundance and temporal and spatial changes in use of the area, and to evaluate the relative importance of different habitat types to different species and in changing seasons.

The Hope Bay Belt is an area known to be important to wildlife. It lies, for example, within the range used for calving during some years by the Bathurst caribou herd. The Bathurst herd is the largest in the Northwest Territories (NWT) and in Nunavut. The area is also of seasonal importance to caribou from the Queen Maud Gulf herd, and is used as winter range by caribou from Victoria Island. Muskoxen also occur throughout the area in populations which may be increasing.

In common with much of the coastal barrens, the area is used as a breeding ground by several species of internationally important waterfowl populations. Passerines and other birds are also abundant during breeding seasons.

High densities of ungulates and birds provide food resources for predators. Portions of the Hope Bay Belt support a high density of nesting Gyrfalcons, Peregrine Falcons, and other raptors. Wolves, foxes, and other carnivores are supported by caribou populations in the area. The Belt also appears to be important to grizzly bears. Seasonal habitat requirements of grizzly bears on the barrens are largely unknown, complicating efforts to conserve important habitat components.

### 9.1.1 Study Area

The area used for different components of the wildlife study in 1996 was somewhat variable according to survey type. For most surveys, the study area boundaries were encompassed by that area searched during caribou surveys (Figure 9.1-1). This area was 30 km wide and of variable length between 74 and 100 km. It was generally centred on the Koignuk River and the proposed winter trail route between the Boston Project site and Roberts Bay. The area immediately northeast of Roberts Bay was also included. The southern boundary was about 21 km south of the Boston exploration area claim block, and the northern boundary was the coastline of Melville Sound. Areas outside of this, particularly to the east, were included in some surveys (*e.g.*, carnivores).

For some analyses (*e.g.*, caribou distribution), the study area was divided into northern and southern sections. The boundary was at the north end of Spyder Lake, between transect lines No. 10 and 11 of the caribou survey route.

### 9.1.2 Methods

#### *9.1.2.1 Ungulate Aerial Surveys*

Aerial surveys were flown between late May and late November, to assess distribution and relative abundance of caribou and muskoxen, and to locate major migration routes. In late May, the survey was flown in a Cessna C-185 fixed-wing aircraft equipped with wheel-skis. Subsequently, all surveys were flown in a Bell 206B helicopter. Survey crew consisted of the pilot, a navigator/observer, and two rear-seat observers. The pilot was encouraged to participate as an observer whenever possible.

The survey route consisted of parallel transect lines 30 km long and spaced 4 km apart (Figure 9.1-1). Transects were aligned east-west, perpendicular to the general orientation of drainages and other topographic features, in order to increase the likelihood of intercepting major migration routes. For the first survey, 22 transect lines were established and flown. On subsequent surveys, four additional lines were added to the south, extending the area of coverage to about 21 km south of the Boston claim block.

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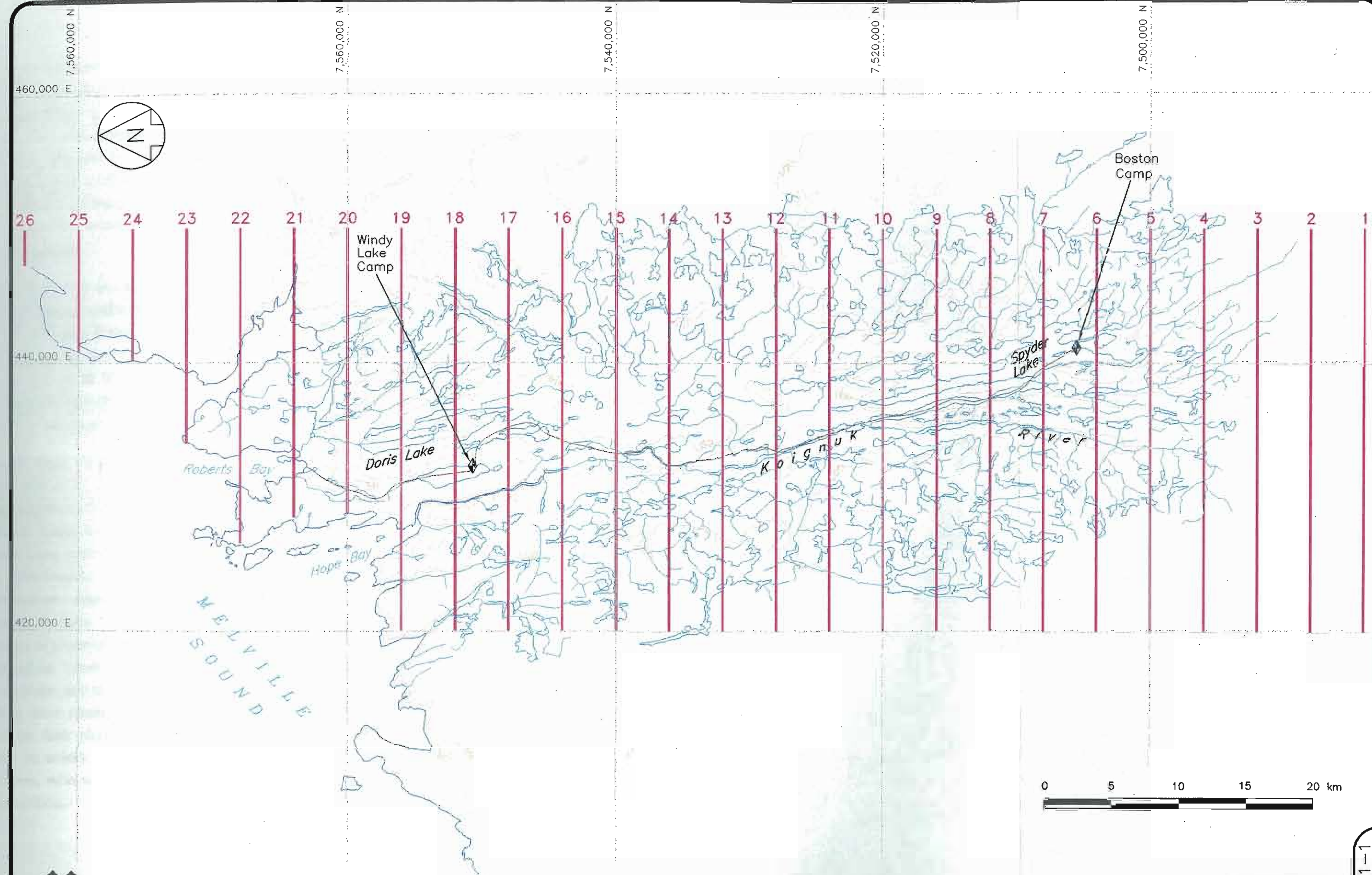


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Caribou Survey Transects

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Fig 9.1-1

Navigation was chiefly by use of a Global Positioning System (GPS). Prior to take-off, map coordinates for each transect endpoint were calculated then entered into a spreadsheet program. This file was uploaded into the aircraft's GPS receiver, with each endpoint creating a GPS waypoint. Navigation was then performed by the pilot steering toward the next waypoint on the survey route. This provided accurate navigation and freed the front-seat passenger for observation responsibilities. At least once on each transect, this observer confirmed adherence to the specified route using reference to landmarks and 1:250,000 scale topographic maps.

Transect width was one and one-half kilometres on each side of the aircraft. Strip width was visually calibrated before each flight using landscape features that were spaced at a known distance of one kilometres, with a central marker. Calibration was performed by overflying at the prescribed altitude the central marker with one landmark spaced at 500 m to the left and one to the right. Observers used this visual spacing as a mental reference to maintain judgment of strip width. This calibration was conducted after each refueling stop.

Transects were overflown at an altitude of about 200 m Above Ground Level (AGL), and at an airspeed of 160 km/hr. All wildlife observations within the 500 m strip on each side of the aircraft were identified, counted, and recorded in a notebook. Large congregations of caribou were photographed to be counted later. At least three photographs were taken of each group, and the highest count was used. The location of each observation was recorded using a separate, hand-held GPS receiver. Again, this provided accurate recording of locations while freeing the observer from the need to constantly refer to maps. Following the survey, locations of observations were downloaded to a personal computer. Caribou were classified as "cows," calves, or bulls; "cows" included all caribou that were one year or older, and that were not large-antlered bulls. During the November survey, caribou were classified as to their herd origin—mainland or Victoria Island—based on their physical characteristics (Victoria Island caribou are smaller and lighter in color). These herd classifications were conducted by the rear-seat observers, who were Inuit hunters with many years of experience differentiating these caribou.

*9.1.2.2 Carnivore Surveys*

Searches for carnivore dens were conducted by helicopter and ground surveys. During the first week of June, all eskers that were identified on National Topographic System (NTS) topographic maps within the study area were searched by helicopter. These surveys involved low-level (30 to 50 m AGL), slow (<60 km/hr) flights following the eskers. In addition, kames and other off-esker sand or gravel deposits were searched the same way. The Koignuk River valley and all tributaries, as well as parts of the Angimajuk River, were also surveyed by an unstructured helicopter search of all likely denning areas. Flight lines followed each bank of the river. Altitude and flight speed varied depending on vegetation density. When carnivore tracks were observed, they were followed backwards as far as possible to help identify denning areas. Each possible den site was inspected on foot. All identifiable dens, regardless of age, were plotted using GPS, and detailed habitat and site characteristics were recorded.

Preliminary data on grizzly bear feeding habitat were collected opportunistically at feeding sites that were observed during other surveys. These sites were defined by either fresh bear feeding sign (*e.g.*, digging), or by visual observation of feeding bears. At each feeding site, the food source was identified and habitat within a 30 m radius was described. Habitat descriptors included location, slope, aspect, elevation, and plant identification.

*9.1.2.3 Raptor Nesting Surveys*

Potential raptor nesting sites were surveyed from a helicopter. Survey routes were unstructured, but concentrated on likely cliff bands. The helicopter was flown close to the elevation of the top of the cliff, at 30 to 50 km/hr. Observers searched for flushing raptors, as well as whitewash and dense lichen growth which can be indicators of a raptor nest. The locations and status of all nests and suspected nests were recorded and mapped using GPS. For the purposes of this survey, owls and Common Ravens were classified as raptors.

The boundaries of the survey area were coordinated with the Government of NWT (GNWT) biologist (C. Shank) to expand survey coverage and avoid overlap. The survey described here was flown immediately following that of GNWT, using their results to help define the survey area. The GNWT survey focused on coastal areas particularly in the vicinity of Hope Bay. This permitted the search area for this study to extend well to the south.

*9.1.2.4 Breeding Bird Census Surveys*

Breeding birds were inventoried to help describe more thoroughly the biodiversity of the project area, and to identify important nesting habitats. The survey consisted of plots at least 25 ha in area, four at the Boston Project claim block and four at the Doris Lake claim block (Figure 9.1-2). At each of the project sites, there was a treatment plot and three reference plots. The treatment plot was established within one kilometre of the project campsite, and the reference plots were two to ten kilometres away. The first plot surveyed was laid out as a 500 x 500 m square, flagged, then surveyed in 100 m wide strips. However, layout of these plot boundaries took >2 hours. Consequently, to conserve time, the remaining seven plots were established as 100 m wide strips at least 2.5 km long.

For all plots, three observers, spaced at 33 m intervals, walked in parallel through the plot and identified all birds observed within the plot. Observer spacing was calibrated using a 100 m string line. Nests that were found were identified and their status recorded. Incidental observations of birds were also recorded during all other surveys.

*9.1.2.5 Waterfowl Surveys*

Waterfowl surveys were conducted to identify species present, breeding species, relative abundance, and important habitats. Objectives did not include a precise census, which is a management goal that is difficult to achieve even with a far more intensive survey program than was appropriate for this study.

Waterfowl surveys were comprised of two components. The first consisted of a transect survey flown by helicopter. Each survey plot was a 15 x 15 km block surrounding each of the two campsites (Figure 9.1-3). The survey team included the pilot, an observer/navigator/recorder, and two rear-seat observers. Transects were spaced two kilometres apart, and were flown at 50 to 60 m AGL and 40 to 80 km/hr. Survey strip width was 200 m on each side of the aircraft. All waterfowl observed on transect were identified, counted, and locations were plotted using GPS. At each of the two survey blocks, eight transect lines were flown, for a total survey area of 48 $km^2$ (eight lines x 15 km x 400 m strip width). Each of these surveys was flown twice, with the replicates separated by two days. For each species within each of the survey blocks, the higher value from the two surveys was used for analyses.

The second component was an intensive ground survey. This was conducted immediately following the aerial waterfowl survey. Randomly-selected lakes and wetlands within the aerial survey blocks were intensively surveyed by walking the shorelines, in order to confirm identification of species. Birds were identified using binoculars and spotting scopes. The objective of this component was to assist in identification of species and to help identify important habitats. This was not a rigorous survey such as would be designed to generate a visibility correction factor to apply to the aerial survey results (Smith 1995).

"Waterfowl" included geese, ducks and loons. Sandhill Cranes were also classified as waterfowl for this survey, based on their affinity for wetlands, the fact that they are a prevalent and sensitive species, and because no other survey specifically addressed them.

#### *9.1.2.6 Small Mammal Surveys*

Design of the small mammal trapping program followed that of the GNWT small mammal inventory. Each trapline consisted of two parallel lines 100 m apart and 250 m long. Along each line, trap stations were spaced at ten metre intervals, and two traps were set at each station. Traps were set at the best locations (*e.g.*, burrows, runways) within two metres of each station. Traps were checked daily for five days, generating a potential total of 500 trapnights at each site. A trapnight was logged for each trap that was set. Traps that were found tripped but empty were presumed to have been set long enough to have made a capture. "Museum Special" snap traps, baited with a mixture of peanut butter and rolled oats, were used. Traps were checked each day by 10:00 a.m., and rebaited and reset as needed. Bait was freshened every two days.

At the Boston Property, and again at the Doris Lake Property, one trapline was established within 500 m of the campsite (treatment), and a second (reference) trapline was established about two kilometres away, in similar habitat (Figure 9.1-4). Transects were aligned to traverse more than one habitat type.

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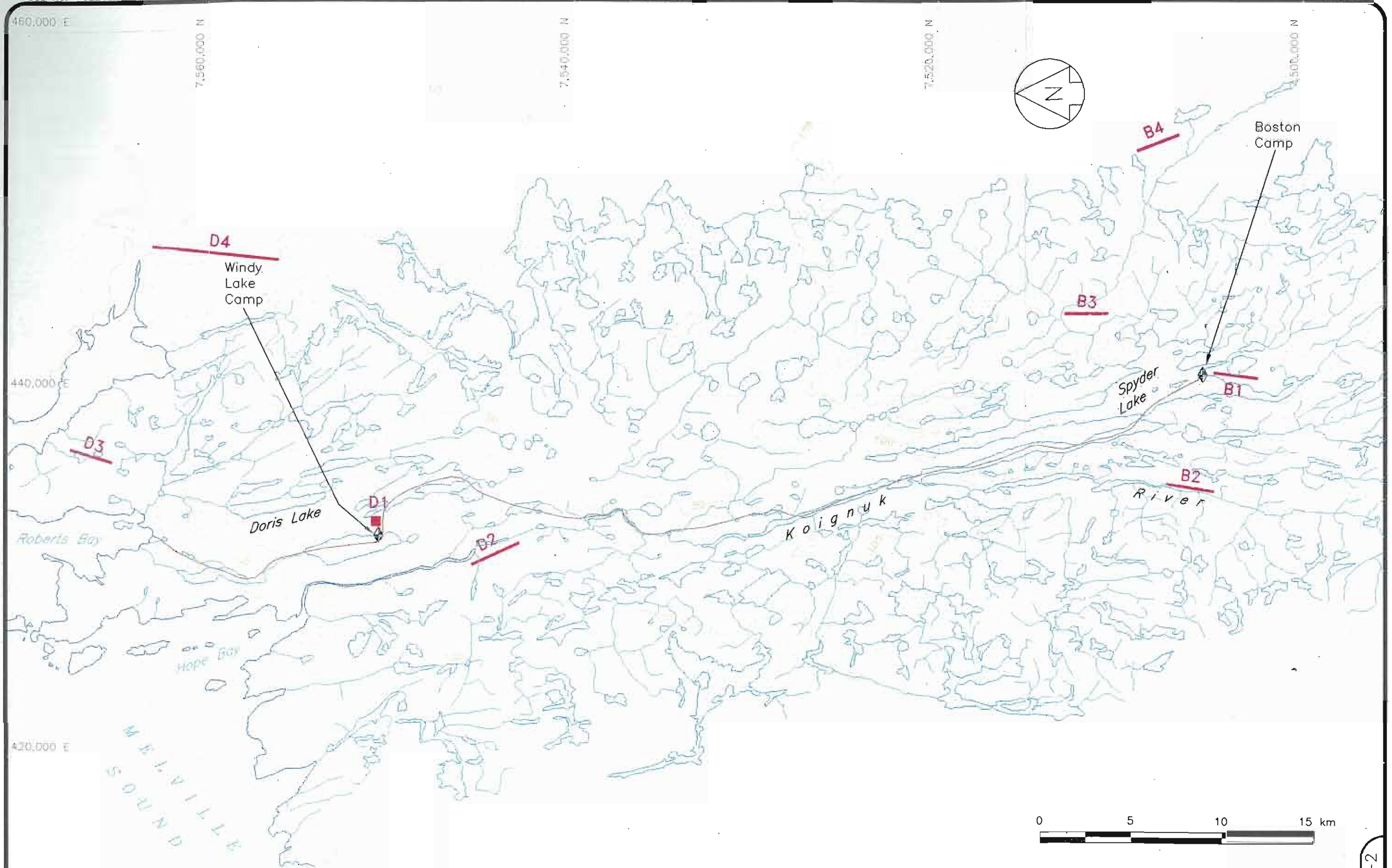
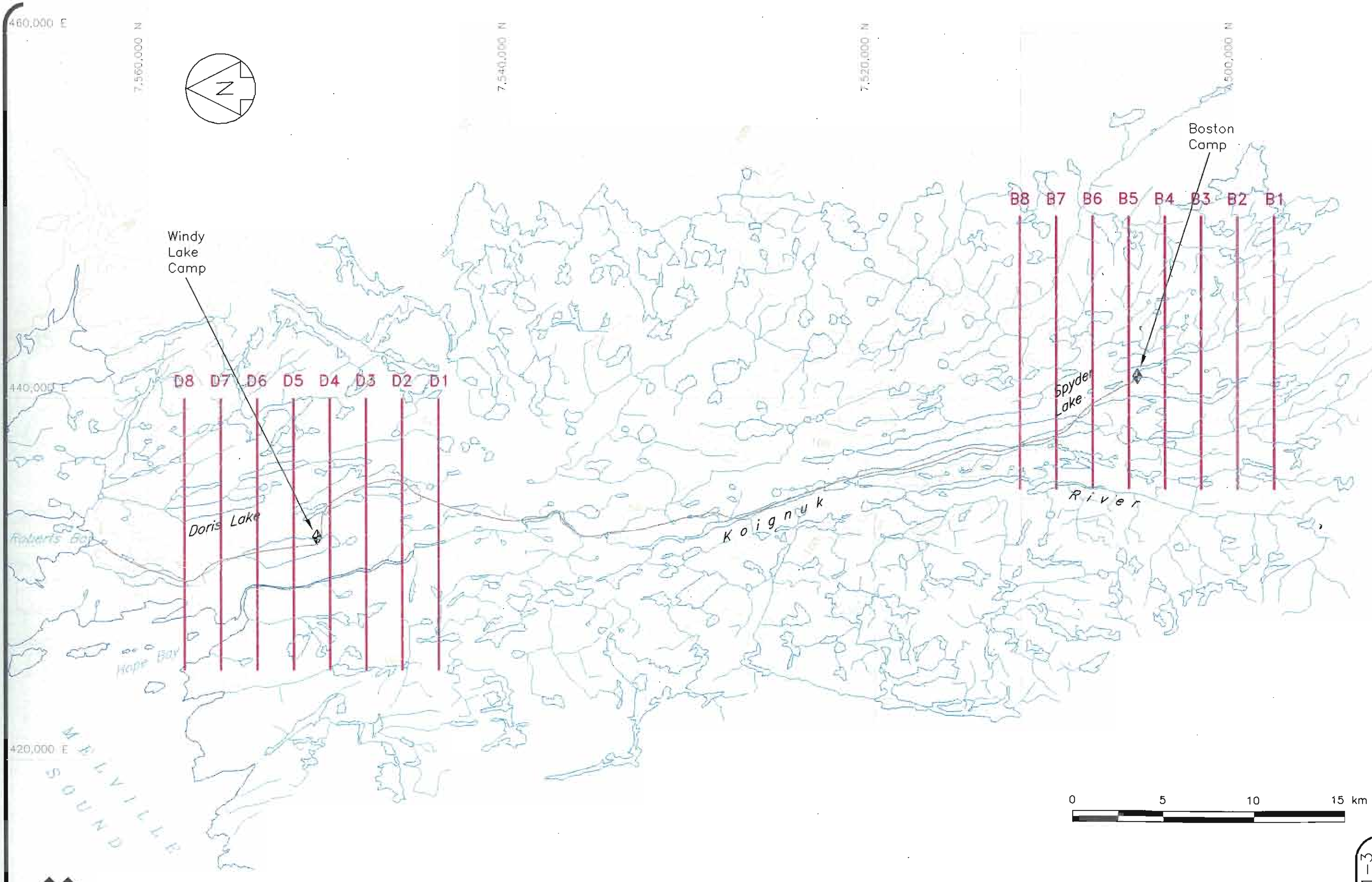



BHP

# Breeding Bird Census Plots

Rescan

Fig 9.1-2




Waterfowl Survey Transects

Fig 9.1-3

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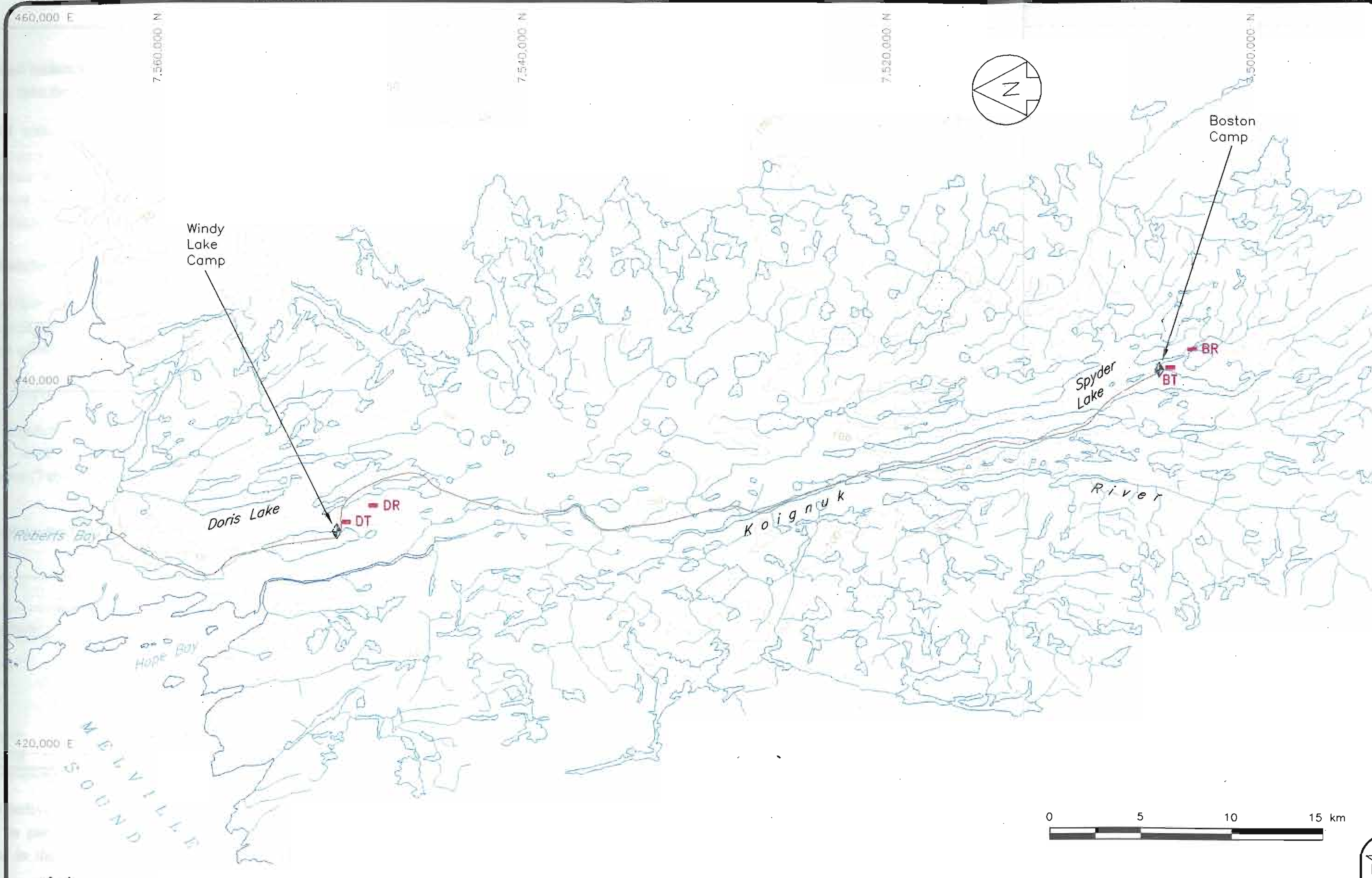


BHP

Small Mammal Trap Lines

Rescan

Fig 9.1-4

The paired treatment and reference traplines were run concurrently at the Boston Property, then the trapping program moved to the Doris Lake Property.

Captured specimens were identified in the field where possible, using gross morphological features and standard references (*e.g.*, Banfield 1974). Specimens of uncertain identification were labelled and collected for future examination and comparison with reference collections. Examination of cranial characteristics using a dissecting microscope was necessary in some cases.

### 9.1.3 Results And Discussion

The wildlife surveys undertaken in the Hope Bay Volcanic Belt in 1996 contributed new knowledge about animal distribution, density, movements and breeding activity in an area which has previously not been intensively studied.

#### *9.1.3.1 Ungulate Aerial Surveys*

Seven ungulate surveys were flown between May 31 and November 28, 1996. Surveys were conducted in May, June, July (three surveys), October, and November (Table 9.1-1).

**Table 9.1-1**
**Caribou and Muskoxen Observations From Aerial Surveys of the Hope Bay Belt Area, 1996**

| | Area Surveyed | On-transect Observations | | On-transect Density (per km$^2$) | |
|---|---|---|---|---|---|
| Survey Date | (km$^2$)[1] | Caribou | Muskoxen | Caribou | Muskoxen |
| May 31 | 584.5 | 273 | 71 | 0.47 | 0.12 |
| Jun 20/21 | 674.5 | 1198 | 57 | 1.78 | 0.08 |
| Jul 3 | 674.5 | 4 | 32 | <0.01 | 0.05 |
| Jul 19 | 674.5 | 653 | 33 | 0.97 | 0.05 |
| Jul 23 | 480.0 | 420 | 66 | 0.88 | 0.14 |
| Oct 18/19 | 300.0 | 4 | 16 | 0.01 | 0.05 |
| Nov 27/28 | 674.5 | 218 | 11 | 0.32 | 0.02 |

**1: Area surveyed is the product of strip width (1 km) and the total length of transects.**

The objective of identifying major migration routes through the study area was not met. In part, this was because large numbers of migratory caribou were not present in the study area during the May survey. In addition, early snow melt meant that few extensive areas were available to support tracks. By May 31, snow cover was estimated at only 30%.

*Caribou*

- *Numbers and Density*

  Caribou (Plate 9-1) numbers and densities within the survey area fluctuated widely (Figure 9.1-5). Caribou observations were of groups ranging in size from 1 to 548 individuals. During the May survey—pre-calving—moderate numbers of mostly “cows” were observed on transect. By June 20, many cows and calves were present. These animals had left the study area by July 3, when only four caribou, all bulls, were counted on transect. Substantial numbers of caribou had returned to the area by July 19. Most of these were in nursery groups.

  The October survey was scheduled to coincide with the caribou rut. However, very few caribou were observed on this survey. Ice had not yet formed between Victoria Island and Kent Peninsula, so Island caribou were not present in the survey area. An ice bridge was present by November 27, and substantial numbers of caribou were observed during that survey.

- *Distribution*

  Caribou were observed in all parts of the study area, although not on all survey transect lines. In general, on-transect density was higher in the southern portion of the study area (Figure 9.1-6). More than 56% of all caribou observations were on transects one to six, south of the Boston Project area (Figure 9.1-7), although this area represented only 27% of the total survey area. Very few caribou ($n = 19$; <1% of total observations) were seen on transects 22 to 26, from Roberts Bay to the north and east. This area comprised about 9% of the total survey area.

  During the post-calving period, there was a clear segregation between nursery groups and bull groups. For example, on the June 20/21 survey, a total of 1,198 caribou was observed on transect. On the most-southerly 12 survey lines 617 (52%) were counted, and nearly all were nursery groups of up to 98 individuals, with at least a few calves. The remainder were mostly in small

Plate 9-1: Bull caribou, Boston area, August 1995.

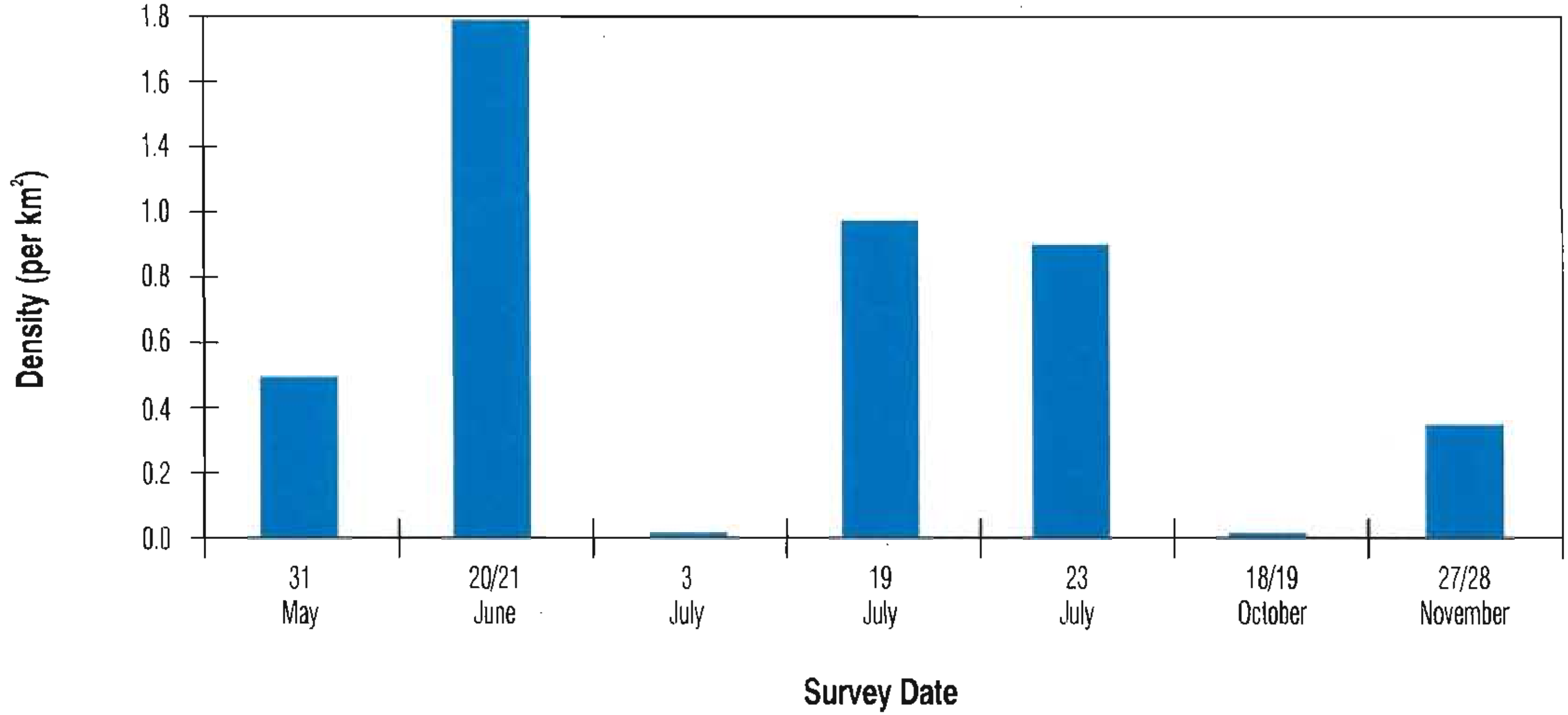


FIGURE 9.1-5

BHP

**Caribou Density Based on On-transect Observations During Aerial Surveys of the Hope Bay Belt Area, 1996**

Rescan

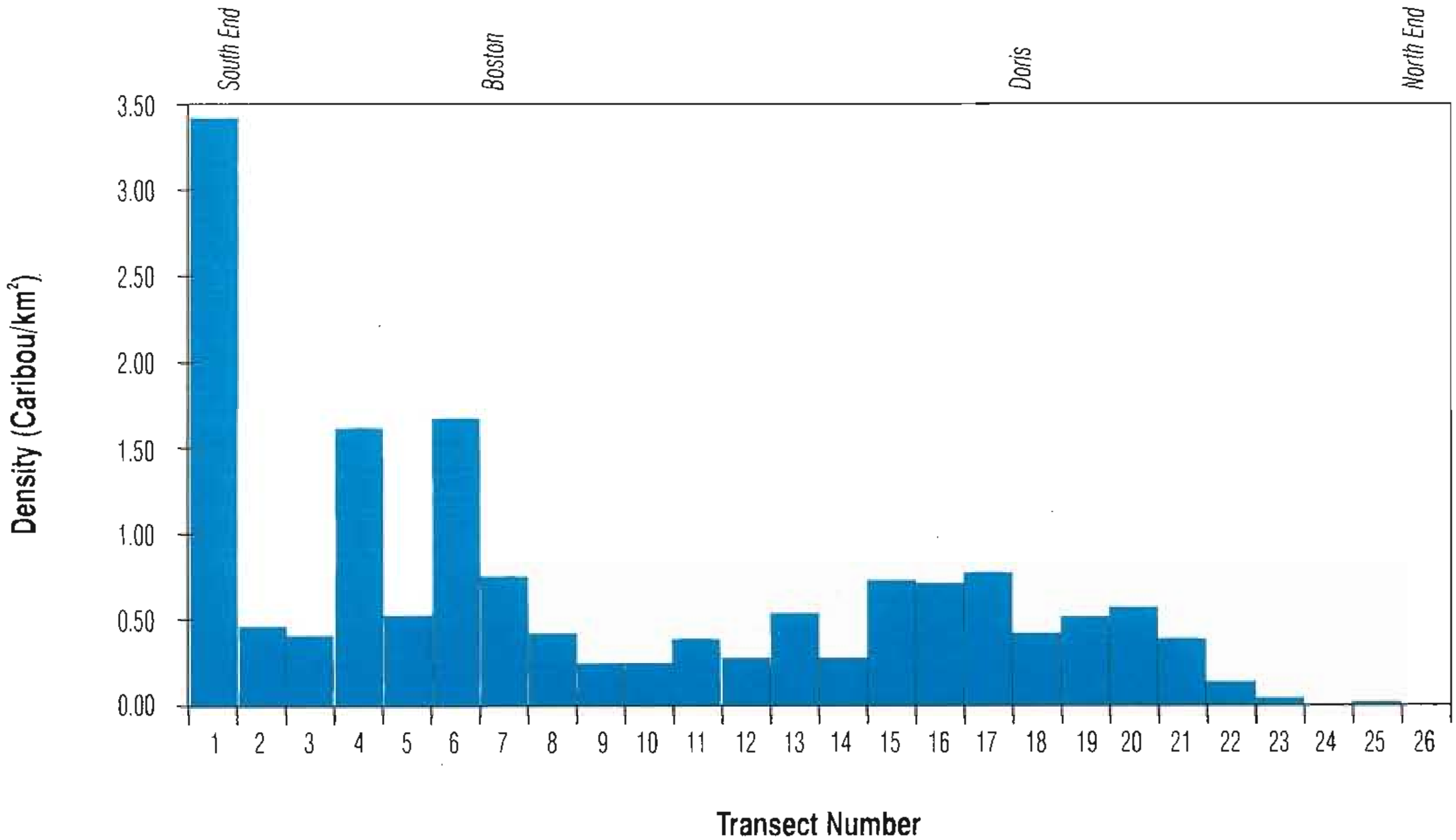


FIGURE 9.1-6

BHP

**Mean Density of Caribou observed During All Surveys, Hope Bay Belt Area, 1996, by Survey Transect Number**

Rescan

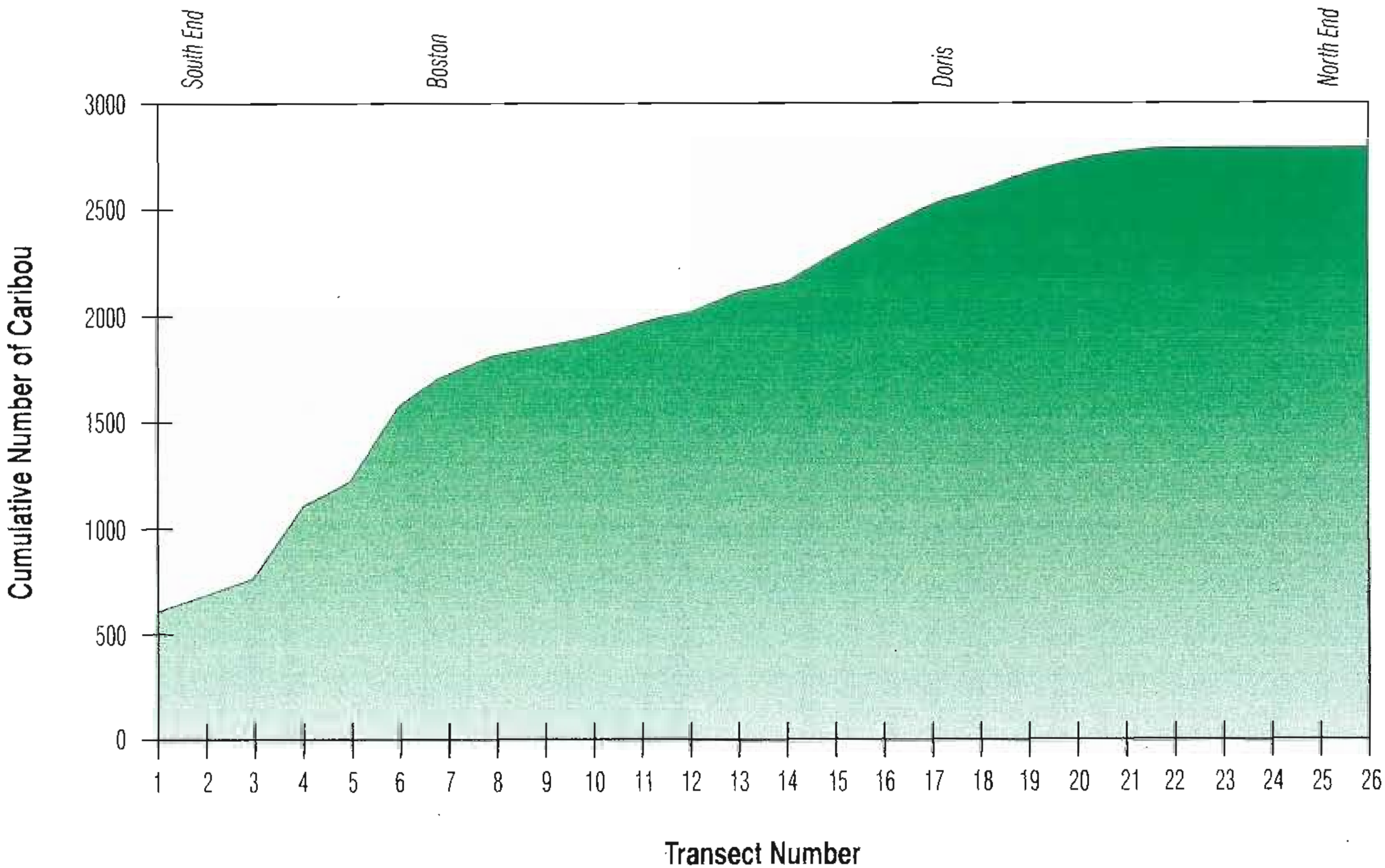


FIGURE 9.1-7

BHP

**Cumulative Totals of Caribou Observed on All Surveys of the Hope Bay Belt Area, 1996, by Survey Transect Number**

Rescan

groups (<10), and most classified caribou were bulls. On the most northerly 14 transect lines, only a single cow-calf pair was recorded. A similar pattern was observed during surveys over the rest of the summer; nearly all caribou observed in the northern section of the survey area were bulls in very small groups. When caribou were present in the southern portion of the survey area, most were nursery groups.

- *Herd Classification*

Caribou were classified as to herd origin (mainland or Victoria Island) during the November survey (Table 9.1-2). Of all caribou classified, 79% were mainland caribou. However, when the survey area was divided into northern and southern sections, roughly at the north end of Spyder Lake, an adjusted distribution was evident (Table 9.1-3). In the northern section, Victoria Island caribou comprised about 91% of classified caribou. In the southern section, mainland caribou dominated, at about 93%. In general, Victoria Island caribou became more prevalent along more northerly transects (Figure 9.1-8).

### Table 9.1-2
### Herd Classification of Caribou Observed On-transect and in Total

| | Number of caribou | | On-transect density |
|---|---|---|---|
| **Herd[1]** | **On Transect** | **Total** | **(per km²)** |
| Mainland | 166 | 236 | 0.246 |
| Victoria Island | 52 | 63 | 0.077 |
| Unclassified | 0 | 46 | 0 |
| Total | 218 | 345 | 0.323 |

**1: Classifications were based on relative body size and pelage coloration.**

### Table 9.1-3
### Distribution of Caribou by Herd Classification, Based on On-transect Observations

| | South[1] | | North[2] | |
|---|---|---|---|---|
| **Herd** | **Number** | **Percent** | **Number** | **Percent** |
| Mainland | 162 | 92.6 | 4 | 9.3 |
| Victoria Island | 13 | 7.4 | 39 | 90.7 |
| Total | 175 | 100 | 43 | 100 |

**1: "South" refers to survey transects 1-10.**
**2: "North" refers to transects 11-26.**

- *Calving*

Relatively few caribou appeared to calve within the study area in 1996. Aerial surveys and satellite telemetry data for the Bathurst caribou herd in 1996 indicated that most cows calved on the west side of Bathurst Inlet, between the Burnside and Hood rivers (Gunn 1996, pers. comm.). This was a calving distribution similar to that observed in 1995 (Gunn 1996), although the mapped calving grounds that year were large and also included an extensive area south and east of the Boston Project area. Gunn (1996) reported observing cows with calves within 15 km of Spyder Lake in June 1995, and concluded that the Boston Project site was within the boundaries of the 1995 calving range. In 1996, we observed cows with calves within 15 km of the Boston camp (but not the Doris Lake Project area) on several occasions in early June. By these criteria, the Hope Bay Belt fell within calving grounds in 1996 as well. The herd origin of these caribou (Bathurst or Queen Maud Gulf) was not determined.

Twelve surveys of the calving grounds of the Bathurst herd were conducted between 1966 and 1995. The Hope Bay Belt area was included within the mapped calving grounds on two of those surveys (1966 and 1995; summary in Hubert and Associates Ltd. 1996). The area used most commonly was east and south of the Boston Project area, close to the Ellice River.

The first calf observed in the study area in 1996 was a newborn recorded on June 3. By June 20, large numbers of cows and calves were observed within the southern half of the survey area, including within two kilometres of the Boston camp. By this date most calves are highly mobile, and these caribou may have traveled a substantial distance from their calving area.

*Muskoxen*

- *Numbers and Density*

Numbers and density of muskoxen observed (Plate 9-2, 9-3) during the seven surveys were variable, but more consistent than for caribou (Table 9.1-1, Figure 9.1-9). Muskoxen were found in groups of 1 to 62 individuals. Group size generally declined from May to November.

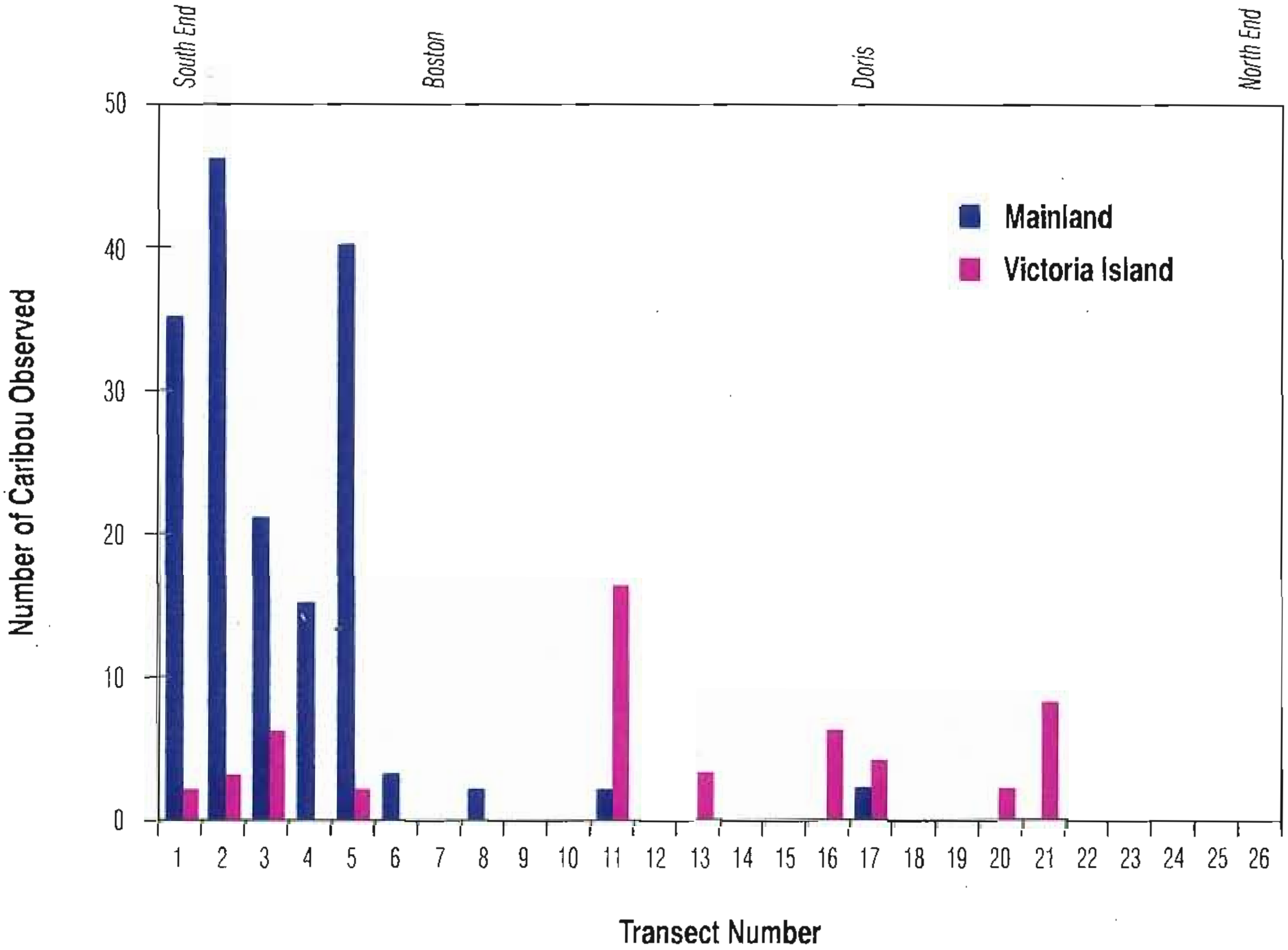


FIGURE 9.1-8

BHP

**Herd Origin of Caribou Observed on Transects During an Aerial Survey of the Hope Bay Belt Area, November 27-28, 1996**

Rescan

Plate 9-2: Muskox bull, Hope Bay Belt.

Plate 9-3: Muskox cow and calf, Hope Bay Belt.

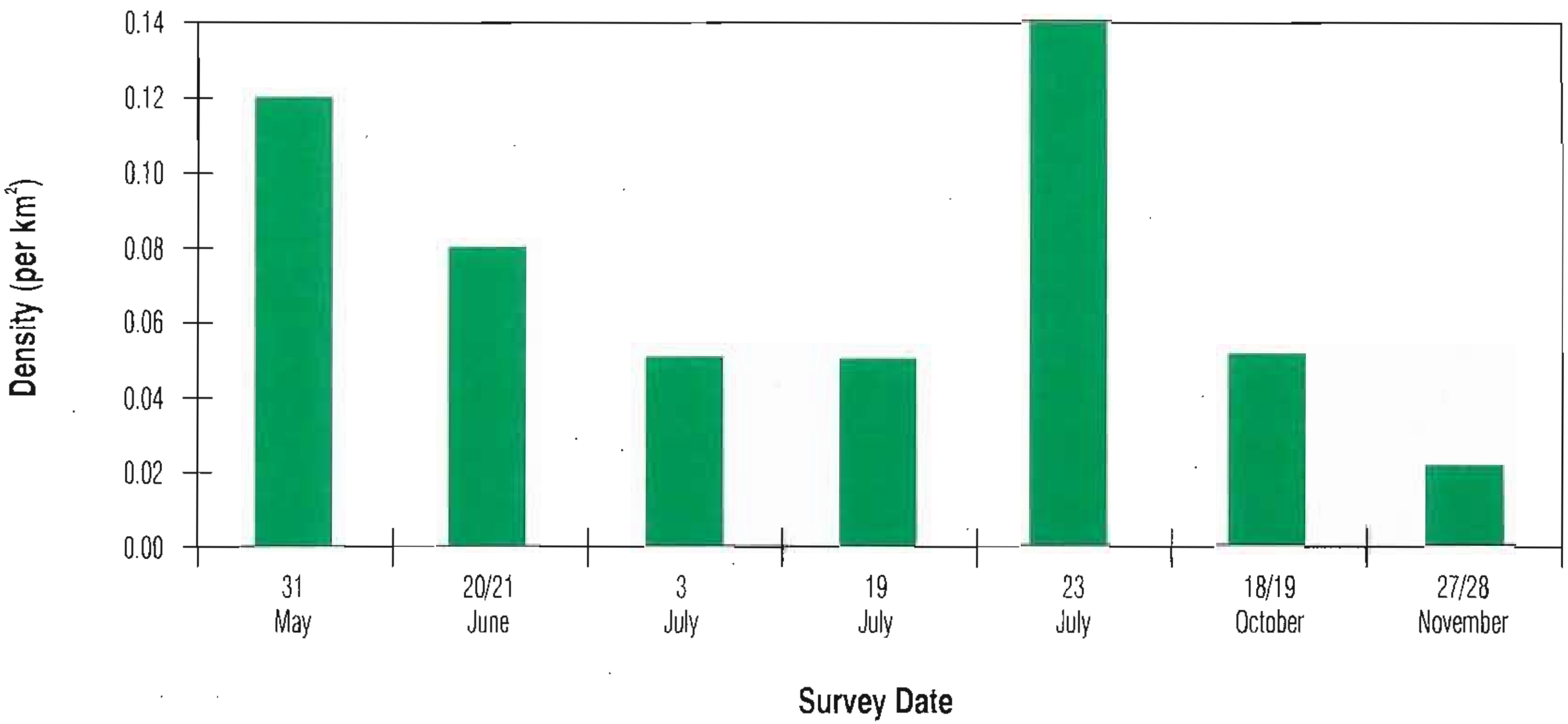


FIGURE 9.1-9

BHP

# Muskox Density Based on On-transect Observations During Aerial Surveys of the Hope Bay Belt Area, 1996

Rescan

Calves were observed on all surveys. It was difficult to accurately count calves, because nursery groups of muskoxen bunched tightly and fled when approached by the helicopter. Therefore, in order to avoid inciting an obvious reaction to the aircraft, no attempt was made to classify muskox herds, except to identify obvious calves and bulls. The largest number of calves was observed on the May 31 survey. Out of a total of 123 muskoxen observed on this survey (on- and off-transect), 15 calves were classified.

- *Distribution*

Muskoxen were widely but unevenly distributed over the study area. There were no muskox observations on eight (31%) of the survey transects.

As with caribou, muskox observations were concentrated towards the southern portion of the survey area (Figure 9.1-10). Almost 50% of all muskox observations were on transects one to six, south of the Boston Property (Figure 9.1-11), although this area comprised only 27% of the total survey area. Transects 15 to 26, representing the northernmost 38% of the survey area, contributed only 7% of muskox observations.

### *9.1.3.2 Carnivore Surveys*

*Grizzly Bear*

Early spring melt in 1996 precluded the efficient use of tracking snow to locate grizzly bear dens; by June 1, snow cover over the study area was estimated at only 30%. No bears dens were found in 1996, despite thorough searches of most potential denning areas.

Grizzly bear observations, however, were fairly common in 1996. The wildlife survey team made six observations of a total of 12 bears. This includes at least eight recognizably individual bears. In addition, the Doris Lake wildlife log recorded nine observations totaling 17 bears. At least two family groups were observed within the study area: one female was accompanied by two cubs-of-the-year, and another was travelling with two large cubs, probably two-year-olds. Grizzly bear observations are summarized on Figure 9.1-12.

Sixteen bear feeding sites were investigated and habitat-use plots were described for each (Appendix 9-1). The food items selected at these sites were ground squirrels (9), roots (mostly *Hedysarum alpinum*; 6), and sedge (*Carex* sp; 1). By mid-August, crowberries (*Empetrum nigrum*) were ripe and several bear scats consisting mostly of crowberry remains were found. However, precise feeding sites were not located in association with these scats, so feeding-site investigations were not conducted.

*Wolf*

One active wolf den was located in 1996 (Figure 9.1-13). This den was on an esker between two lakes, about nine kilometres south of the Boston Project area. Additionally, an aborted den attempt was found about one kilometre from the active den. Adult wolves, but not pups, were observed at the den several times between May 31 and July 3, but not later. During a ground inspection on July 21, no fresh wolf sign was observed. Only two caribou were observed within 40 km of the den site on the July 3 aerial survey, so the wolves may have abandoned the den in search of prey. Wolf observations throughout the study area during 1996 were infrequent and not localized, and there was no evidence of any other occupied den. There were five observations of a total of seven wolves recorded in the Doris Lake wildlife log (Appendix 9-2).

*Fox*

Two active red fox dens were found within the study area (Figure 9.1-13). One was located about one kilometre south of the Boston Project campsite, and produced several pups in 1996. The other den was located on a kame about 24 km east of Windy Lake, and also produced pups. Red foxes were reported in the Doris Lake and Boston Project wildlife logs fairly commonly, and very likely other dens occurred within the study area.

Arctic foxes were not observed within the study area until October. During aerial surveys in late October and late November, several Arctic foxes were observed, particularly between Windy Lake and Omingmaktok.

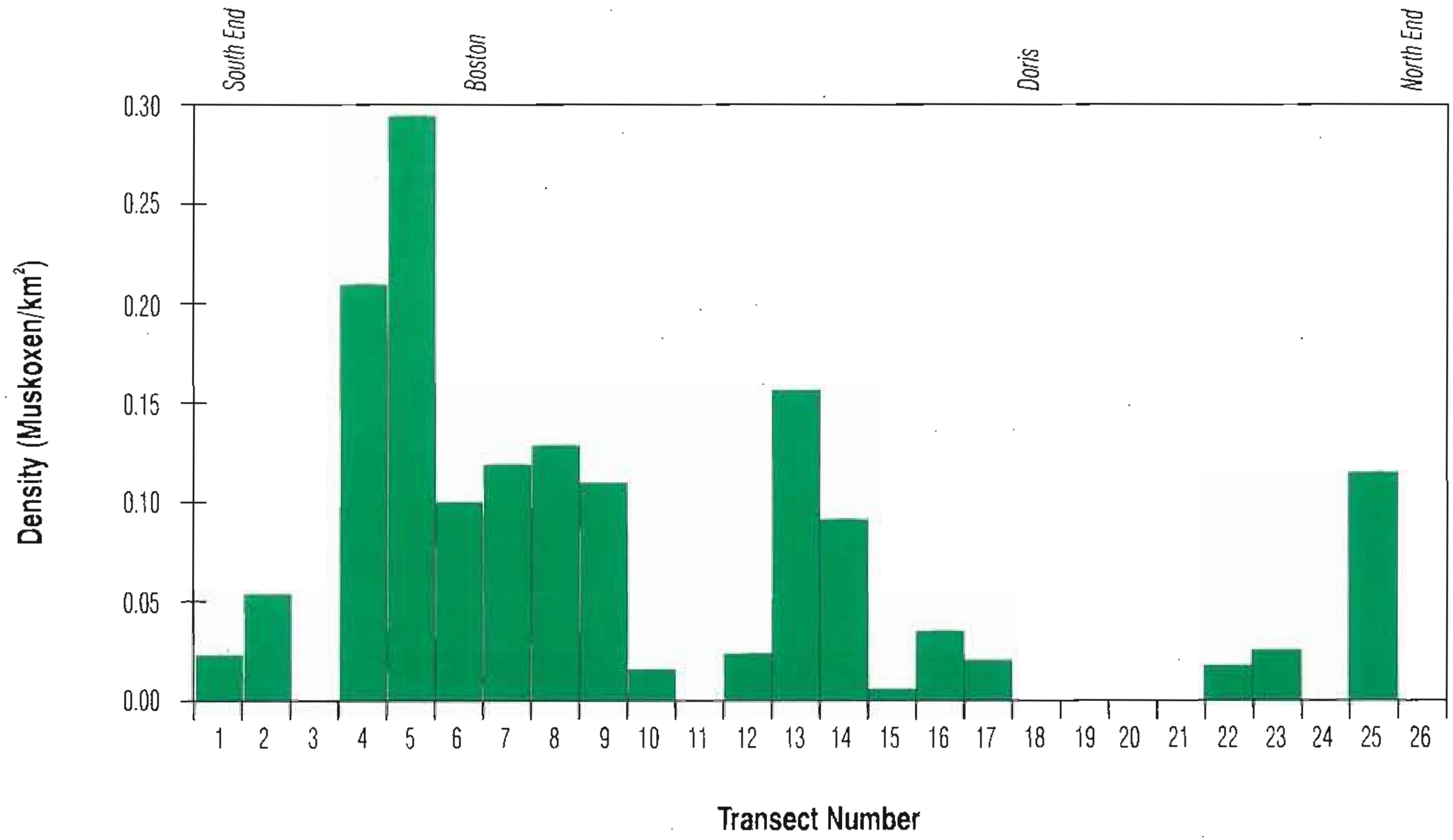


FIGURE 9.1-10

BHP

**Mean Density of Muskoxen observed During All Surveys, Hope Bay Belt Area, 1996, by Survey Transect Number**

Rescan

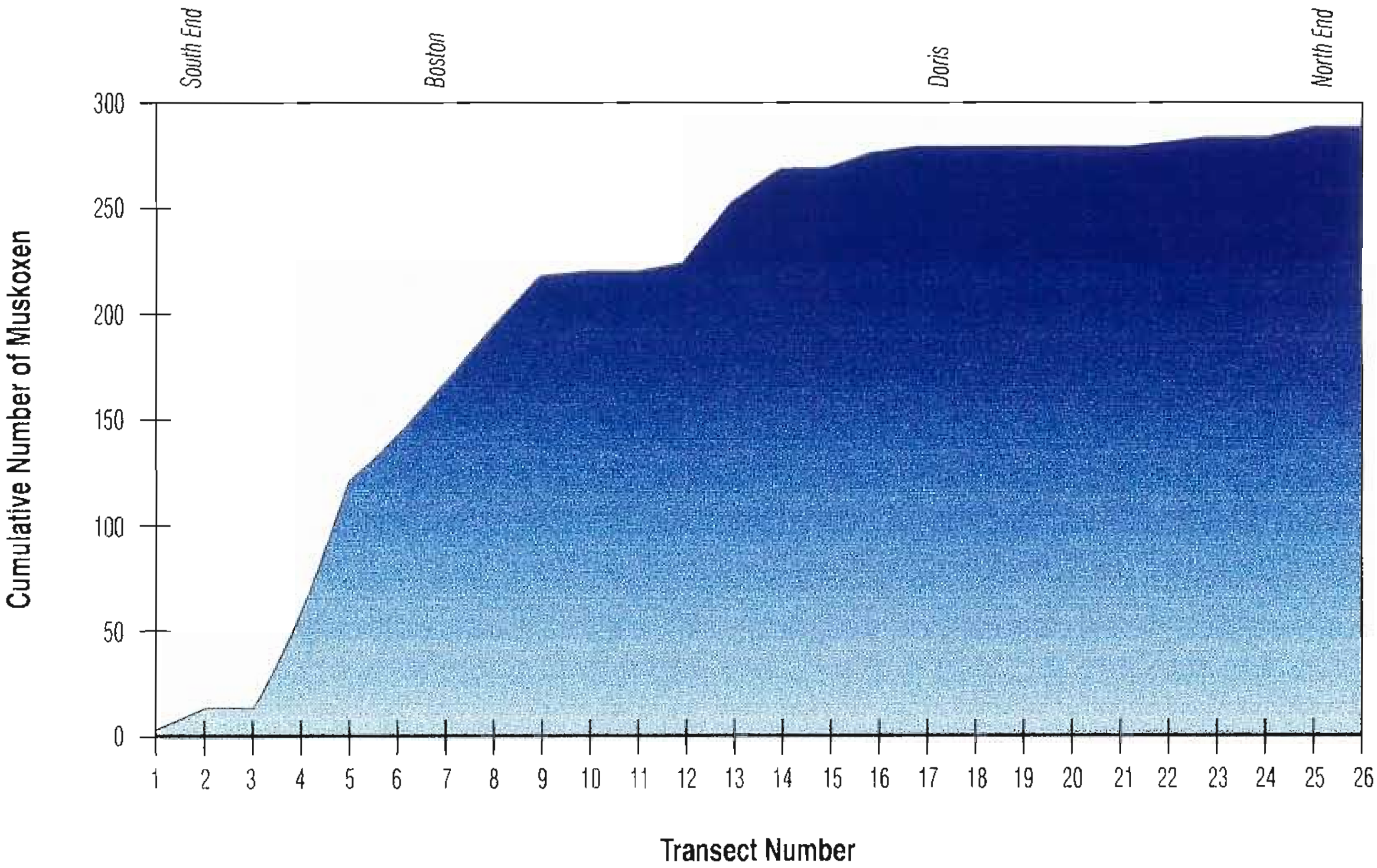


FIGURE 9.1-11

BHP

**Cumulative Totals of Muskoxen Observed on All Surveys of the Hope Bay Belt Area, 1996, by Survey Transect Number**

Rescan

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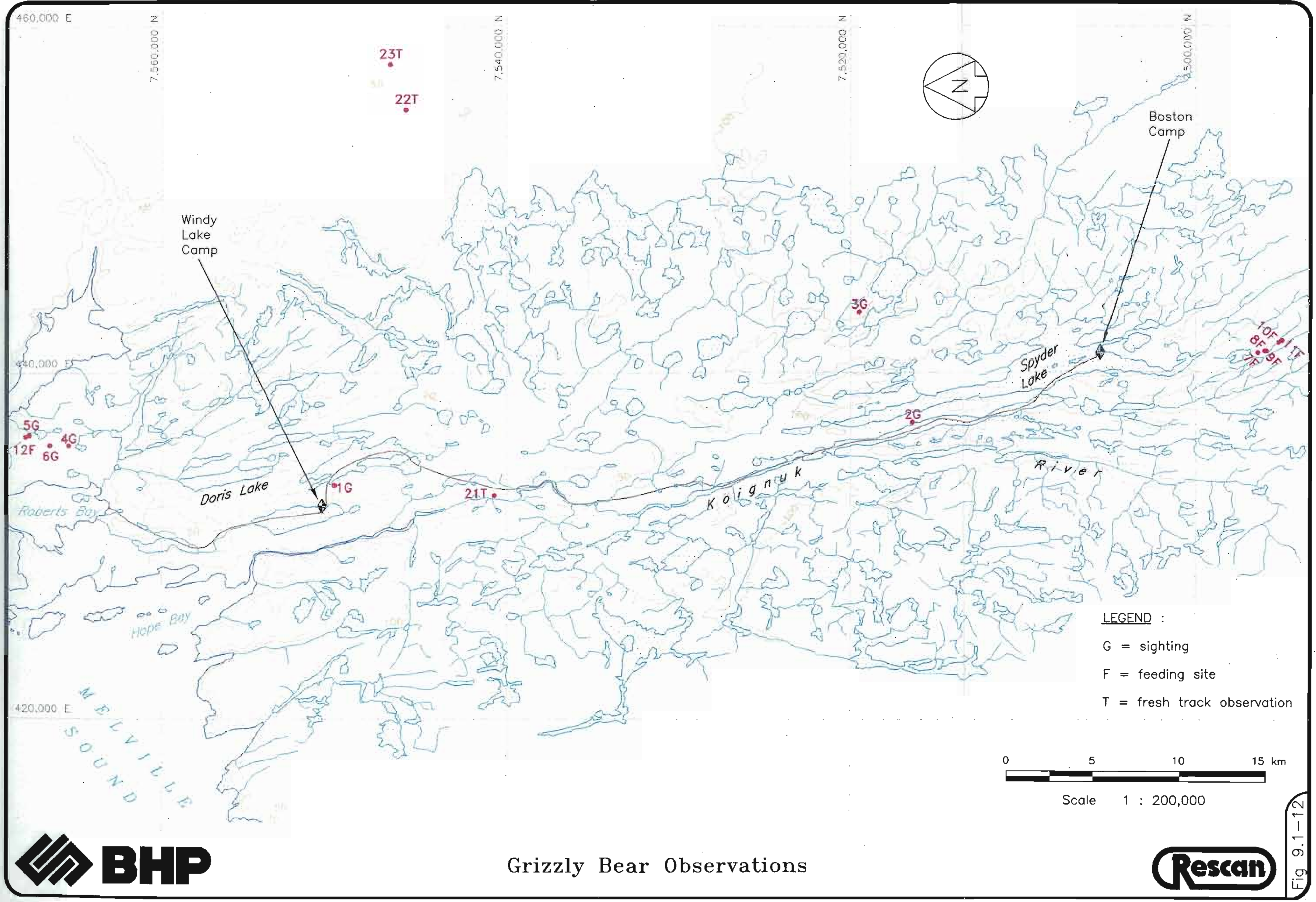


Grizzly Bear Observations

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BHP

Wolf and Fox Dens

Rescan

Fig 9.1-13

*Wolverine*

For several reasons, primarily their relative scarcity, wolverines were not specifically surveyed in this study. They are large enough to be visible from the air, but are not easily seen against most backgrounds. No wolverines were observed during wildlife surveys in 1996. There was, however, one observation recorded in the Doris Lake wildlife log. This was of a large, dark wolverine, and it was observed on the west side of Finger Lake, south-southwest of Windy Lake.

Wolverines are regularly killed, although in small numbers, within the Hope Bay Belt by hunters and trappers from Omingmaktok and Cambridge Bay. Most years, no more than two wolverines are likely to be taken within the study area proper.

*Short-tailed Weasel*

No survey component addressed weasels. Short-tailed weasels were observed several times, and may be fairly common in the study area. On August 18, a weasel was observed foraging along a creek southwest of Boston. Weasels were also reported in the Doris Lake wildlife log on five occasions. One of these observations was of five weasels, which is likely indicative of breeding.

*9.1.3.3 Raptor Nesting Surveys*

A helicopter survey for raptor nests (Plate 9-4) was conducted on July 18. The survey began at the south end of Windy Lake and moved southward. Areas north of Doris Lake camp were surveyed by GNWT just prior to the July 18 survey. However, at the request of the GNWT biologist, several sites to the north were revisited during the July 18 survey to confirm the GNWT results.

A total of 36 raptor observations was made, of which 26 included active nests (Table 9.1-4). An additional three observations involved probable nests, based on the behavior of adult birds. The remaining seven observations were of adult birds with no evidence of an active nest in the immediate vicinity. It was not possible to survey the entire study area, and many suitable nest sites were not visited. It is likely that several or even many occupied raptor nests were not documented during this survey. Five species were recorded: Gyrfalcon, Peregrine Falcon, Rough-legged Hawk, Golden Eagle, and Common Raven. In addition, raptors, including nests, were recorded incidentally to other surveys during 1996.

## Table 9.1-4
## Summary of Raptor Observations during an Aerial Survey of the Hope Bay Belt Area

| Site No.[1] | Species | Presence of Nest | Status |
|---|---|---|---|
| G1 | Gyrfalcon | yes | 2 fledglings |
| H1 | Rough-legged Hawk | yes | 3-4 nestlings |
| G2 | Gyrfalcon | yes | fledglings |
| G3 | Gyrfalcon | yes | fledglings |
| P1 | Peregrine Falcon | yes | 3-4 nestlings |
| H2 | Rough-legged Hawk | yes | 3 nestlings |
| H3 | Rough-legged Hawk | yes | 3 nestlings |
| P2 | Peregrine Falcon | yes | 3 nestlings |
| P3 | Peregrine Falcon | probable | |
| P4 | Peregrine Falcon | probable | |
| H4 | Rough-legged Hawk | yes | 4 nestlings |
| H5 | Rough-legged Hawk | yes | 3-4 nestlings |
| P5 | Peregrine Falcon | yes | 3-4 nestlings |
| P6 | Peregrine Falcon | probable | |
| P7 | Peregrine Falcon | yes | 3 nestlings |
| P8 | Peregrine Falcon | yes | 1 egg |
| P9 | Peregrine Falcon | unknown | |
| P10 | Peregrine Falcon | yes | 2 nestlings |
| P11 | Peregrine Falcon | yes | 2 nestlings |
| E1 | Golden Eagle | yes | 2 fledglings |
| E2 | Golden Eagle | no | |
| P12 | Peregrine Falcon | yes | 1 nestling |
| G4 | Gyrfalcon | yes | 1 fledgling |
| P13 | Peregrine Falcon | no | |
| G5 | Gyrfalcon | yes | 2 fledglings |
| E3 | Golden Eagle | yes | unknown |
| H6 | Rough-legged Hawk | yes | 3 nestlings |
| H7 | Rough-legged Hawk | yes | 3 nestlings |
| G6 | Gyrfalcon | no | |
| H8 | Rough-legged Hawk | yes | 3 nestlings |
| R1 | Common Raven | no | 6 fledglings |
| G7 | Gyrfalcon | yes | 3 fledglings |
| G8 | Gyrfalcon | no | 2 adults |
| H9 | Rough-legged Hawk | yes | 4 nestlings |
| H10 | Rough-legged Hawk | yes | 3 nestlings |

**1: Site numbers correspond to point labels on Figure 9.1-15.**

Plate 9-4: Golden Eagle nest, Hope Bay Belt.

Two more species, Snowy Owl and Short-eared Owl, were recorded during these surveys.

Results of the GNWT raptor survey were not available at the time this report was prepared. Therefore, the description of raptor nesting activity for the northern portion of the study area is incomplete. Raw data from the GNWT survey have been included where possible.

Occupied raptor nests were more common in the northern half of the study area (Figure 9.1-14). Suitable nest sites (*i.e.*, cliffs) were much more prevalent there than in the south. In the southern portion, cliffs occur occasionally along rivers and lake shores, but in few other places. However, a high proportion of sites that appeared to be suitable were, in fact, occupied by nesting raptors.

A few sites were particularly noteworthy. The sill located at the north end of Doris Lake was the site of at least four active raptor nests in 1996. These included Gyrfalcon (2), Peregrine Falcon (1), and Golden Eagle (1). Due to its proximity to the proposed bulk sample site at Doris Lake, consideration will be required to ensure these birds are not displaced by human activity in 1997. However, industrial activity, including many take-offs and landings of aircraft, was prominent at the Doris Lake camp in 1996, and raptors continued to use nest sites in the immediate vicinity. There were two Rough-legged Hawk nests and one Gyrfalcon nest within 1.5 km of the camp site in 1996, as well as another Rough-legged Hawk nest and a Peregrine Falcon nest further north along Windy Lake.

The dyke immediately south of Windy Lake (north end is about 3.7 km south of the Doris Lake Property camp situated on Windy Lake) is another heavily used area. Two Gyrfalcon nests were observed at this site, and the GNWT found several more raptor nests along this structure (Shank 1996, pers. comm.).

Cliffs adjacent to Stickleback Lake, about 2.5 km south of Boston campsite, were occupied by a pair of Peregrine Falcons in 1995. There was no sign of falcon activity at this site during 1996.

*Gyrfalcon*

Eight Gyrfalcon observations were recorded on the July 18 aerial survey. Six of these involved nests occupied by one or more fledglings. A total of three adults comprised the remaining two observations. One of these was a pair which may have had a nest nearby which was not located. Fledging from the nest for one Gyrfalcon brood was known to occur between July 18 and 20.

Gyrfalcon nests are particularly common on the cliffs in the northernmost part of the Hope Bay Belt, north of Windy Lake. This area was surveyed primarily by GNWT, and results of that survey were not available at the time this report was prepared. However, Gyrfalcon nests were observed on the sill at the north end of Doris Lake (two nests), and on the cliff at the south end of Windy Lake (one nest).

*Peregrine*

Thirteen observations of Peregrine Falcons were made on July 18. Eight of these included nests, and an additional three involved adult birds that were behaving in a defensive manner. Nests contained one to four nestlings. One nest held a single egg.

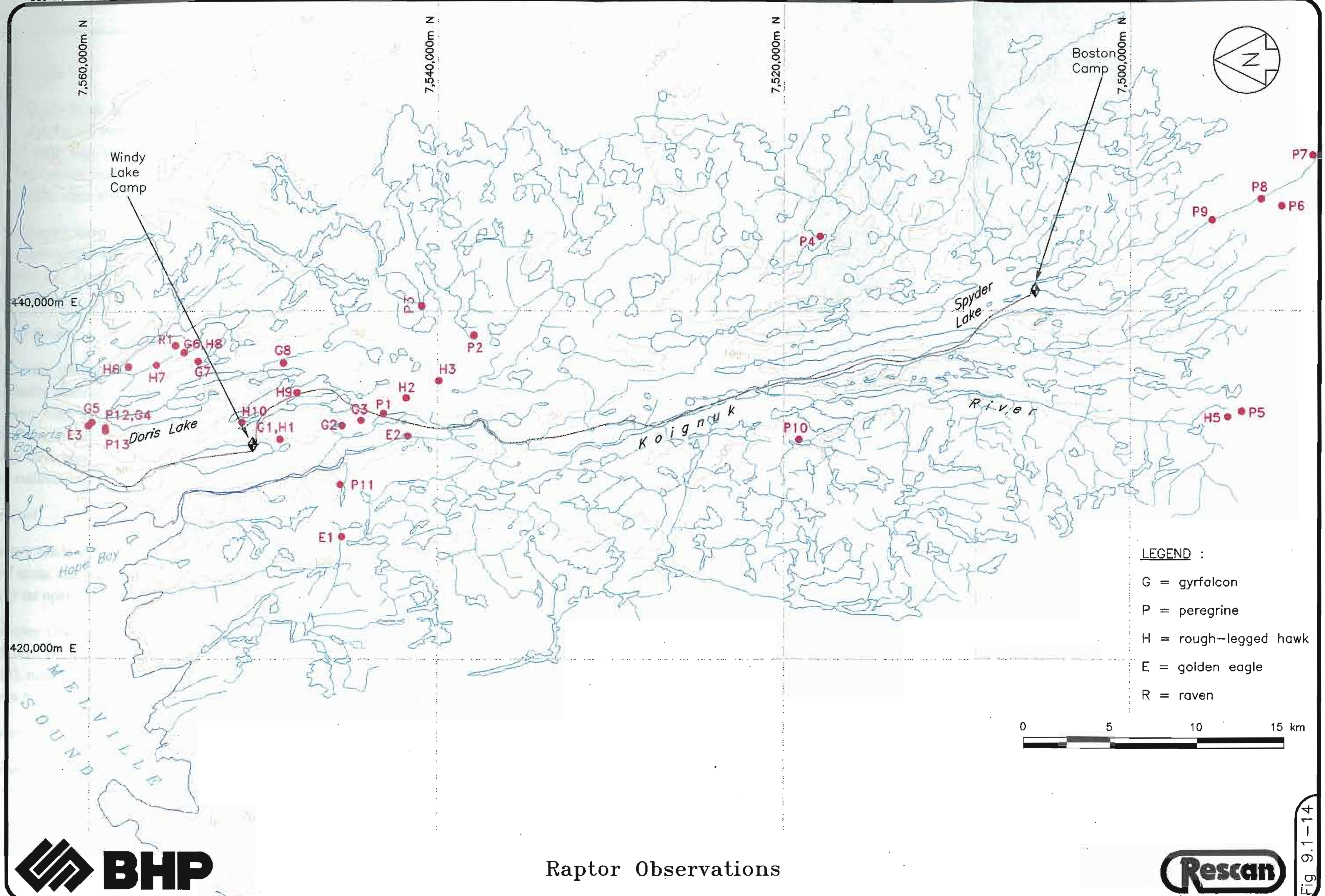
Like Gyrfalcons, Peregrine Falcons commonly nest in the cliffs in the vicinity of Hope Bay, especially north of Windy Lake. This was the area surveyed by GNWT; those results were not available at the time this report was prepared. One Peregrine Falcon nest was observed on the sill immediately north of Doris Lake.

Probable Peregrine Falcon nests, presumed because of territorial-defense behavior of adult birds, were located in cliff bands at several sites along the Koignuk River south of Windy Lake. These sites, however, were never visited specifically to confirm the existence of nests.

*Rough-legged Hawk*

Rough-legged Hawks are also a common raptor species in the study area. Ten observations of Rough-legs were recorded, and all included occupied nests. Nests held three to four nestlings. Two nests within 1.5 km of the Doris Lake Property camp situated on Windy Lake were occupied in 1996. One nest contained three nestlings and a ground squirrel carcass.

Cad No. a2218s | Scale: 1:200 000 | Job No. 526-1 | 14/03/1997-11:58am | RES_BF




Raptor Observations

Fig 9.1-14

*Golden Eagle*

Golden Eagle nests appeared to be relatively uncommon south of Windy Lake. Aside from the sill north of Doris Lake (where there was one occupied nest), only a single eagle nest was found. This nest contained two fledgling eagles. Eagle nest observations from the coastal portion of the study area (GNWT survey) were not available when this report was written.

Golden Eagles were commonly seen in the study area in 1994, 1995, and 1996. Eagle observations were recorded during surveys as early as May 31 and as late as November 27. From this, it seems likely that some Golden Eagles remain in the area all year.

*Common Raven*

Ravens were observed infrequently in the study area during 1996. Singles were occasionally observed incidentally in most parts of the study area during spring-fall. There were no occupied nests found on July 18. However, two adults with a brood of six juveniles were observed. These birds were moving across the ground, and may have been close to the site of their nest. The juveniles appeared capable of only rudimentary flight.

*Snowy Owl*

No Snowy Owls were observed on the July 18 survey. This survey concentrated on cliff areas and was therefore not likely to locate Snowy Owl nests which are typically on open tundra.

Few Snowy Owls were observed in the study area in 1996. Incidental records totaled four owls and no nests. Observations occurred near the Boston claim block (2), near Windy Lake (1), and near Hope Bay (1). One nest containing eight eggs was reported in the Doris Lake wildlife log for July 1.

*Short-eared Owl*

Short-eared Owls were not observed during the July 18 survey. However, they were recorded incidentally to other surveys during 1996.

One Short-eared Owl was observed south of the Boston camp on July 21. A Short-eared Owl was recorded in the Doris Lake wildlife log for August 12. This bird was seen northeast of Windy Lake.

*Other Species*

No other raptor species were recorded during any survey in 1994, 1995, or 1996. The Doris Lake wildlife log, however, contained a record of a pair of Ospreys at a nest containing three young. The location of this observation was not confirmed. However, given the known distribution of this species (generally within treed habitats), it is unlikely that this identification was correct. Most likely, this was an observation of Rough-legged Hawks.

*9.1.3.4 Breeding Bird Census Surveys*

Breeding bird census plots were surveyed during June 21 to 24. The area of the eight plots surveyed totaled 252 ha. Four plots (B1-B4) were located within 13 km of the Boston camp, and four (D1-D4) were within 16 km of the Doris Lake Property camp situated on Windy Lake. Within each group, one plot (designated the "treatment" plot) was located within one kilometre of the camp (plots B1 and W1).

*Numbers, Density, and Species Diversity*

A total of 403 "adult" (fully fledged) birds was observed on transect, comprised of 15 or 16 species (most redpolls were not identified to species; they could have been hoary or common redpolls; Table 9.1-5). Thirteen nests containing eggs or young were found, although no particular effort was made to locate nests, in order to minimize disturbance by field personnel. Overall density was 1.60 birds/ha, and ranged between plots from 0.54 to 2.68 birds/ha. Between five and nine species of birds were identified on each plot, and species Diversity Indices (number of species per hectare) ranged from 0.11 to 0.35.

There were no apparent differences between the Boston plots and the Doris Lake plots in total number of species recorded, number of nests found, or observed bird density. Diversity Index rating was slightly higher for the Boston Project plots than the Doris Lake plots.

# Table 9.1-5

## Number of Adults[1] and Nests of Bird Species Observed on Breeding Bird Plots Surveyed in the Hope Bay Belt Area, June 1996

| | Plot Number | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | B1 | | B2 | | B3 | | B4 | | D1 | | D2 | | D3 | | D4 | | Total | |
| Species | Ad[2] | Nest | Ad | Nest | Ad | Nest | Ad | Nest | Ad | Nest | Ad | Nest | Ad | Nest | Ad | Nest | Ad | Nest |
| Redpoll spp. | 4 | | 12 | | 1 | | | | 8 | | 48 | 1 | 8 | | 1 | | 82 | 1 |
| American Tree Sparrow | 7 | 1 | 5 | | | | | | 8 | 2 | 1 | | | | | | 21 | 3 |
| Lapland Longspur | 21 | 1 | 13 | | 34 | 1 | 8 | | 18 | 1 | 12 | | 12 | | 42 | 1 | 160 | 4 |
| Willow Ptarmigan | | | 1 | | 1 | | | | | | | | | | | | 2 | |
| Rock Ptarmigan | | | 1 | | | | | | | | | | | | | | 1 | |
| Ptarmigan spp. | 1 | | | | | | | | 1 | | | | | | | | 2 | |
| Horned Lark | 15 | 1 | 3 | | 5 | 1 | | | 13 | | 7 | 1 | 4 | | 21 | 1 | 68 | 4 |
| Savannah Sparrow | | | 17 | | 2 | | | | 2 | | 7 | | 5 | | 3 | | 36 | |
| Semipalmated Sandpiper | | | | | | | 1 | | 1 | | | | | | 6 | | 8 | |
| Lesser Golden Plover | | | 6 | | | | 2 | | | | | | | | | | 8 | |
| Long-tailed Jaeger | | | 1 | | 2 | | 3 | | | | | | | | | | 6 | |
| Spotted Sandpiper | 1 | | | | | | | | | | | | 2 | | | | 3 | |
| Semipalmated Plover | | | | | | | | | | | | | | | 2 | | 2 | |
| American Pipit | | | | | | | | | | | | | | | 2 | | 2 | |
| White-crowned Sparrow | | | | | | | | | | | | | | | 1 | | 1 | |
| White-fronted Goose | | | | | | | 1 | 1 | | | | | | | | | 1 | 1 |
| Total birds | 49 | | 59 | | 45 | | 15 | | 51 | | 75 | | 31 | | 78 | | 403 | |
| Total nests | | 3 | | 0 | | 2 | | 1 | | 3 | | 2 | | 0 | | 2 | | 13 |
| Total species | 6 | | 9 | | 6 | | 5 | | 7 | | 5 | | 5 | | 8 | | 16 | |
| Plot area (ha) | 25 | | 26 | | 25 | | 28 | | 25 | | 28 | | 25 | | 70 | | 252 | |
| Bird density (# birds/ha) | 1.96 | | 2.27 | | 1.80 | | 0.54 | | 2.04 | | 2.68 | | 1.24 | | 1.11 | | 1.60 | |
| Diversity Index (# sp/ha) | 0.24 | | 0.35 | | 0.24 | | 0.18 | | 0.28 | | 0.18 | | 0.20 | | 0.11 | | 0.06 | |

**1: Adult birds include all fully-fledged birds.**
**2: Ad = Adult.**

Similarly, there were no apparent differences between the treatment plots and the reference (more remote) plots in number of species recorded, number of nests found, observed bird density, or species Diversity Index, at either of the Boston Project or Doris Lake Properties. In all cases, sample sizes were too small to statistically test for differences.

*Habitat Association*

Because ecological mapping had not been completed at the time of this survey, plot locations were irrespective of ecological mapping units. Consequently, habitats within plots were described using dominant vegetation types assessed on the scale of the plot itself.

Mesic tundra was the most prevalent habitat type surveyed in the breeding bird census (Table 9.1-6). It was present on each plot, at between 20 and 70% occurrence. Within this type, no vegetation exceeded 15 cm in height, and plants above 10 cm were sparse. Some birds, notably Lapland Longspurs, nested directly on the ground within this habitat type. Other nests were found within patches of broken rock cover (*e.g.*, horned larks).

**Table 9.1-6**
**Habitat Descriptions of Breeding Bird Census Plots**
**Surveyed in the Hope Bay Belt Area**

| | Plot Number and % of plot covered by habitat | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Habitat type** | **B1** | **B2** | **B3** | **B4** | **D1** | **D2** | **D3** | **D4** |
| Mesic tundra | 70 | 30 | 50 | 50 | 50 | 40 | 20 | 60 |
| Moist birch tundra | 20 | 60 | 40 | | 25 | 25 | | 10 |
| Riparian willow | | 5 | | | | 25 | | 5 |
| Moist tundra | | | | 20 | 15 | | | |
| Shoreline | | | | 10 | | | | |
| Wet sedge | | | | | | | 30 | |
| Rock/xeric tundra | | | | | | | 50 | 25 |
| Gravel | | 5 | | 20 | | | | |
| Rock | 10 | | 10 | | 10 | 10 | | |

Most nests, however, were found suspended in above-ground vegetation 30 to 70 cm tall. Nests found in shrubs included those of American Tree Sparrows, White-crowned Sparrows and Redpolls. Within each plot, more birds were observed within shrubby vegetation types (moist birch tundra and riparian willow habitat types) than other areas. There was a direct relationship between the prevalence of shrubby vegetation on a plot and the bird density observed; the amount of shrub cover on plot explained about 71% of the variability in observed bird density (Figure 9.1-15). The highest and second-highest observed bird density values were for transects D2 and B2, which comprised 50 and 65% shrub types, respectively. The lowest observed bird density occurred on transect B4, which followed an esker east of the Boston claim block, and which sampled mostly dry esker materials and no shrub areas.

Shrub areas with vegetation >30 cm tall are relatively uncommon in the Hope Bay Belt. River valleys, lake verges, and other riparian zones provide some of the few extensive shrub stands. Because of their high degree of use by breeding birds, these areas must be considered important habitat for these species. Additionally, because large expanses of the Hope Bay Belt lack any shrubby cover at all, even small stands are likely of relatively high value.

#### *9.1.3.5 Waterfowl Surveys*

Two aerial waterfowl surveys were conducted in 1996. The first was flown on July 20, then a replicate was flown on July 22. Results were tabulated by species for the Boston Project and Doris Lake survey blocks (Tables 9.1-7 to 9.1-11). For each species within each of the survey blocks, the higher count from the two surveys was used for analyses. This presumes that there was no significant migration between the Boston and Doris Lake blocks between July 20 and July 22.

Eleven species of waterfowl were recorded, including Sandhill Cranes. Most prevalent were Canada Geese, followed by White-fronted Geese and Pacific Loons. Species which were rarely recorded included Red-throated Loon, Northern Pintail, and Yellow-billed Loon. Broods were documented for all species except Red-throated Loon and Yellow-billed Loon. However, breeding Red-throated Loons were recorded during other surveys in 1996.

Species diversity, indicated by the number of species recorded on transect, was similar between the two areas. Pintails and Red-breasted Mergansers were not recorded on the Doris Lake block, whereas no Yellow-billed Loons were observed in the Boston claim block area.

More than twice as many total adult birds were observed on the Boston claim block than on the Doris Lake claim block. This difference was most evident with Canada Geese, which were 4.6 times more abundant around the Boston block than further north. Oldsquaws were also more prevalent in the south. By contrast, three times as more Greater Scaup were recorded on the Doris Lake block than on the Boston block.

*Canada Goose*

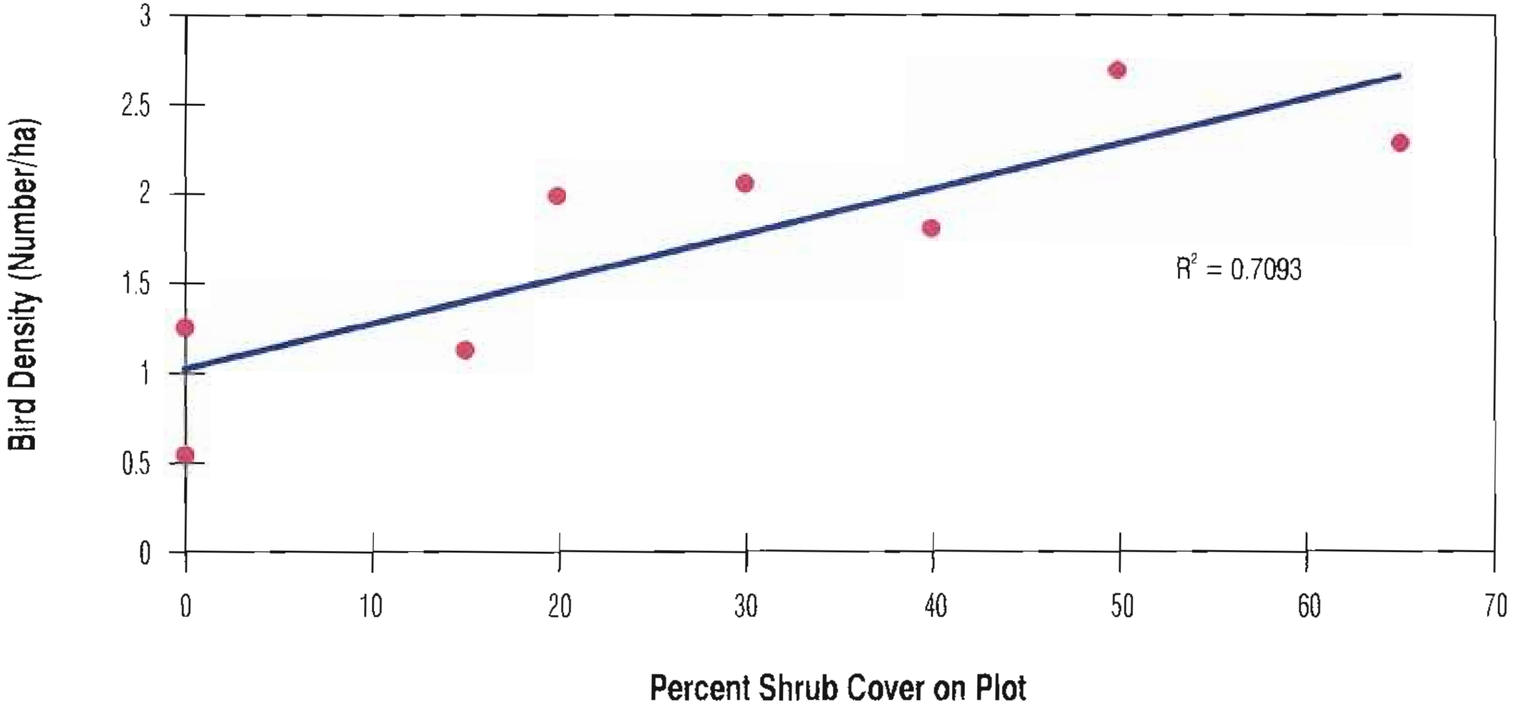
Canada Geese were the most prevalent waterfowl recorded on this survey. A total of 208 adult Canada Geese was recorded, totalling 52% of all adult birds recorded during Survey 1, and 59% of adult birds recorded during Survey 2. They were also widespread, and were recorded on all eight survey lines in the Boston area, and on four of the Doris Lake lines.

Canada Geese breed commonly within the study area as well. A minimum of 14 broods was recorded on surveys, more than for any other species. Although quantitative data are not available, the study area is also used by large numbers of Canada Geese during spring and fall migrations.

*Greater White-fronted Goose*

White-fronted Geese were the second most-common waterfowl species recorded on the aerial surveys, with a total of 72 adults observed. They comprised 20% and 15% of adult birds observed on Surveys 1 and 2, respectively. White-fronted Geese are also widely distributed, with observations recorded on five of the Boston Project lines and six of the Doris Lake lines.

White-fronted Geese are also common breeders here; at least 12 broods were recorded on this survey. Large numbers of White-fronted Geese were recorded staging in the study area during fall (August-early September) in 1994, 1995, and 1996.




*Note: Data are from 8 breeding bird census plots surveyed in the Hope Bay Belt Area, June 1996*

FIGURE 9.1-15

**Relationship Between Percent Shrub Cover on Plot and Observed Bird Density**

BHP Rescan

## Table 9.1-7

## Number of Adult[1] Birds and Broods Observed in the Hope Bay Belt Area, July 20, 1996

| | Species[2] | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | C. Goose | | WF Goose | | T. Swan | | G. Scaup | | Oldsquaw | | Pintail | | Merganser | | P. Loon | | RT Loon | | YB Loon | | S. Crane | |
| Line No. | Ad[3] | Brood | Ad | Brood | Ad | Brood | Ad | Brood | Ad | Brood | Ad | Brood | Ad | Brood | Ad | Brood | Ad | Brood | Ad | Brood | Ad | Brood |
| B1 | 7 | 4 | | | | | 1 | | | | | | | | 4 | 1 | | | | | | |
| B2 | 37 | | 4 | 1 | | | | | | | | | | | 1 | | | | | | | |
| B3 | | | | | | | | | 2 | 2 | | | 2 | 1 | 2 | | | | | | | |
| B4 | 6 | 1 | 2 | 1 | 2 | 1 | | | | | | | | | 2 | 1 | | | | | | |
| B5 | 6 | | 8 | 2 | 4 | | | | | | | | | | 1 | | | | | | | |
| B6 | 41 | 2 | | | | | | | 2 | | | | | | 2 | | 2 | | | | | |
| B7 | 1 | 1 | | | | | | | 2 | 1 | | | | | 2 | 1 | | | | | 4 | 1 |
| B8 | 14 | 1 | 20 | 2 | 3 | | | | | | | | 2 | | 2 | | | | | | | |
| D1 | | | | | | | 1 | | | | | | | | | | | | | | | |
| D2 | | | 10 | 2 | | | | | | | | | | | 5 | | | | | | 2 | 1 |
| D3 | 2 | | 3 | 1 | 2 | 1 | | | | | | | | | | | | | | | | |
| D4 | 4 | 2 | 3 | 1 | | | | | | | | | | | | | | | | | 2 | |
| D5 | | | | | 4 | 2 | | | | | | | | | 2 | 1 | | | | | | |
| D6 | | | | | | | | | | | | | | | | | | | | | | |
| D7 | 31 | 1 | 6 | 1 | | | 5 | | 4 | | | | | | | | | | | | | |
| D8 | | | 2 | 1 | | | 8 | | | | | | | | | | | | 1 | | | |
| TOTAL | 149 | 12 | 58 | 12 | 15 | 4 | 15 | 0 | 10 | 3 | 0 | 0 | 4 | 1 | 23 | 4 | 2 | 0 | 1 | 0 | 8 | 2 |

**1: Adult birds include all fully-fledged birds.**

**2: C. Goose = Canada Goose, WF Goose = White-fronted Goose, T. Swan = Tundra Swan, G. Scaup = Greater Scaup, P. Loon = Pacific Loon, RT Loon = Red-throated Loon, YB Loon = Yellow-billed Loon, and S. Crane = Sandhill Crane.**

**3: Ad = Adult.**

# Table 9.1-8

## Number of Adult[1] Birds and Broods Observed in the Hope Bay Belt Area, July 22, 1996

| | Species[2] | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | C. Goose | | WF Goose | | T. Swan | | G. Scaup | | Oldsquaw | | Pintail | | Merganser | | A. Loon | | RT Loon | | YB Loon | | S. Crane | |
| **Line No.** | **Ad[3]** | **Brood** | **Ad** | **Brood** | **Ad** | **Brood** | **Ad** | **Brood** | **Ad** | **Brood** | **Ad** | **Brood** | **Ad** | **Brood** | **Ad** | **Brood** | **Ad** | **Brood** | **Ad** | **Brood** | **Ad** | **Brood** |
| B1 | 15 | 1 | | | 2 | | 2 | 1 | 4 | | | | | | 1 | | | | | | | |
| B2 | | | | | | | | | | | | | | | 1 | | | | | | | |
| B3 | 24 | 3 | 2 | | 2 | | | | 11 | | | | | | 4 | | | | | | | |
| B4 | 9 | | | | 1 | | 3 | 1 | 2 | | | | | | | | | | | | | |
| B5 | 17 | 3 | | | 4 | | | | | | | | | | | | | | | | | |
| B6 | 15 | | | | | | | | | | | | | | 5 | | | | | | | |
| B7 | 86 | 2 | | | | | | | | | | | | | | | | | | | | |
| B8 | 5 | 2 | 8 | 4 | | | 1 | | 1 | 1 | 1 | 1 | | | 3 | | | | | | | |
| D1 | | | 34 | | 2 | 1 | | | | | | | | | 2 | 1 | | | | | 2 | |
| D2 | | | | | | | | | | | | | | | 3 | | | | | | | |
| D3 | | | | | 2 | 1 | | | 2 | 1 | | | | | | | | | | | | |
| D4 | 10 | 1 | | | | | | | | | | | | | | | | | | | | |
| D5 | | | | | 2 | | | | | | | | | | 2 | | | | | | | |
| D6 | 4 | 1 | | | 1 | | | | | | | | | | 2 | | | | | | | |
| D7 | | | 4 | 1 | | | 1 | 1 | 3 | 1 | | | | | 1 | | 1 | | | | | |
| D8 | | | | | 2 | 1 | 5 | 2 | 1 | | | | | | | | | | 1 | | | |
| TOTAL | 185 | 13 | 48 | 5 | 18 | 3 | 12 | 5 | 24 | 3 | 1 | 1 | 0 | 0 | 24 | 1 | 1 | 0 | 1 | 0 | 2 | 0 |

**1: Adult birds include all fully fledged birds.**

**2: C. Goose = Canada Goose, WF Goose = White-fronted Goose, T. Swan = Tundra Swan, G. Scaup = Greater Scaup, P. Loon = Pacific Loon, RT Loon = Red-throated Loon, YB Loon = Yellow-billed Loon, and S. Crane = Sandhill Crane.**

**3: Ad = Adult.**

# Table 9.1-9

## Number of Adult[1] Birds and Broods Observed in the Boston Property Area, July 20 (1) and July 22 (2), 1996

| | Species[2] | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | C. Goose | | WF Goose | | T. Swan | | G. Scaup | | Oldsquaw | | Pintail | | Merganser | | A. Loon | | RT Loon | | YB Loon | | S. Crane | |
| Line No. | Ad[3] | Brood | Ad | Brood | Ad | Brood | Ad | Brood | Ad | Brood | Ad | Brood | Ad | Brood | Ad | Brood | Ad | Brood | Ad | Brood | Ad | Brood |
| B1-1 | 7 | 4 | | | | | 1 | | | | | | | | 4 | 1 | | | | | | |
| B2-1 | 37 | | 4 | 1 | | | | | | | | | | | 1 | | | | | | | |
| B3-1 | | | | | | | | | 2 | 2 | | | 2 | 1 | 2 | | | | | | | |
| B4-1 | 6 | 1 | 2 | 1 | 2 | 1 | | | | | | | | | 2 | 1 | | | | | | |
| B5-1 | 6 | | 8 | 2 | 4 | | | | | | | | | | 1 | | | | | | | |
| B6-1 | 41 | 2 | | | | | | | 2 | | | | | | 2 | | 2 | | | | | |
| B7-1 | 1 | 1 | | | | | | | 2 | 1 | | | | | 2 | 1 | | | | | 4 | 1 |
| B8-1 | 14 | 1 | 20 | 2 | 3 | | | | | | | | 2 | | 2 | | | | | | | |
| TOTAL | 112 | 9 | 34 | 6 | 9 | 1 | 1 | 0 | 6 | 3 | 0 | 0 | 4 | 1 | 16 | 3 | 2 | 0 | 0 | 0 | 4 | 1 |
| B1-2 | 15 | 1 | | | 2 | | 2 | 1 | 4 | | | | | | 1 | | | | | | | |
| B2-2 | | | | | | | | | | | | | | | 1 | | | | | | | |
| B3-2 | 24 | 3 | 2 | | 2 | | | | 11 | | | | | | 4 | | | | | | | |
| B4-2 | 9 | | | | 1 | | 3 | 1 | 2 | | | | | | | | | | | | | |
| B5-2 | 17 | 3 | | | 4 | | | | | | | | | | | | | | | | | |
| B6-2 | 15 | | | | | | | | | | | | | | 5 | | | | | | | |
| B7-2 | 86 | 2 | | | | | | | | | | | | | | | | | | | | |
| B8-2 | 5 | 2 | 8 | 4 | | | 1 | | 1 | 1 | 1 | 1 | | | 3 | | | | | | | |
| TOTAL | 171 | 11 | 10 | 4 | 9 | 0 | 6 | 2 | 18 | 1 | 1 | 1 | 0 | 0 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Maximum | 171 | 11 | 34 | 6 | 9 | 1 | 6 | 2 | 18 | 3 | 1 | 1 | 4 | 1 | 16 | 3 | 2 | 0 | 0 | 0 | 4 | 1 |

**1: Adult birds include all fully fledged birds.**

**2: C. Goose = Canada Goose, WF Goose = White-fronted Goose, T. Swan = Tundra Swan, G. Scaup = Greater Scaup, P. Loon = Pacific Loon, RT Loon = Red-throated Loon, YB Loon = Yellow-billed Loon, and S. Crane = Sandhill Crane.**

**3: Ad = Adult.**

# Table 9.1-10

## Number of Adult[1] Birds and Broods Observed in the Doris Lake Property Area July 20 (1) and July 22 (2), 1996

| | Species[2] | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | C. Goose | | WF Goose | | T. Swan | | G. Scaup | | Oldsquaw | | Pintail | | Merganser | | A. Loon | | RT Loon | | YB Loon | | S. Crane | |
| **Line No.** | **Ad[3]** | **Brood** | **Ad** | **Brood** | **Ad** | **Brood** | **Ad** | **Brood** | **Ad** | **Brood** | **Ad** | **Brood** | **Ad** | **Brood** | **Ad** | **Brood** | **Ad** | **Brood** | **Ad** | **Brood** | **Ad** | **Brood** |
| D1-1 | | | | | | | 1 | | | | | | | | | | | | | | | |
| D2-1 | | | 10 | 2 | | | | | | | | | | | 5 | | | | | | 2 | 1 |
| D3-1 | 2 | | 3 | 1 | 2 | 1 | | | | | | | | | | | | | | | | |
| D4-1 | 4 | 2 | 3 | 1 | | | | | | | | | | | | | | | | | 2 | |
| D5-1 | | | | | 4 | 2 | | | | | | | | | 2 | 1 | | | | | | |
| D6-1 | | | | | | | | | | | | | | | | | | | | | | |
| D7-1 | 31 | 1 | 6 | 1 | | | 5 | | 4 | | | | | | | | | | | | | |
| D8-1 | | | 2 | 1 | | | 8 | | | | | | | | | | | | 1 | | | |
| TOTAL | 37 | 3 | 24 | 6 | 6 | 3 | 14 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 7 | 1 | 0 | 0 | 1 | 0 | 4 | 1 |
| D1-2 | | | 34 | | 2 | 1 | | | | | | | | | 2 | 1 | | | | | 2 | |
| D2-2 | | | | | | | | | | | | | | | 3 | | | | | | | |
| D3-2 | | | | | 2 | 1 | | | 2 | 1 | | | | | | | | | | | | |
| D4-2 | 10 | 1 | | | | | | | | | | | | | | | | | | | | |
| D5-2 | | | | | 2 | | | | | | | | | | 2 | | | | | | | |
| D6-2 | 4 | 1 | | | 1 | | | | | | | | | | 2 | | | | | | | |
| D7-2 | | | 4 | 1 | | | 1 | 1 | 3 | 1 | | | | | 1 | | 1 | | | | | |
| D8-2 | | | | | 2 | 1 | 5 | 2 | 1 | | | | | | | | | | 1 | | | |
| TOTAL | 14 | 2 | 38 | 1 | 9 | 3 | 6 | 3 | 6 | 2 | 0 | 0 | 0 | 0 | 10 | 1 | 1 | 0 | 1 | 0 | 2 | 0 |
| Maximum | 37 | 3 | 38 | 6 | 9 | 3 | 14 | 3 | 6 | 2 | 0 | 0 | 0 | 0 | 10 | 1 | 1 | 0 | 1 | 0 | 4 | 1 |

**1: Adult birds include all fully fledged birds.**

**2: C. Goose = Canada Goose, WF Goose = White-fronted Goose, T. Swan = Tundra Swan, G. Scaup = Greater Scaup, P. Loon = Pacific Loon, RT Loon = Red-throated Loon, YB Loon = Yellow-billed Loon, and S. Crane = Sandhill Crane.**

**3: Ad = Adult.**

## Table 9.1-11
## Number of Adult[1] Birds and Broods Observed in the Boston (B) and Doris Lake (D) Property Areas, July 20 (1) and July 22 (2), 1996

| Survey No. and Block | Species[2] | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | C. Goose | | WF Goose | | T. Swan | | G. Scaup | | Oldsquaw | | Pintail | | Merganser | | A. Loon | | RT Loon | | YB Loon | | S. Crane | |
| | Ad[3] | Brood | Ad | Brood | Ad | Brood | Ad | Brood | Ad | Brood | Ad | Brood | Ad | Brood | Ad | Brood | Ad | Brood | Ad | Brood | Ad | Brood |
| B-1 | 112 | 9 | 34 | 6 | 9 | 1 | 1 | 0 | 6 | 3 | 0 | 0 | 4 | 1 | 16 | 3 | 2 | 0 | 0 | 0 | 4 | 1 |
| B-2 | 171 | 11 | 10 | 4 | 9 | 0 | 6 | 2 | 18 | 1 | 1 | 1 | 0 | 0 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| D-1 | 37 | 3 | 24 | 6 | 6 | 3 | 14 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 7 | 1 | 0 | 0 | 1 | 0 | 4 | 1 |
| D-2 | 14 | 2 | 38 | 1 | 9 | 3 | 6 | 3 | 6 | 2 | 0 | 0 | 0 | 0 | 10 | 1 | 1 | 0 | 1 | 0 | 2 | 0 |

**1: Adult birds include all fully fledged birds.**

**2: C. Goose = Canada Goose, WF Goose = White-fronted Goose, T. Swan = Tundra Swan, G. Scaup = Greater Scaup, P. Loon = Pacific Loon, RT Loon = Red-throated Loon, YB Loon = Yellow-billed Loon, and S. Crane = Sandhill Crane.**

**3: Ad = Adult.**

*Tundra Swan*

Tundra Swans are widespread throughout the study area at low densities. A total of 18 adult swans was recorded. This amounted to 5 and 6% of the Survey 1 and Survey 2 totals, respectively. Swans were documented on five of the Boston survey lines, and six of the Doris Lake survey lines.

Although on this survey a minimum total of only three broods was recorded, incidental observations indicated that Tundra Swans breed commonly in the study area. Swans are also frequently observed during spring and fall migrations. On June 2, 1996, a total of 44 Tundra Swans in eight groups (range one to ten swans) was observed flying north.

*Greater Scaup*

Scaup were not commonly seen on this survey, with a total of only 20 adults. They were more prevalent near the coast; only six of these birds were observed on the Boston block. A total of five scaup broods was recorded.

*Oldsquaw*

Oldsquaws were the most common duck observed on transect. A total of 24 adults was recorded. They were three times as abundant on the Boston block as on the Doris Lake block. The total of five broods recorded on this survey was not indicative of the level of breeding activity that was apparent through incidental observations. Oldsquaws are likely the most common duck within the study area, and the most common breeders.

*Northern Pintail*

During aerial surveys, pintails appeared to be uncommon within the study area. A single adult with a brood was observed on the Boston survey block.

During the follow-up ground survey, however, Northern Pintails were among the most commonly observed waterfowl. Despite the fact that the ground survey covered a relatively small area, six observations of pintails were recorded, and all six included broods. By comparison, the ground survey produced few other surprises in terms of relative abundance of adult birds or broods. One explanation is that pintails with broods have a relatively strong affinity for dense weedy vegetation at this time of year, making them less visible from the air. Irrespectively, this finding reinforces the inadequacy of aerial surveys as a stand-alone technique for inventory of breeding waterfowl.

*Red-breasted Merganser*

Only four adult Red-breasted Mergansers were observed during this survey, all on the Boston block. One pair was accompanied by a brood. During other surveys, mergansers were occasionally recorded, but in small numbers and with few broods.

*Pacific Loon (previously called Arctic Loon)*

The Pacific Loon was common and widespread in the study area. A total of 26 was observed on transect. Sixteen were on the Boston block, and ten were observed in the Doris Lake block. Pacific Loons were recorded on each of the eight Boston transect lines, and on five of the Doris Lake lines.

Pacific Loons are among the most common breeders in the area. A minimum of four broods was recorded during this survey, but incidental observations indicate that breeding was much more widespread than this value indicates.

*Red-throated Loon*

Red-throated Loons were rarely observed during this survey. A pair was observed on the Boston block, and a single was recorded on the Doris Lake transects. Successful breeding for this species was not documented. However, during another survey in late July 1996, a Red-throated Loon was observed sitting on a nest.

*Yellow-billed Loon*

There were two observations of single Yellow-billed Loons on this survey. Both were in the same location (Hope Bay), two days apart, and may have been the same individual. These were the first observations of Yellow-billed Loon in this study. Breeding has not been documented in this study.

*Sandhill Crane*

As mentioned previously, Sandhill Cranes were classified as waterfowl for this survey, because of their affinity for wetlands, and because no other survey specifically addressed them.

Sandhill Cranes were widespread at low densities in the Hope Bay Belt area. Four cranes were observed in the Boston area, and another four in the Doris Lake area. Cranes appeared on three of the Doris Lake transect lines, but just one of the Boston lines.

Breeding has been documented in the study area. A single brood was recorded on this survey. However, all eight adult cranes observed were in pairs, so additional broods may have been present but missed. Nesting cranes and broods were observed incidentally several times in 1996.

*Other Species*

Other species of waterfowl have been recorded in the study area, but were not detected during this survey. Snow Geese were recorded during spring and fall migrations in 1994, 1995, and 1996. Flocks of >100 birds have been observed. However, no Snow Geese were observed in the study area between June 20 and August 24, and it is unlikely that they bred here in 1996.

Ross' Goose may also occur within the study area, although none were recorded during site visits in 1994, 1995, and 1996. Some white geese that were observed from aircraft and were classified as Snow Geese may have been, in fact, Ross' Geese.

Common Eiders and King Eiders were not recorded on any surveys of the study area. However, King Eiders are commonly seen and hunted on Bathurst Inlet by residents of Omingmaktok (Stern 1996, pers. comm.).

One gull species, one tern, and two jaegers are common residents. Herring Gulls and Arctic Terns are seen throughout the study area during summer. In addition, Glaucous Gulls are observed occasionally, especially in the north near the coast. Long-tailed and Parasitic Jaegers may be seen throughout the study area during summer.

### *9.1.3.6 Small Mammal Surveys*

Small mammal surveys were conducted in 1996 by trapping (Plate 9-5) during August 14 to 24. Of a potential total of 2,000 trapnights, 1,980 were logged. In total, 84 small mammals were captured, comprised of five species (Table 9.1-12). Four microtine species were captured in similar numbers (range 17 to 23), and a single shrew was trapped. Summaries of the trapping program are presented in Tables 9.1-13 to 9.1-15 and Figure 9.1-16.

Two species of lemming (collared and brown), two species of vole (northern red-backed and tundra), and one shrew (Arctic) were captured. This is close to the full complement of species which might be expected to occur in the Hope Bay Belt area. According to range maps in Banfield (1974), the masked shrew occurs here and the distributions of meadow vole, and root vole are marginal to this area.

Results of the trapping program may have been influenced by extreme weather conditions during the session at the Doris Lake claim block. A heavy, wet snowfall, about 15 cm, accompanied by very strong winds occurred on August 21, the second day of trapping at Doris Lake. All traps were snow-covered, and some were buried in drifts >50 cm deep. Although the snow began to melt immediately, snow still covered the ground at some sites for the balance of the trapping period. In other areas, meltwater inundated some trap sites. Each of these factors affected the performance of traps and likely influenced the movements and distribution of small mammals, and therefore the results of the trapping program.

Two other species of small-medium sized herbivores—Arctic ground squirrel and Arctic hare—were also present in the study area, but were not sampled by the trapping program or any other systematic survey.

*Collared Lemming*

Collared lemmings were the second-most commonly captured species in the Boston area. However, only a single, juvenile was captured at the Doris Lake Property. Collared lemmings appeared to have a strong affinity for dry habitats with short vegetation cover. They were by far the most common small mammal captured on the treatment line near Boston camp site. This line was comprised primarily of the mesic birch-bearberry/heath-rock habitat type. This habitat type, or similar ones, were not sampled during trapping in the Doris Lake area. Of all collared lemmings trapped, 85% (17/20) were juveniles.

*Brown Lemming*

Brown lemmings were tied for the most-commonly trapped species. They were particularly abundant on the Boston reference line, and accounted for all captures made on the Doris Lake reference line. Their strongest habitat association was for moist areas dominated by sedges with sparse shrub cover. Adults comprised 39% of brown lemming captures, the highest proportion of any species.

*Northern Red-Backed Vole*

The red-backed vole was the most commonly-captured small mammal, tied with the brown lemming. All captures, however, were on the Boston traplines, and most were on the reference line. All red-backed voles were trapped in moist habitats, primarily those dominated by sedge and birch-sedge cover. Similar habitats were sampled at the Doris Lake Property, so it is possible that the species is simply less common there than at Boston. Almost all (91%) red-backed vole captures were of juveniles.

*Tundra Vole*

Tundra voles were the most widely-distributed species captured; they were trapped on three of the four lines. They were associated most with shrub-dominated moist habitats, particularly on the Doris Lake treatment line. Juveniles comprised 71% of tundra vole captures.

*Arctic Shrew*

A single Arctic shrew was captured. This occurred in a moist sedge-birch habitat near the Boston Property. This individual was a juvenile (total length 8.0 cm).

The Hope Bay Belt is outside of the distribution of the Arctic shrew as reported in Banfield (1974). Identification of this specimen was confirmed based on dental characteristics and the morphology of the mandible. Because of their small size, shrews are difficult to capture with the Museum Special snap trap, so they may

Plate 9-5: Small mammal trapping site.

## Table 9.1-12

## Small Mammals Captured During Trapping on Treatment (T) and Reference (R) Lines in the Boston (B) and Doris Lake (D) Property Areas, August 1996

| | | Species[1] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | CL | | BL | | RBV | | TV | | Shrew | |
| **Date** | **Line No.** | **Ad.** | **Juv.** | **Ad.** | **Juv.** | **Ad.** | **Juv.** | **Ad.** | **Juv.** | **Juv.** | **Total** |
| Aug 15 | BT | 2 | 4 | | | | | 1 | | | 7 |
| | BR | | | 1 | 3 | 1 | 6 | | 1 | | 12 |
| Aug 16 | BT | 1 | 4 | | | | 1 | 1 | | | 7 |
| | BR | | | 3 | 1 | 1 | 3 | | | | 8 |
| Aug 17 | BT | | 6 | | | | 2 | | | | 8 |
| | BR | | | | 3 | | 2 | | 1 | | 6 |
| Aug 18 | BT | | 2 | | | | | | | | 2 |
| | BR | | | 2 | 3 | | 1 | | | | 6 |
| Aug 19 | BT | | | | | | 1 | | | | 1 |
| | BR | | | | | | 5 | 1 | 1 | 1 | 8 |
| Aug 20 | DT | | | | | | | 1 | 1 | | 2 |
| | DR | | | | | | | | | | 0 |
| Aug 21 | DT | | 1 | | | | | | 1 | | 2 |
| | DR | | | 1 | | | | | | | 1 |
| Aug 22 | DT | | | | | | | | 1 | | 1 |
| | DR | | | 1 | | | | | | | 1 |
| Aug 23 | DT | | | | | | | 1 | 4 | | 5 |
| | DR | | | 1 | 3 | | | | | | 4 |
| Aug 24 | DT | | | | | | | | 2 | | 2 |
| | DR | | | | 1 | | | | | | 1 |
| Total | | 3 | 17 | 9 | 14 | 2 | 21 | 5 | 12 | 1 | 84 |

**1: CL = Collared lemming, BL = Brown lemming, RBV = Northern red-backed vole, TV = Tundra vole, Shrew = Arctic shrew , Ad = Adult, Juv. = Juvenile.**

## Table 9.1-13
## Summary of Small Mammals Captured During Trapping on Treatment (T) and Reference (R) Lines in the Boston (B) and Doris Lake (D) Property Areas, August 1996

| | Species[1] | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | CL | | BL | | RBV | | TV | | Shrew | | Number of |
| Line No. | Ad. | Juv. | Ad. | Juv. | Ad. | Juv. | Ad. | Juv. | Juv. | Total | Trapnights |
| BT | 3 | 16 | 0 | 0 | 0 | 4 | 2 | 0 | 0 | 25 | 497 |
| BR | 0 | 0 | 6 | 10 | 2 | 17 | 1 | 3 | 1 | 40 | 498 |
| DT | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 9 | 0 | 12 | 490 |
| DR | 0 | 0 | 3 | 4 | 0 | 0 | 0 | 0 | 0 | 7 | 495 |
| Total | 3 | 17 | 9 | 14 | 2 | 21 | 5 | 12 | 1 | 84 | 1980 |

**1: CL = Collared lemming, BL = Brown lemming, RBV = Northern red-backed vole, TV = Tundra vole, Shrew = Arctic shrew, Ad = Adult, Juv. = Juvenile.**

## Table 9.1-14
## Number of Small Mammal Captures Per 100 Trapnights During Trapping on Treatment (T) and Reference (R) Lines in the Boston (B) and Doris Lake (D) Property Areas, August 1996

| | | Species[1] | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Trap** | **Number of** | **CL** | | **BL** | | **RBV** | | **TV** | | **Shrew** | | **Total** | |
| **Line** | **Trapnights** | **Number** | **Index** | **Number** | **Index** | **Number** | **Index** | **Number** | **Index** | **Number** | **Index** | **Number** | **Index** |
| BT | 497 | 19 | 3.82 | 0 | 0.00 | 4 | 0.80 | 2 | 0.40 | 0 | 0.00 | 25 | 5.03 |
| BR | 498 | 0 | 0.00 | 16 | 3.21 | 19 | 3.82 | 4 | 0.80 | 1 | 0.20 | 40 | 8.03 |
| DT | 490 | 1 | 0.20 | 0 | 0.00 | 0 | 0.00 | 11 | 2.24 | 0 | 0.00 | 12 | 2.45 |
| DR | 495 | 0 | 0.00 | 7 | 1.41 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 7 | 1.41 |
| Total | 1980 | 20 | 1.01 | 23 | 1.16 | 23 | 1.16 | 17 | 0.86 | 1 | 0.05 | 84 | 4.24 |

**1: CL = Collared lemming, BL = Brown lemming, RBV = Northern red-backed vole, TV = Tundra vole, Shrew = Arctic shrew.**

**Table 9.1-15**
**Percent Occurrence of Habitat Types Found on Treatment (T) and Reference (R) Small Mammal Traplines in the Boston (B) and Doris (D) Property Areas, August 1996**

| | Trapline[1] | | | |
|---|---|---|---|---|
| **Habitat Type** | **BT** | **BR** | **WT** | **WR** |
| Mesic birch-bearberry/heath-rock | 78 | 12 | | |
| Mesic willow/birch-saxifrage | | | 20 | |
| Mesic Ledum/willow-bearberry | | | 8 | 6 |
| Moist sedge-birch/willow | 10 | 26 | 22 | 76 |
| Moist birch-willow | 12 | | | |
| Moist birch-sedge tussocks | | 50 | | |
| Moist willow-sedge | | | 38 | |
| Wet sedge | | 12 | 12 | 18 |

**1: Values refer to percent occurrence of each type.**

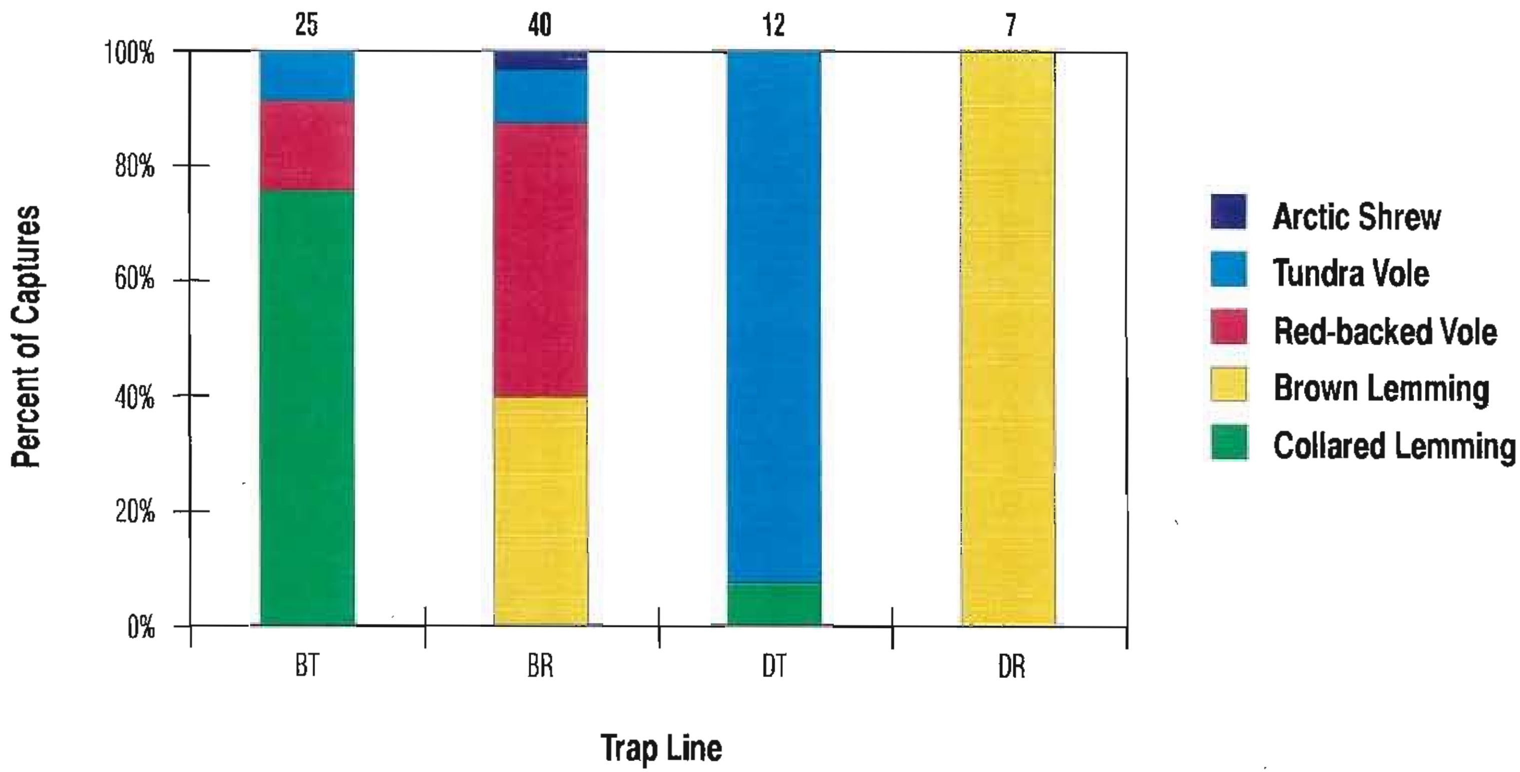
have been more abundant than is indicated by their low capture rate. It is interesting to document this species' occurrence in the area.

The distribution of the masked shrew does include the Hope Bay Belt. However, this species was not detected during the 1996 trapping program.

*Arctic Ground Squirrel*

Arctic ground squirrels are common throughout the study area. A detailed habitat-use analysis was not conducted for this species. However, burrows can be found in most suitable substrates (*i.e.*, well-drained sand or gravel slopes). Arctic ground squirrels were particularly evident around Doris Lake Property camp, situated on Windy Lake, where they enjoyed artificial food sources and reduced predation pressure.

Arctic ground squirrels are an important food source for predators. Evidence was found in the study area for predation by Rough-legged Hawks, red foxes, and grizzly bears.




*Note: Numbers over columns are sample sizes (total number of captures)*

BHP

**Proportion of Small Mammal Captures on Treatment (T) and Reference (R) Traplines in the Boston (B) and Doris Lake (D) Areas, 1996**

FIGURE 9.1-16

Rescan

*Arctic Hare*

Arctic hares are widespread throughout the study area. No attempt was made to determine habitat-use patterns for this species. During 1996, hares appeared to be fairly abundant, although they can be inconspicuous against most backgrounds.

## 9.2 Marine Mammals

Should one of the exploration targets in the Hope Bay Belt area be proposed for development, a barge loading facility will be required at Roberts Bay on the south shore of Melville Sound (Figure 9.2-1). Vessels would traverse outer Bathurst Inlet and Melville Sound en route to and from Roberts Bay. A knowledge of the marine mammals of the area is thus needed to enable the assessment of potential effects of BHP's planned activities and to design appropriate mitigation measures. As a contribution to the understanding of the marine environment of the region, aerial surveys for seals were conducted in June 1996. In addition, information was reviewed on other marine mammals that may be encountered.

### 9.2.1 Previous Research

The primary purpose of these surveys was to determine the distribution and relative abundance of ringed seals. To accomplish this, three aerial surveys were flown during June, when it was expected that many seals would be hauled out for their annual molt. There has been little previous work on the marine mammals of this area, and this was the first aerial survey conducted specifically for seals. Similar seal surveys have, however, been conducted elsewhere in the Canadian Arctic.

Marine mammals expected in the study region include:

- ringed seals - Phoca hispida;
- bearded seals - Erignathus barbatus;
- polar bears - Ursus maritimus;
- beluga whales - Delphinapterus leucas;
- narwhal - Monodon monocerus; and
- bowhead whales - *Balaena mysticetus*.

#### *9.2.1.1 Ringed Seals*

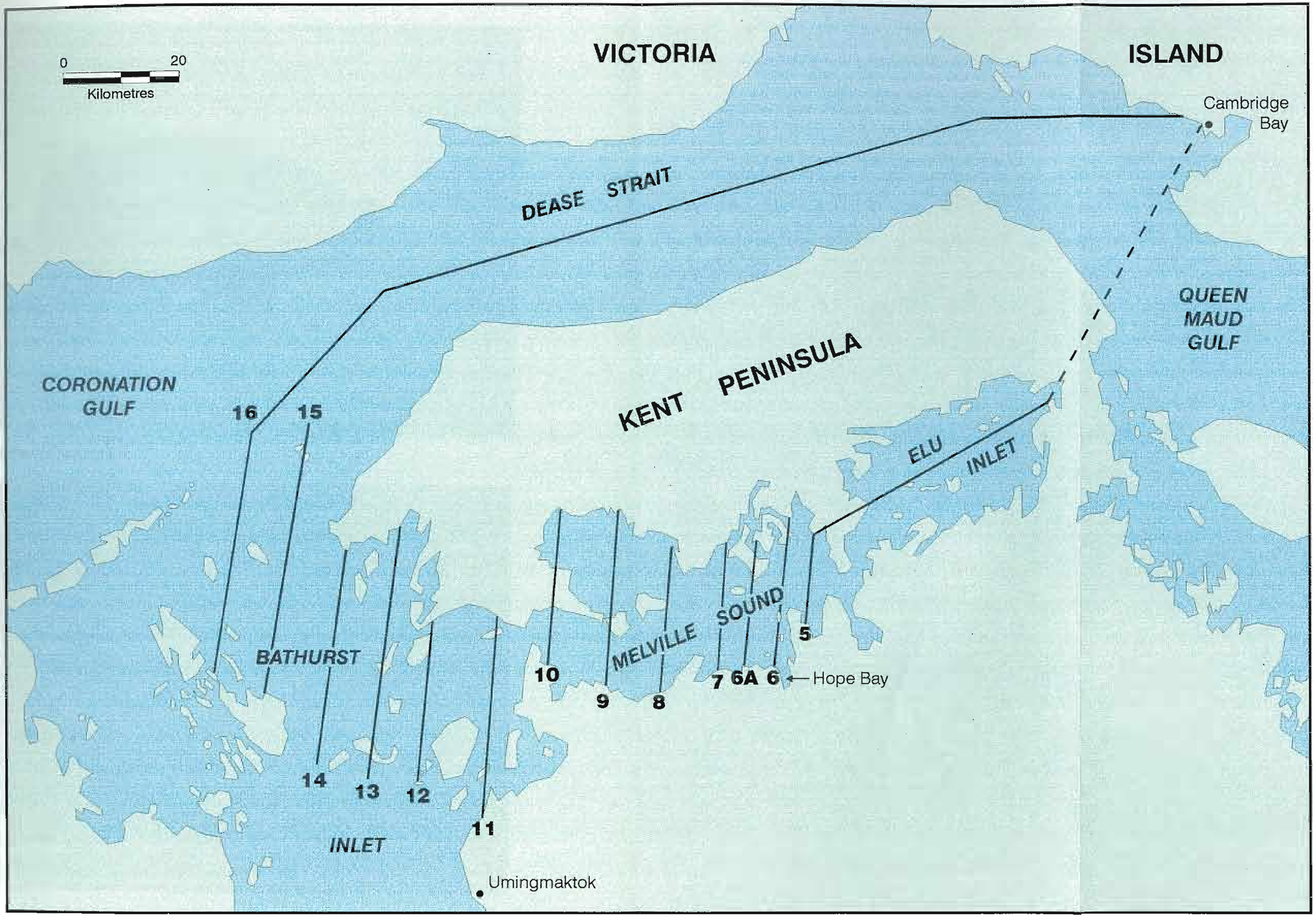
Ringed seals are by far the most abundant and widespread marine mammal in the Arctic, and specifically in the Cambridge Bay region. While population estimates vary considerably, it is clear that the numbers in the Canadian Arctic are in the millions (Stewart *et al.* 1986). They are the primary prey of polar bears and the primary source of food (mainly as scavenged carrion) for arctic foxes that winter on sea ice.

Ringed seals are dark gray, with lighter circular markings, from which their name is derived (Plate 9-6). A typical adult, male or female, is about 1.15 m long and weighs about 50 kg. Their front claws are specialized to enable them to penetrate ice to create and maintain breathing holes.

Ringed seals are relatively sedentary, making only local movements during the year. As the ice forms in the fall, adults occupy territories where they create and maintain holes to access air (Plate 9-7). Mature animals tend to occupy areas of stable ice, while immature seals tend to be relegated to areas of relatively unstable ice. Pressure ridges in stable ice areas are the preferred breeding habitat. Snow accumulates in the lee of the ridges in which the females create birth lairs there. Pups are born in March and April and are nursed for five to seven weeks, during which time they accumulate a blubber layer and shed their infantile lanugo fur. The lanugo fur, which is a good insulator in air, keeps the pup warm until the insulating blubber layer is acquired. Thus, although ringed seal pups are competent in water at birth, they are vulnerable to hypothermia until they acquire adequate blubber during the first few weeks of life.

In June, adult ringed seals haul-out onto the ice surface to molt their pelage. While they are lying on the surface of the ice they are most conspicuous and most easily censused. Later in the molting period, the ice begins to melt and create a puddled surface with dark melt holes. The best time to conduct a census is before the ice begins to melt, while the dark seals contrast most strongly with the light colored ice.

In the past, ringed seals have played an important role in the economy of northern residents, providing skins, meat, and blubber, and a source of cash income when skins have had commercial value. The Government of the NWT hopes to increase




BHP

Transect Locations for Seal Observation, June 1996

FIGURE 9.2-1

Rescan

Plate 9-6: Adult ringed seal on ice.

Plate 9-7: Seal breathing holes in ice cover, Melville Sound, June 1996.

the market for seal pelts, and thereby increase the commercial harvest and economic return to communities with limited access to cash income (Omilgoetok 1996, pers. comm.).

In the Cambridge Bay area, hunting ringed seals is not a major activity, and only 20 to 40 ringed seals per year are taken (Omilgoetok 1996, pers. comm.). Most seals are used locally. For example, in 1994/1995, only six pelts were sold and exported from Cambridge Bay (Omilgoetuk, pers. comm.); none were exported from Bathurst Inlet and only three were exported from Omingmaktuk (Erasmus 1996, pers. comm.). Hunting occurs mainly in late spring when seals are hauled out near their holes and along cracks in the ice. Most hunters approach the seals using a white canvas shield until they are within range of a .22 long-rifle or .22 rim-fire magnum rifle. Some seals are hunted from boats in the fall.

The NWT Department of Resources, Wildlife and Economic Development started a Fur Pricing Program in 1994 (Erasmus 1996, pers. comm.). The aim of the program is to stimulate harvest by guaranteeing a minimum price to hunters for certain species, including ringed seals. The minimum price for a prime ringed seal is $30. This effort does not appear to have increased harvests in the Cambridge Bay area, Bathurst Inlet, or Omingmaktuk.

#### *9.2.1.2 Bearded Seals*

The bearded seal, like the ringed seal, has a circumpolar distribution, but its populations may be less than ten percent of the size of ringed seal populations. Bearded seals are considerably larger than ringed seals, with an adult length of about 2.3 m and weight of 300 kg (Burns 1981).

They are less well adapted to a life in solid ice than are ringed seals, so they tend to spend the winter in areas where the ice is sufficiently active to maintain access to air. They are uncommon in the Cambridge Bay area. Small numbers of bearded seals have been observed in upper Wellington Bay and near Cambridge Bay in summer (Omigoetok 1996, pers. comm.). None were seen during these surveys.

*9.2.1.3 Polar Bears*

Polar bears occur only occasionally in the Cambridge Bay region (Taylor 1996, pers. comm.; Omilgoetok 1996, pers. comm.). Stirling and Øritsland (1995) examined the relationship between the densities of polar bears and their primary prey, ringed seals, in the Canadian Arctic. They show substantial populations of polar bears in the Beaufort Sea and other areas where the seal densities are similar or lower than were found during these surveys. Thus there would appear to be sufficient ringed seals in the general study region to support a polar bear population. The reasons why polar bears are rare in the study region is not clear (Stirling 1996, pers. comm.; Taylor 1996, pers. comm.).

Although polar bears are important to people of the region, hunting does not take place within the study area. The polar bear population closest to Cambridge Bay occurs to the east and north in McClintock Channel, numbering about 700 individuals (Omilgoetok 1996, pers. comm.). The annual community quota has been ten for several years. In 1995/1996, nine bears were killed, three by sport hunters and six by local hunters. Sport hunting is a source of income to the community. Each hunter must be accompanied by two guides, each of whom receives $5,000 per hunt. Thus, in the 1995/1996 season, the three sport hunters paid a total of $30,000 for the services of their guides.

*9.2.1.4 Bowhead Whales*

Bowhead whales are large baleen whales that were formerly abundant throughout the Arctic. For several centuries they were the mainstay of a whaling industry which greatly reduced their numbers and drove some populations to near extinction. In the eastern Arctic, a few hundred survive from the Davis Strait stock, while in the western Arctic, the Bering-Chukchi-Beaufort stock is estimated at 7,800 (Zeh *et al*. 1993). While some individuals may occasionally enter the study region in summer, from either the east or the west, there are no published records of these movements.

*9.2.1.5 Beluga Whales*

Beluga whales are abundant in both the western and eastern Arctic. Occasionally small numbers enter the waters of Coronation Gulf and Queen Maud Gulf in summer. Sightings of small numbers of belugas have been reported near Cambridge Bay (Omilgoetok 1996, pers. comm.; Semotiuk 1996, pers comm.).

#### *9.2.1.6 Narwhal*

Narwhal are common in the eastern Arctic but have not been recorded near Cambridge Bay.

### 9.2.2 Methods

The aerial survey protocol was developed and has been applied in the Canadian Arctic since the mid-1970s by the Canadian Wildlife Service (*e.g.,* Stirling *et al*. 1977; 1981). The technique is based on the fact that many (but not all) ringed and bearded seals *(Phoca hispida* and *Erignathus barbatus)* haul-out onto the surface of the sea ice during their annual molt in June. There is a diurnal haul-out pattern with the largest number of seals on the ice from late morning to late afternoon (Burns and Harbo 1972; Smith 1973).

#### *9.2.2.1 Survey Design and Procedure*

Surveys were flown along north-south transect lines at about ten kilometre intervals, with an additional line added in the Hope Bay area (Figure 9.2-1). Transect strips were 400 m wide, one on each side of the aircraft (Figure 9.2-2). Table 9.2-1 shows the lengths of the lines.

The aircraft, a DeHavilland Twin-Otter (DHC-6), flew at an altitude of 152 m (500 ft) and an airspeed of 220 km/h (120 knots). The survey strips were defined on the ice using a clinometer. Observers periodically checked the location of the outer strip boundary during the survey and checked the location of particular seals that were near the edge of the strip. Surveys were flown during afternoon, since previous work has shown that the maximum number of seals are hauled out between late morning and late afternoon (Stirling *et al*. 1981).

*9.2.2.2 Timing*

Based on the results of surveys elsewhere in the Arctic and consultations with other Arctic marine mammal biologists, the period from June 11 to 22 was selected during which to conduct the surveys. It was hoped that this period would permit at least one day with excellent ice and weather conditions when the seals would be conspicuous. Because of variability in weather, ice conditions, and haul-out behavior, the survey was replicated three times on June 14, 17, and 20, 1996.

*9.2.2.3 Geographical Scope*

Because any shipping routes into and out of Roberts Bay will traverse Melville Sound and adjacent outer Bathurst Inlet, the study focused on these areas (Figure 9.2-1). Although transect lines were defined for Elu Inlet, it was decided to focus the survey more intensively on the probable shipping route and to cover Elu Inlet by flying the centre line. After the first survey, the sequence of survey lines was arranged so that the aircraft could return to Cambridge Bay by way of Dease Strait. To help identify any areas that might have particularly high or low densities, the data have been stratified into Elu Inlet, Melville Sound (lines five to ten), outer Bathurst Inlet (lines 11 to 16), and Dease Strait.

*9.2.2.4 Data Collection*

Two observers, one on each side of the aircraft, recorded data into a tape recorder. Data recorded were:

- number of ringed seals within the transect strip;
- date and time;
- aircraft altitude; and
- weather conditions.

The Principal Investigator was Mark A. Fraker. He was assisted by two residents of Cambridge Bay; Colin Amegainik assisted on June 14 and 17, while Ernest Pokiak assisted on June 20.

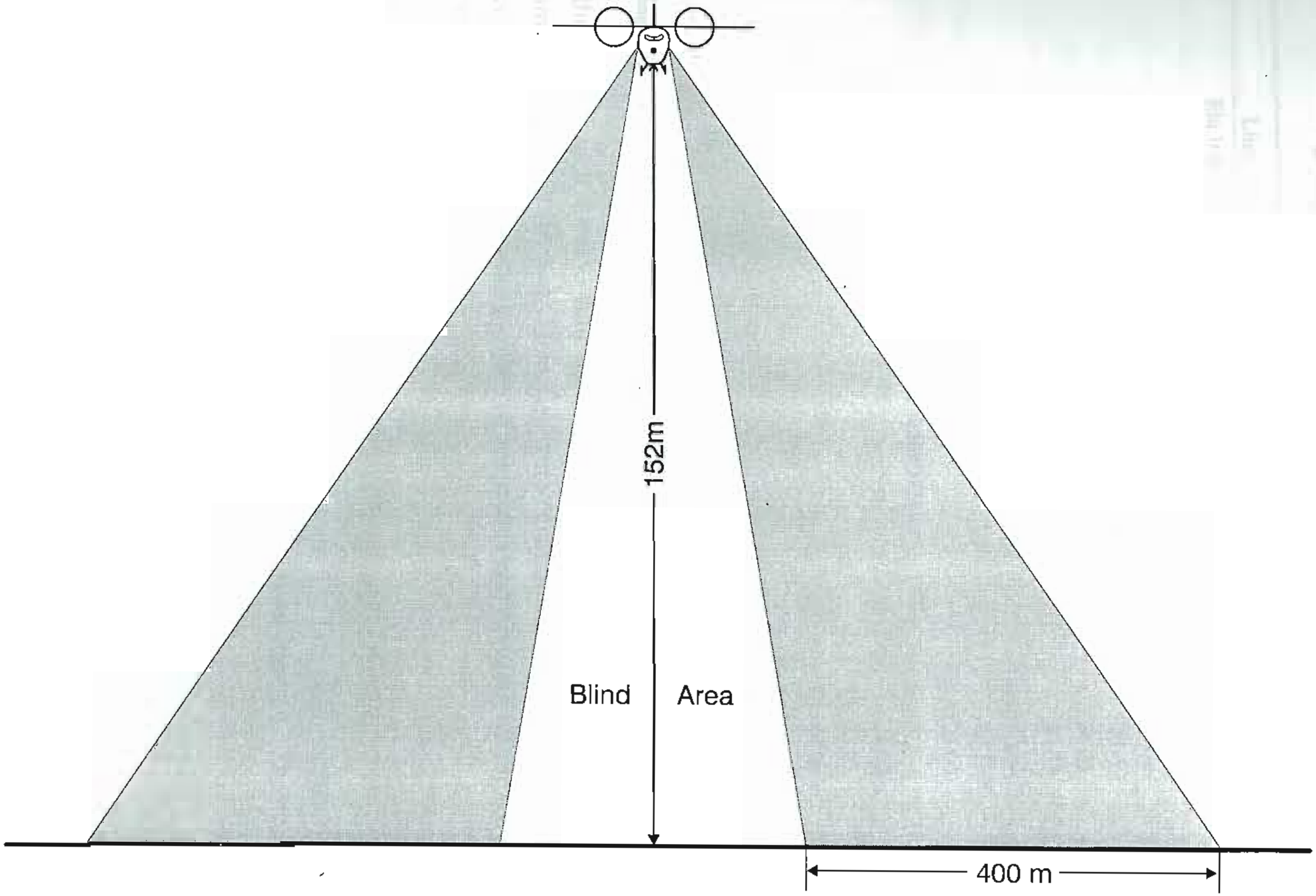



FIGURE 9.2.-2

BHP

# Aerial Transect Strips

Rescan

**Table 9.2-1**
**Lengths of Survey Lines in the Study Area[1]**

| Line | | Length (km) |
|---|---|---|
| Elu Inlet | | 35.25 |
| | Melville Sound | |
| 05 | | 16.75 |
| 03 | | 21.5 |
| 06A | | 24.25 |
| 07 | | 24.75 |
| 08 | | 27.75 |
| 09 | | 27.50 |
| 10 | | 23.00 |
| | Outer Bathurst Inlet | |
| 11 | | 31.00 |
| 12 | | 33.25 |
| 13 | | 44.00 |
| 14 | | 40.25 |
| 15 | | 44.75 |
| 16 | | 44.00 |
| Dease Strait | | 190.25 |

**1: Lengths are of only water areas and do not include islands.**

At the end of each survey, data were transcribed onto standard forms, and were summarized for each stratum. Densities were calculated for the different strata and survey dates by summing the number of seals seen and dividing by the survey area in each stratum.

### 9.2.3 Results and Discussion

The principal arrived in Cambridge Bay on June 11, but poor weather and the unavailability of the aircraft delayed the first survey until June 14. The second and third surveys were conducted on June 17 and 20.

#### *9.2.3.1 Survey Conditions*

The June 14 survey was conducted under excellent conditions. The sky was either clear or high, thin overcast. The ice surface was <50% puddled, meaning that seals were relatively conspicuous and that there were few dark-appearing objects (*e.g.*, shadows and dark melt holes) on the ice that could have been mistaken for seals.

The conditions for the June 17 survey were good to fair. Although the weather was again favorable, the ice surface was more heavily puddled and melt holes were more numerous than they were on the first survey. Elu Inlet and Dease Strait were the least changed. The melt holes forced the observers to focus on a number of dark objects to decide whether they were seals, thus preventing them from searching more widely across the transect. There were also a few relatively large areas of open water, which, of course, could not contain hauled-out seals.

The conditions for the June 20 survey were good to fair. As before, the weather was favorable, with clear or high overcast sky, but the ice had deteriorated further. Again, Elu Inlet and Dease Strait had changed the least.

*9.2.3.2 Seal Counts*

Seal counts and densities in each stratum are summarized in Table 9.2-2 and Figure 9.2-3.

*Elu Inlet*

Ice conditions in Elu Inlet changed the least over the course of the surveys, and the observed seal densities differed little between surveys, ranging only from 0.68 to 0.79 seals/km$^2$.

*Melville Sound*

The observed densities of seals in Melville Sound were highest (0.71 seals/km$^2$) on June 14, but subsequently dropped to < 0.30 seals/km$^2$.

*Outer Bathurst Inlet*

The pattern of density change in outer Bathurst Inlet was similar to that seen in Melville Sound. The highest density (0.82 km$^2$) was observed on June 14, with densities seen on later surveys dropping to < 0.40 seals/km$^2$.

**Table 9.2-2**
**Estimated Densities of Ringed Seals in the Study Area**

| Survey Stratum | Area Surveyed ($km^2$) | Seals Observed | | Mean Density ($seals/km^2$) |
|---|---|---|---|---|
| | | aircraft left side | aircraft right side | |
| | | June 14, 1996 | | |
| Elu Inlet | 28 | 7 | 13 | 0.71 |
| Melville Sound | 166 | 80 | 38 | 0.71 |
| Bathurst Inlet | 237 | 87 | 55 | 0.60 |
| Dease Strait | | not surveyed | | |
| | | June 17, 1996 | | |
| Elu Inlet | 28 | 6 | 13 | 0.68 |
| Melville Sound | 166 | 23 | 23 | 0.28 |
| Bathurst Inlet | 237 | 36 | 56 | 0.39 |
| Dease Strait | 95 | data | 43 | 0.45 |
| | | June 20, 1996 | | |
| Elu Inlet | 28 | 6 | 16 | 0.79 |
| Melville Sound | 166 | 13 | 23 | 0.22 |
| Bathurst Inlet | 237 | 23 | 34 | 0.24 |
| Dease Strait | 190 | 29 | 34 | 0.33 |

*Dease Inlet*

On June 14 the observers were unable to survey Dease Strait owing to low fuel, however, they did survey this area as they returned to Cambridge Bay on June 17 and 20. The densities were 0.45 and 0.54 seals/$km^2$. Whether the observed densities would have been greater on June 14, as they were in Melville Sound and outer Bathurst Inlet, is unknown.

*9.2.3.3 Comparisons to Other Surveys and Studies*

To place these three June 1996 surveys in regional context; the results of several previous aerial seal surveys in the Canadian arctic were reviewed. Comparisons with data from other earlier studies showed that seal densities in this study area are relatively high.

*Changes in Observed Density Between Surveys*

Except for Elu Inlet and Dease Strait, where no survey was conducted on June 14, there was a clear tendency for the density of seals to decrease over the course of the study. Because it is unlikely that seals emigrated during this time, the decrease in the number of observations was probably a result of deteriorating ice conditions, which made it more difficult to distinguish seals from other dark objects, from a smaller proportion of seals hauling out on the ice, or both. Whether higher densities would have been observed had there been earlier surveys is unknown.

The ice in Elu Inlet remained stable and deteriorated the least over the course of these surveys, and most likely as a consequence, the observed density of seals did not change. The observed densities in Dease Strait were similar for both surveys.

*Comparison of Seal Densities in the Study Area and Other Arctic Areas*

Several seal surveys were conducted in the Canadian Arctic during the 1970s and 1980s using the same methodology as was used in these surveys. Smith (1973) carried out surveys of eastern Amundsen Gulf and major inlets of southwestern Victoria Island (*i.e.*, Minto Inlet and Prince Albert Sound). Stirling *et al*. (1981a) conducted six years of surveys in the Beaufort Sea and western Amundsen Gulf. Kingsley *et al*. (1985) surveyed among the High Arctic Islands, including the area north of Victoria Island.

The densities observed during this study in Melville Sound and outer Bathurst Inlet were relatively high (Table 9.2-3). They were considerably higher than densities observed in the Beaufort Sea, but not as high as those seen in parts of eastern Amundsen Gulf and the inlets of western Victoria Island or certain parts of the High Arctic Islands.

*Distribution*

The distribution of seal observations failed to show any areas of conspicuously higher or lower densities (Figures 9.2-4 to 9.2-6). While there was some variability, no pattern is apparent.

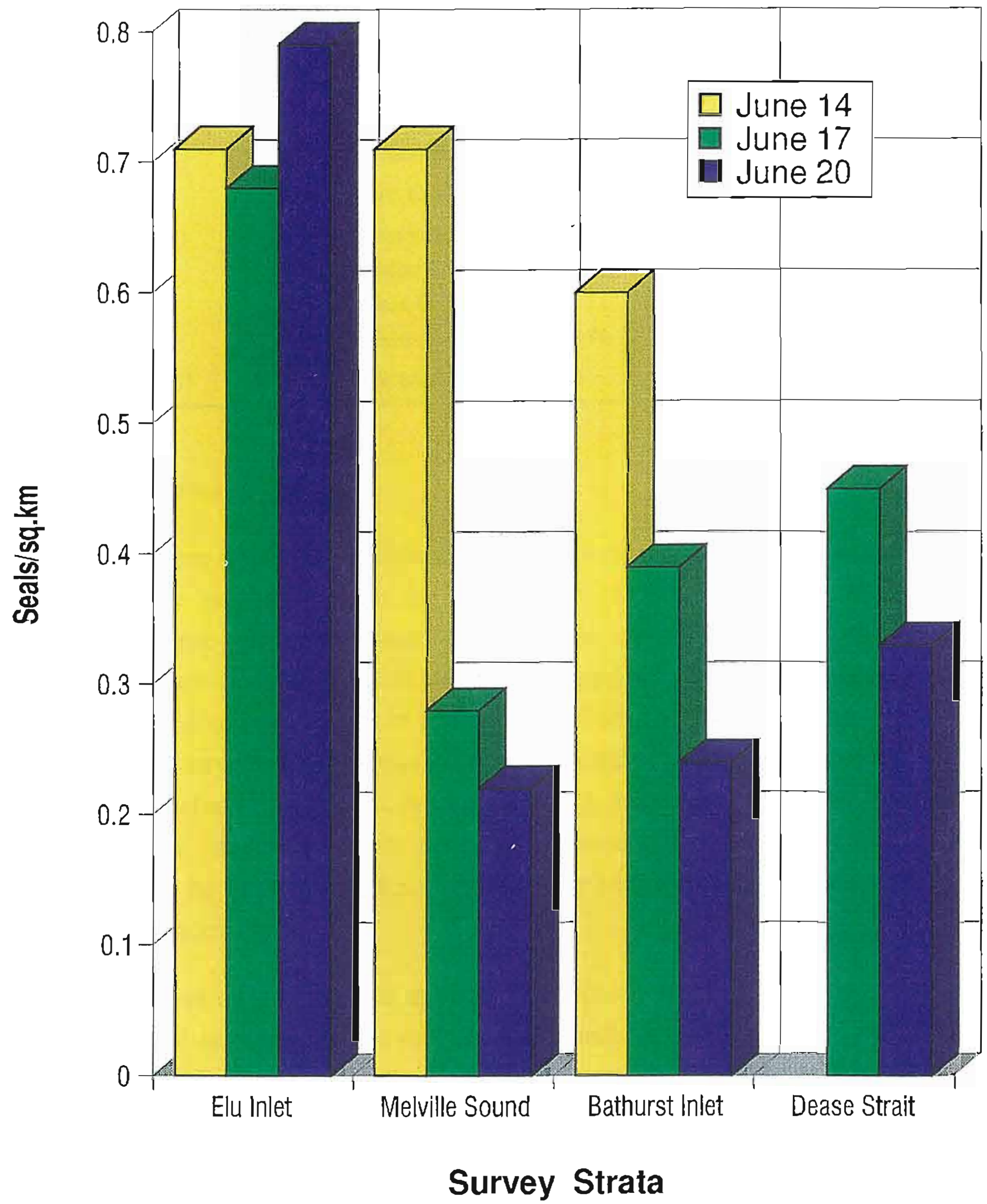



FIGURE 9.2-3

# Observed Seal Densities by Stratum and Survey Date

BHP

Rescan

**Table 9.2-3**
**Comparison of Observed Ringed Seal Densities Recorded in This Study with Those Recorded in Other Surveys**

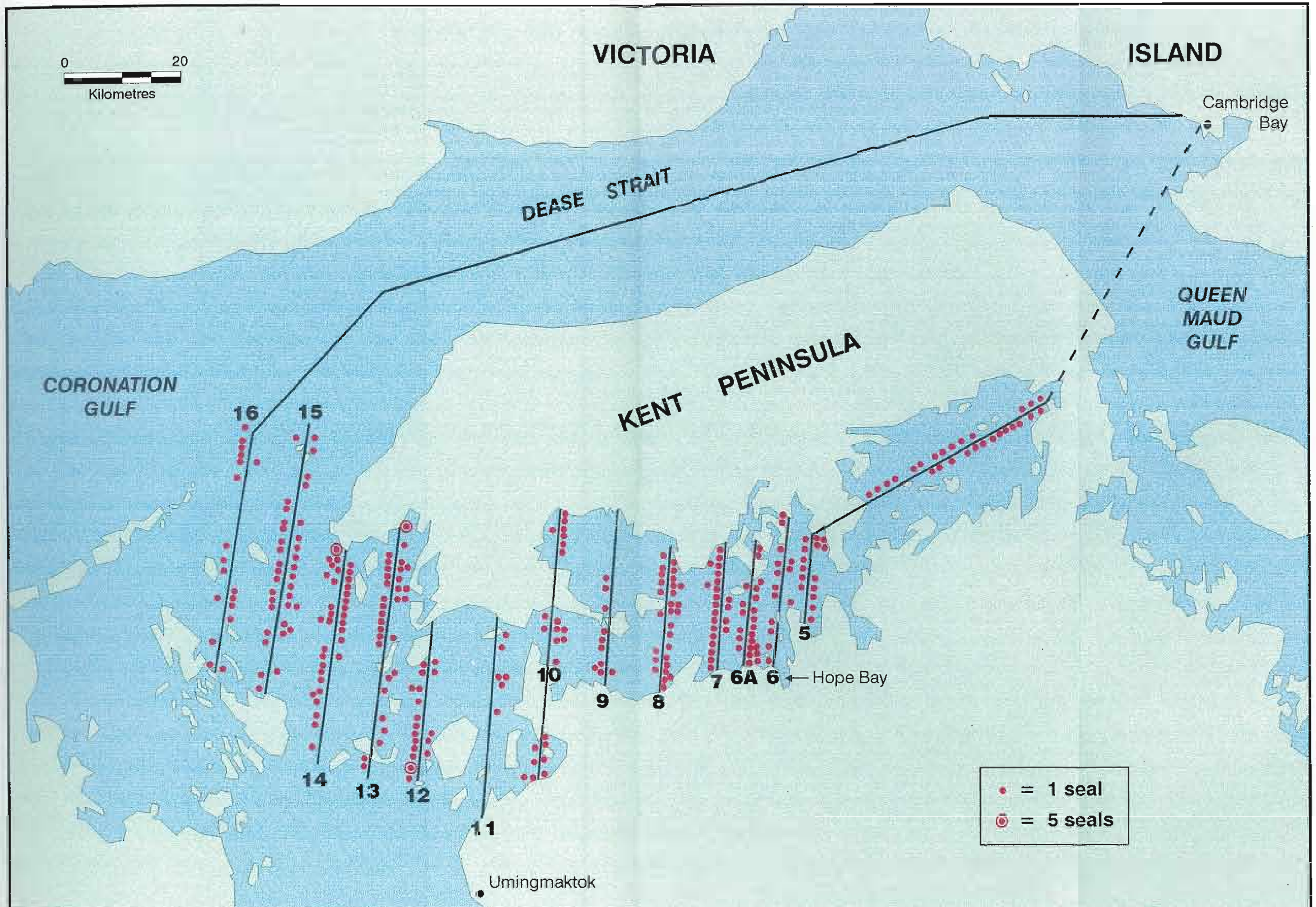
| Source | Area | Density Range ($seals/km^2$) |
|---|---|---|
| This study | Melville Sound/Bathurst Inlet, June 14 | 0.60 - 0.71 |
| Smith (1973) | E Amundsen Gulf/W Victoria Island inlets | 0.18 - 2.13 |
| Stirling et al. (1981a) | Yukon Coast to 160 km N 1974-79 | 0.0053 - 0.14 |
| | NWT Beaufort Coast to 160 km N 1974-79 | 0.014 - 0.052 |
| | W Amundsen Gulf 1974-79 | 0.0096 - 0.037 |
| | W Banks Island to 160 km W 1974-79 | 0.0010 - 0.032 |
| Kingsley et al. (1985) | High Arctic Islands 1980 | 0.21 - 1.16 |

### 9.2.4 Conclusions

Ringed seals were relatively abundant in the study region in 1996. The best survey conditions were encountered on the first survey, which was flown on June 14; later surveys were conducted under less favorable ice conditions. On the June 14 survey, densities ranged from 0.60 to 0.71 $seals/km^2$, which appears to be relatively high compared to other areas in the Canadian Arctic. They were not concentrated in any particular areas. Although bearded seals and polar bears might have been expected to be present in such an Arctic area, none were seen during the surveys, and all local informants agreed that these species are uncommon. Ice conditions may be unfavorable for overwintering bearded seals, but the scarcity of polar bears is puzzling.

The harvest level of ringed seals appears to be about 20 to 40 per year, with few pelts being sold at present. The most economically important marine mammal in the Cambridge Bay region is the polar bear, with sport hunters paying about $10,000 each for guide services for each hunt. However, polar bears are rare in the study region, so that hunting takes place well to the north and east of Cambridge Bay.

Three species of cetaceans, narwhal, beluga, and bowhead whale, might occur in the study region occasionally in the open-water period. Further east, narwhal and belugas are common during open water, and there is a small population of bowheads. To the west, in the Beaufort Sea and Amundsen Gulf, bowheads and belugas are common in summer.

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Distribution of Observed Seals, June 14, 1996

FIGURE 9.2-4

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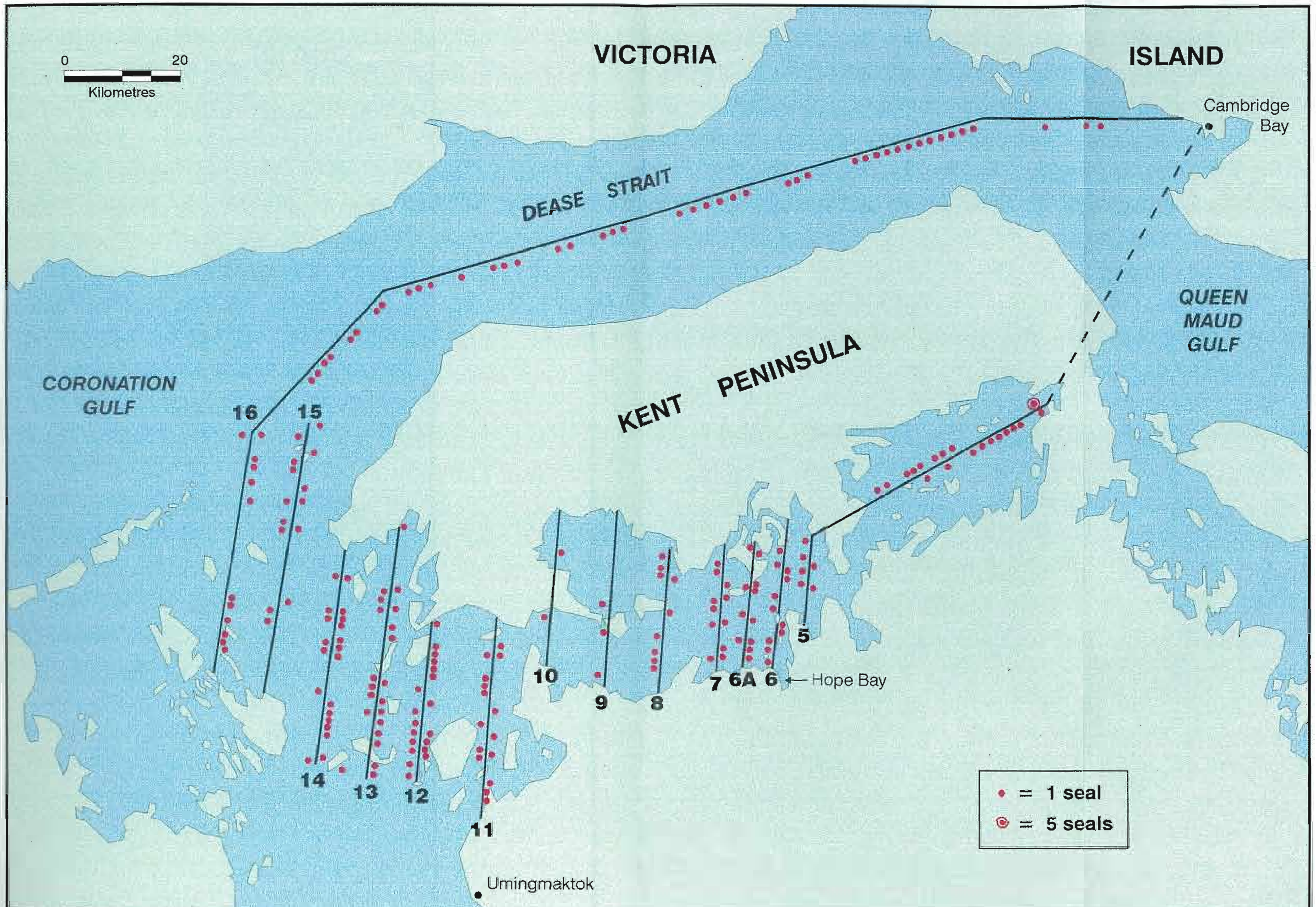


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Distribution of Observed Seals, June 17, 1996

FIGURE 9.2-5

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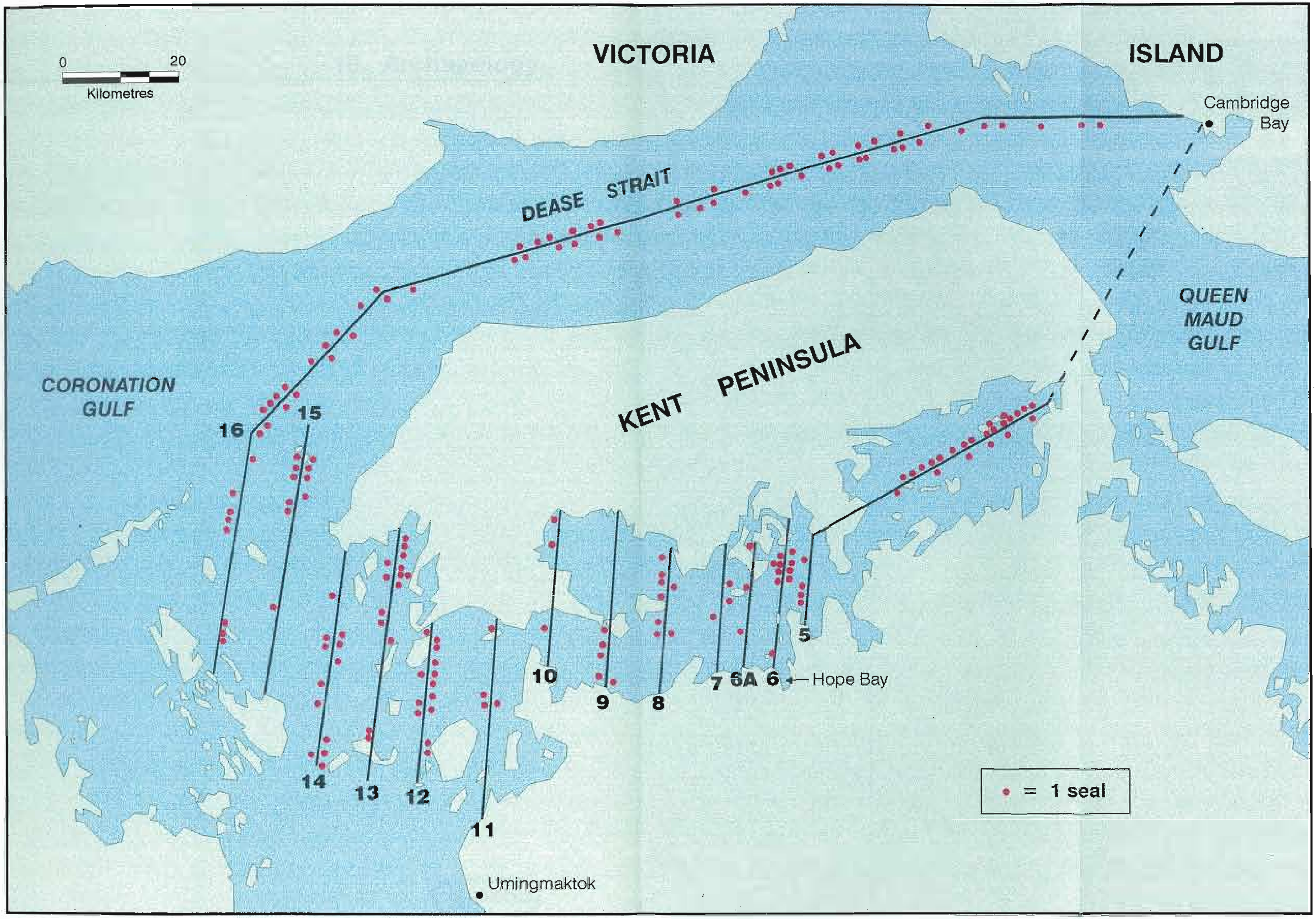


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Distribution of Observed Seals, June 20, 1996

FIGURE 9.2-6

Rescan

# 10. Archaeology

# 10. ARCHAEOLOGY

Archaeological investigations were conducted for three possible developments within the Hope Bay Belt Project area:

1) Boston bulk sampling project area;
2) Doris Lake exploration area; and
3) Roberts Bay proposed port/barge locations.

In addition, a potential winter trail route between the Boston Property and Roberts Bay was examined. The project was directed by G. Prager of Points West Heritage Consulting Ltd. Field assistance was provided by C. Rushworth and J. Franklin, a resident of Coppermine. Field studies were carried out between July 22 and August 1, 1996.

The locations of the Boston bulk sampling project and the Doris Lake exploration project is given in Figure 1-1. The study area for the archaeological investigations can be considered to be a corridor east of Bathurst Inlet from just south of the Boston Property almost directly north to the western edge of Roberts Bay, a distance of approximately 60 km. All environmental studies conducted in this region that relate to both BHP's Boston and Doris Lake projects are grouped together hereafter and referred to as the Hope Bay Belt Project.

### 10.1.1 Project Background

In 1995, a mitigative excavation of a tent ring site (MjNh-1) was conducted within the Boston Project development area. A preliminary assessment of an island in Roberts Bay was identified as a possible port location (Bussey 1995a). In the latter area, 13 archaeological sites were recorded, and additional field investigations were recommended for both areas.

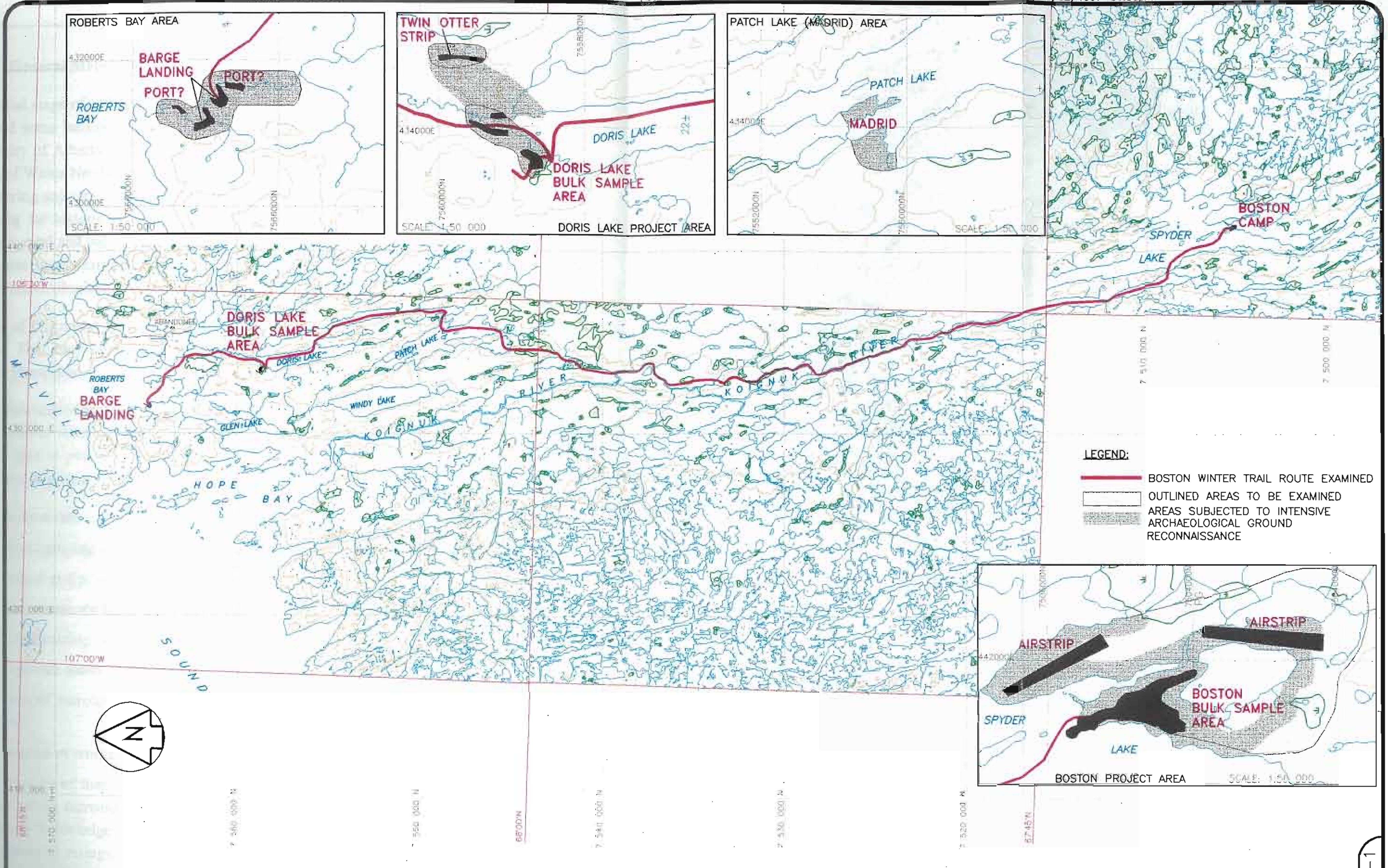
For 1996, BHP requested that an inventory and impact assessment of planned development areas within the Boston and Doris Lake properties be performed; the boundaries were delineated on maps provided by BHP (Figure 10.1-1). In response to the high site yield found on the island in Roberts Bay (Bussey 1995a), BHP proposed several new possible port and barge landing locations on the west side of Roberts Bay which required detailed archaeological assessments (Figure 10.1-1). In addition, a winter trail route was proposed between the Boston Project and Roberts Bay (Figure 10.1-1). Because the Doris Lake to Roberts Bay portion of this proposed trail was to be used this winter, this section required detailed assessment; the remainder of the trail was still in the preliminary planning stages, consequently, it was requested that high potential areas along the route be identified in order to assist in planning (Wuertz 1996, pers. comm). If time permitted a final component of the archaeological field work was to examine and record any sites that had been reported by various survey and geology crews working in the area.

An additional aspect of the 1996 project involved a revisit of one of the 1995 archaeological sites. A group of Inuit Elders were given a tour of the Boston and Doris Lake projects, which included a demonstration of some examples of archaeological sites found as a result of investigations for BHP. This was part of the traditional knowledge study being undertaken by another consultant (Hanks 1996, pers. comm.).

Section 10.2 of this report provides a discussion of the methodology, both general and specific, used in this archaeological study; Section 10.3 presents background data consisting of environmental information, human history of the region, as well as previous ethnographic, historical and archaeology studies relevant to the project area. Archaeological investigations are discussed in Section 10.4, by development project, and the proximity of recorded sites to potential development is noted. Section 10.5 provides individual descriptions of all sites recorded as well as a brief preliminary analysis of the sites and features. Section 10.6 contains a summary of the archaeological study and findings and presents recommendations. Because of the number of photographs and site maps, these have been placed in Appendices 10-1 and 10-2 to maintain the continuity of the text.

## 10.2 Methodology

This section presents the general methodology employed in the conduct of the archaeological research and investigations for BHP's Hope Bay Belt Project, as well as presenting the specific field methods used in each project area.




BHP

Winter Trail Route with
Areas Examined within the Hope Bay Belt

Rescan

Fig.10.1-1

### 10.2.1 General Methodology

The initial stage of archaeological investigations for BHP's Hope Bay Belt Project involved some background research at the Canadian Circumpolar Institute at the University of Alberta in Edmonton, the University of Alberta libraries, and at the Prince of Wales Northern Heritage Centre in Yellowknife. Such research consists of gathering any reports on archaeological work done in the general area as well as searching for historic or ethnographic documentary information. Any available environmental and paleoecological information was also gathered. These types of data assist in assessing the potential of specific areas and certain landforms to contain archaeological resources.

A copy of this report will be submitted to the Prince of Wales Northern Heritage Centre. That copy includes detailed text citations, which are also available from Rescan, if required.

The assessment of archaeological potential in any region is based on an assessment of the natural resources and landscape features and how these combine in any specific area to provide possibilities to meet basic human needs. The following factors are of primary importance in human location:

- fresh water;
- level camping area of suitable size or some other shelter possibilities;
- animal and plant food resources;
- fuel source for heating and cooking;
- travel routing possibilities;
- exposure (south facing generally preferred where possible);
- view of surrounding area (both for game sighting and defensive purposes); and
- sources of workable stone or other specific raw materials needed.

As the number of these factors that exist in any particular location increases, the potential rating increases. Additionally, historic, ethnographic, archaeological or oral history knowledge of human uses in a region can be incorporated to further adjust potential ratings. In general, a rating system of low, moderate and high categories is used in most areas to assess archaeological potential; other systems, such as a two tiered system of some and high may be used in regions with little previous archaeological research or where little ethnographic or historic information is available.

In the central Arctic regions, the most important site location factors would probably be the availability of game resources and fuel sources. As observed by Stefansson, (1919) who directed one of the first explorations of the region in the early 1900s, fresh water can be found almost anywhere in the central Arctic heather was the preferred fuel for Coronation Gulf people, and their camps would usually overlook good game feeding grounds or lake or river game crossing points (Stefansson 1919). Hence, the locations which would provide the highest archaeological potential in this region would be elevated landforms providing dry ground, overlooking shallow lake, river narrows or grassy meadows. Waterlogged or sloped land would have low archaeological potential. The range of landforms and ground types in between these extremes would be variously rated as having low, medium or high potential, depending on the location's specific features and setting.

Standard archaeological techniques were utilized for the ground reconnaissance. The detailed inventory and impact assessment portion of the archaeological field study generally involved foot traverses supplemented by low level helicopter overflights to provide full visual inspection of the areas delineated on project maps. The foot traverses were conducted near terrain unit edges and/or those portions of a landform with potential or of an entire landform where limits were readily evident, supplemented by examination of ground exposures and subsurface shovel tests. Due to the high degree of ground exposure and limited soil development in this region, shovel tests were rarely necessary to locate sites. Subsurface tests were judgementally placed in the highest potential locations where there was significant soil development. The spacing and number of tests varied depending on the size of the landform, the amount of exposure and degree of soil deposition and the potential for archaeological resources. Tests were generally 40 x 40 cm, although occasionally they were larger or smaller, depending on local vegetation and soil conditions. The depth of the tests varied, but because of the generally poor soil development and extensive gravel deposits and bedrock outcrops characteristic of this study area, depths of subsurface tests usually ranged from 10 to 30 cm.

In those cases where archaeological resources were encountered, more detailed investigations were conducted. The site boundaries were determined through examination of exposures, by the limits of the landform or site features, or by subsurface testing. Recommendations as to whether more intensive investigations to determine site content, depth, *etc*. should be undertaken, were dependent on the potential for the site to be impacted, perceived importance of the site and various other considerations. For all sites recorded, archaeological site inventory forms were completed, site maps drawn and photographs taken. Completed site forms were submitted to the Canadian Museum of Civilization and the Prince of Wales Northern Heritage Centre for inclusion in the national and territorial inventories. Temporary site numbers were assigned in the field, and the permanent Borden numbers (based on latitude and longitude) were provided by the Canadian Museum of Civilization. The Borden system involves a series of capital and small case letters and a number, for example, MjNh-1. Numbers are usually consecutively assigned, in the order sites are discovered.

Only artifacts judged to be in imminent danger of direct impact by possible development were collected; all other artifacts were recorded and photographed *in situ*. This season, only two artifacts were judged to be in enough danger to require collection. These are currently being examined by a conservation consultant (Cross 1996, pers. comm), to determine the level of conservation required. After they have been treated, if necessary, they will be submitted to the Prince of Wales Northern Heritage Centre.

### 10.2.2 Specific Field Methods

The archaeological field work began with a contribution to a tour of BHP projects by Inuit Elders by visiting some good examples of archaeological sites recorded in the region. Because of the need to use a helicopter to reach the sites and the passenger limitations imposed by the size of the available helicopter, and therefore, only two Elders, John Akana and Steve Anavilok, could participate. They were taken to the island in Roberts Bay on which several sites were found last year (Bussey 1995a), shown some sites from the air and visited one site (NbNh-3). They examined the features and made comments about their significance. This information was incorporated in this year’s study and is referred to in this report where appropriate. They also pointed out some features which had not been identified last year; this emphasizes the value of discussions with local residents and opportunities to view archaeological features with them - useful information can often be forthcoming.

Archaeological field investigations began at the Boston Project. The field crew stayed at Boston camp for the investigation of that area as well as the southern section of the proposed trail route. The boundaries of the Boston study area were determined by the area delineated on the map provided by the BHP Resource Development office in San Francisco, (Figure 10.1-1) and focused on two possible airstrip locations as well as a large bulk sample area. In addition, one large site, MjNh-2, that had been preliminarily recorded last year (because it was outside of the planned developments), was revisited to gain a clearer picture of the extent of the site and the features present.

The proposed winter trail route (Figure 10.1-1) was observed by low, slow helicopter overflight from Boston camp to Doris Lake. The main goals were to identify landforms with good archaeological potential and to record any archaeological sites in the vicinity, that had been reported by survey crews last year. In addition, because of the good visibility of rock features on the landscape, several additional sites were observed during the overflight and were recorded, time permitting.

For the remainder of the field investigations, the archaeological team moved to Windy Lake camp, in the vicinity of Doris Lake. For the portion of the proposed winter trail route between Doris Lake and Roberts Bay, a more detailed assessment was necessary because that portion of the trail was to be used this winter. A low, slow helicopter overflight was followed by ground reconnaissance of high potential areas.

In the Doris Lake development area, selected portions, as delineated on the project map (Figure 10.1-1), were subjected to ground reconnaissance. These included the proposed camp location, a possible air strip location and a planned bulk sample area, all at the north end of Doris Lake. In addition, any possible development areas in the Doris Lake Project area identified while the archaeological investigations were going on were to be included in the detailed assessment. Only one possible exploration area (Madrid) near the north end of Patch Lake was identified, and that area was also subjected to ground reconnaissance. Finally, because time permitted, several sites that had been reported by survey and geology crews in the general Doris Lake vicinity were also visited and recorded (Klohn-Crippen 1995).

The final development area requiring examination was on the west side of Roberts Bay and included two possible port and two possible barge landing locations. A larger area, delineated on the project map (Figure 10.1-1), was viewed by low, slow helicopter overflight, followed by foot traverses which provided good coverage of most of the landscape within the outlined area.

## 10.3 Background

This section includes background information on the regional environment, human history and archaeology. This information provides the setting necessary to place the archaeological study findings in proper context for interpretative purposes and assists in the determination of archaeological potential of various landforms.

### 10.3.1 Environmental Setting

The Hope Bay Belt study area is located within the north-central Arctic region, within the Back Lowland of the Canadian Shield (Rogers and Smith 1981). The entire region was covered by the Laurentide ice sheet; deglaciation is thought to have been nearly complete by about 9,000 years before present (B.P.). The landscape was formed by the scouring and deposition of glaciers and is dominated by smoothed and rounded surfaces (Stager and McSkimming 1984). Landforms and lakes are generally aligned north-south, signifying the direction of glacial movement. An important phenomenon in the Arctic is crustal rebound, the rising of the land surface after the glacial ice retreated. This has resulted in old beach ridges occurring many miles inland at heights of up to 150 m above present sea levels (Stager and McSkimming 1984). Curves have been developed measuring this process and most of the rebound occurred in the first several thousand years after ice retreat; consequently, this phenomenon is only relevant in the cases of the oldest archaeological sites in a region.

The landscape is characterized by low lying, gently rolling or flat land frequently interspersed by rocky bluffs, ridges or knolls. Bedrock often occurs at the surface, but in small depressed areas, soil has accumulated to provide an environment for plant life. In larger depressions, formed by the melting out of glacial ice, water has accumulated to form the many lakes that dot the landscape and much of the low lying terrain is swampy. Frost heaving and shattering are the dominant processes that continue to modify the landscape and form the various types of formations. The surface is generally typified by boulders, rocks and gravel of various sizes.

The climate is classified as cold continental, with mean daily temperatures ranging from -30 °C in January to 10 °C in July (Stager and McSkimming 1984). The region has a low mean annual precipitation rate of less than 20 cm (Stager and McSkimming 1984) and is considered an Arctic desert. Most of the snow falls at the beginning of winter; after that time, little new snow is added but strong winds constantly cause drifting; this region is known as the windy belt of the central Arctic (Stager and McSkimming 1984). Because of the lack of climatic warming in the summer, the study area is within the continuous permafrost region (Stager and McSkimming 1984). The coastal waters of the study area are usually ice-free for between two and four months each year, but the summer pack ice can extend fairly close (Stager and McSkimming 1984).

The entire area covered by the Hope Bay Belt Project is within the tundra zone and is well above the tree line (Stager and McSkimming 1984). The Arctic ecosystem is characterized by a lack of biological diversity; few plant and animal species have adapted to the harsh environment (Freeman 1984). Vegetation is generally low growing, due to soil infertility and aridity, short growing season and high wind velocity. Lichens, mosses, and grasses dominate, with patches of dwarf birch and willow (Wilkinson 1970). Fields of grassy tussocks are common. Arctic cotton grass and Arctic poppy color the landscape. There are few plants that provide edible material in large enough consistent quantities to have been regularly exploited, and vegetal matter was almost non-existent in the local diet (see Section 10.3-3) until relatively recent transportation improvements provided goods from the south.

The primary large mammals in the region are caribou, muskoxen, wolves and grizzly bears (Wilkinson 1970). Ringed seals occur along the coast. Numerous small mammals include lemmings, foxes, hares, weasels, and the abundant “sik sik” (ground squirrels). Bird species include eagles, falcons, owls, ravens, ptarmigan, gulls, swans, ducks and geese. Arctic char is the primary anadromous fish in the region, and various types of fresh water fish such as lake trout, grayling, cisco and whitefish are found in the many lakes and streams.

### 10.3.2 Human History

The study area is on the eastern edge of the Copper Inuit ethnographic territory, as it is currently identified (Damas 1984). This is one of the five groups classified as Central Eskimo, so designated because they live in the area that is the approximate centre of the region traditionally occupied by the Eskimo people who were the ancestors of current Inuit residents. The Copper Inuit traditional range is generally considered to be from Wise Point on the west, to the southern shore of Banks Island on the north, including most of Victoria Island, to a line running just east of Cambridge Bay to Perry River, and south almost to Back River and Contwoyto Lake (Damas 1984); a map by Jenness (1922) shows most of this territory as well as indicating locational and group names mentioned by other sources, thus, it is included here as a reference (Figure 10.3-1).

The central Arctic was probably the last region in the Arctic to experience extended contact with white culture. Ethnographically, the Central Eskimo represent the least studied of all Inuit groups; there seems to have been much more historically documented contact with western and eastern groups (cf. Wissler's introduction to Stefansson's (1919) report on the 1908 to 1912 explorations: "The region between Cape Bathurst and King William Island was formerly so little known that one could do no more than conjecture as to what groups of Eskimo lived therein"). This late investigation of the region may have been for a combination of several reasons:

1) greater difficulty in reaching the area;
2) fewer unique or interesting artifacts; and
3) a more marginal existence, which may imply simpler social organization and, consequently, may have provided less interest to ethnographers of the day.

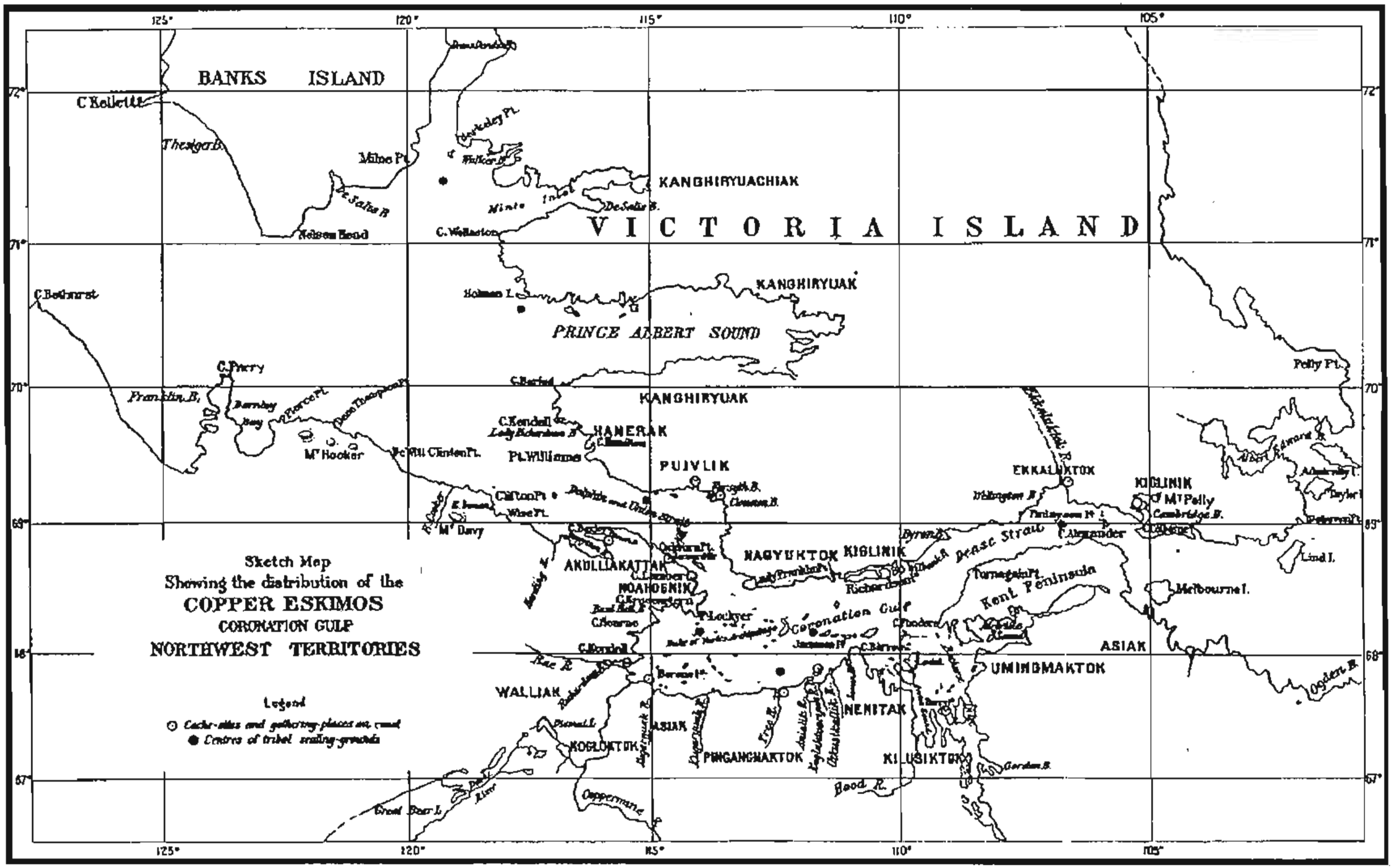
The central barrenlands and adjacent Arctic coast of the Mackenzie and Keewatin districts have been thought by some to have always had low population densities (Maxwell 1980). Part of the reason for this is believed to be a result of the relatively low biomass of the region, compared to the western, eastern and high

Arctic regions where marine environments provide a plentiful economic base (cf. Jenness's (1922) comment on the "greater resources and population west of Kent Peninsula").

The first person documented to have travelled through Copper Inuit territory was Samuel Hearne, who was hired by the Hudson's Bay Company to travel overland from Hudson Bay to the Arctic coast at the Coppermine River in 1770 to 1772 (Jenness 1922). In 1820 to 1821, Sir John Franklin was commissioned by the British government to explore the polar sea. He proceeded down the Coppermine River by canoe and travelled the length of Coronation Gulf, mapping the shoreline (Jenness 1922).

After Franklin's disappearance in the central Arctic in 1848 while conducting another exploration, several expeditions searching for him passed through and/or near the Coronation Gulf area (*e.g.,* M'Clintock and Simpson, Hall, and McClure), but it was not until the turn of the century that active exploration of this portion of the Arctic was revived. These included the Stefansson-Anderson explorations for the American Museum of Natural History in 1908 to 1912 (Stefansson 1919), the Canadian Arctic Expedition (1913 to 1918) of which the eminent ethnographer Diamond Jenness was a part (Jenness 1922), and the Danish Thule Expeditions (the Fifth [1921 to 1924] extended into the central Arctic; Rasmussen 1932). These are the primary references for Copper Inuit ethnography; although these studies generally focused on the western portions of the range, that is, west of Bathurst Inlet, it can be assumed that subsistence practices were similar throughout the territory.

Other prominent studies which have some relevance to the Central Eskimo include Boas' (1964) studies of eastern Central Eskimo groups in the 1880s and Smith's (1959) extensive comparative studies of various Inuit groups conducted in the 1920s. Later travellers consisting of explorers, traders, and missionaries wrote popular accounts of their times in the central Arctic; for example, the Oblate missionary Father Raymond de Coccola lived at Cambridge Bay and Burnside post, at the south end of Bathurst Inlet, from 1937 to 1949 and travelled extensively throughout Copper Inuit territory (de Coccola and King 1986).




# Sketch Map Showing the Distribution of Copper Inuit on the Coronation Gulf Region, NWT

FIGURE 10.3-1

BHP Rescan

Source: Jeness 1922

The fur trade in this region began in the 1920s with the establishment of trading posts in the Bathurst Inlet/Kent Peninsula area (Usher 1971). Several were clustered along the coast between the Coppermine River and Bathurst Inlet. The early posts on Bathurst Inlet were located on the west side, at the Burnside River (operated between 1930 and 1964) and Hood River (between 1936 and 1941), and at the southern tip of the inlet at Western River (open between 1925 and 1927). Another early post was in operation on the southern shore of Kent Peninsula between 1920 and 1927. The only post on the eastern side of Bathurst Inlet was operating at Baychimo Harbour (now known as Umingmaktok), between 1964 and 1970; this replaced the Burnside River post. This influx of traders likely served to change the focus of subsistence activities and travel patterns, toward more fox hunting than was carried on previously (Jenness 1922), and increased the hunting pressures on caribou (cf. comment by Captain Bernard regarding the changes he had witnessed by 1920: "The Eskimo were leaving their winter sealing grounds about two months earlier than usual and devoting their attention to the trapping of foxes"; Jenness 1922).

### 10.3.3 Copper Inuit Life

The primary focus of the Copper Inuit was and is west of Bathurst Inlet; however, some have historically lived on the eastern shore of Bathurst Inlet. The evidence suggests that these eastern Copper Inuit did not frequently penetrate very far into the inland area east of the Inlet. Short distance incursions were made to hunt caribou and muskox (cf. Riewe 1992), and some trading expeditions were conducted to trade with the Netsilik people whose territory was immediately east. Some mention was also made in ethnographic literature of one-half to two year long journeys carried out to trade with the Caribou Eskimo to the south, most particularly for the very valuable wood resources (Jenness 1922).

According to Rasmussen (1932), the people living on the east side of Bathurst Inlet were known as the Muskox people because they hunted the muskoxen that frequented that area. He noted that the vicinity of Hope Bay (west of Roberts Bay) once abounded with muskoxen (Rasmussen 1932). The name "Umingmaktok," now applied to the settlement on the east side of Bathurst Inlet, means "where the muskoxen are many" (Rasmussen 1932). The end sheet maps in De Coccola and King (1986) show the names of several regional groups within the Copper Inuit territory, all signifying locational or subsistence focus; they also record the "People of the Muskox" living on the east side of Bathurst Inlet. It is interesting to note, however, that in spite of the name, the subsistence focus of this group was the same as all other Copper Inuit, that is, caribou, and that muskox were only hunted occasionally. Even Rasmussen noted that the Muskox people hunted caribou from May to October, and large herds of caribou could be found scattered throughout the region (Rasmussen 1932).

The subsistence cycle of the Copper Inuit was based on seasonal movements to harvest specific resources within the region. From December until May, the main economic focus of the Copper Inuit was breathing-hole sealing. Because this activity involved the cooperative efforts of a number of hunters (one was stationed at each hole to wait until the seal rose) and their dogs (to find the holes), groups aggregated into winter snowhouse villages on the sea ice.

During the second half of May, the winter villages were abandoned and the people dispersed to the land and began to exploit resources such as caribou, fish, birds and small game. In spring and early summer, fishing through ice on lakes was more important, while caribou hunting dominated from about the beginning of August to November, when the animals were fairly fat and their skins most suitable for clothing. In late summer, fishing for Arctic char was carried out by using weirs in the streams to which the char returned after their time in the ocean.

For a period of two to four weeks beginning in November, the Copper Inuit subsisted mainly on cached frozen and dried foods. This was a period when summer hunting groups aggregated at traditional locations (known as "finishing places") to permit the women to concentrate on sewing the winter garments (see Figure 10.3-1). It was also the time to wait for the sea ice to become solid enough to permit moving out to the winter snowhouse village locations (McGhee 1972).

In general, the Copper Inuit's social focus was the nuclear family. No consistent larger groups, such as tribes, were known, nor was there a group hierarchy or leadership. In fact, it has been pointed out that, historically, the Copper Inuit believed in equality to the extreme, and anyone who stood out in any way was frowned upon, or dealt with in some manner to put him back in place (Stevenson 1997). Summer hunting groups generally consisted of the single family with occasional "accidental" groupings when people gathered at particularly good fishing or caribou hunting locations. The sewing groups would represent a moderate sized aggregation, Damas (1984) estimates from 40 to 50 people. The winter villages would have been the largest gathering, which Damas (1984) estimates ranged between 50 and 166 people, averaging between 90 and 120 (1984). No constant group composition is discernible; sometimes related people came together, other times, friends or acquaintances gathered. Consequently, it could be concluded that kinship ties were loose, at best.

Technology of the Copper Inuit was composed primarily of bone and antler implements. Sealing was carried out with harpoons made of bone and wood. Caribou were hunted with bows and arrows, the former made of wood, antler or horn or, more often, a combination of these materials held together with sinew. Arrows were tipped with copper, iron, bone or antler. Sometimes converging rows of rock piles would be constructed and women and children would chase caribou toward the waiting hunters. Other times, caribou were intercepted at lake and stream crossing points.

Fishing through the ice utilized copper, iron or bone hooks attached to a line. A variety of household implements were made of bone, soapstone, wood and copper and include lamps, cooking pots, baskets, scrapers, needles and knives of various types. Clothing and bedding were made primarily from caribou skin, before the influx of cloth and sleeping bags. Transportation was by sled pulled by dogs and humans in winter and in summer, dogs and people would carry packs on their backs. In the Central Eskimo region, kayaks were used mainly for hunting caribou at lake and stream crossings, rather than as a form of transportation (Damas 1984).

The dispersal of family groups over the summer meant that many summer sites would simply consist of one or two tents, marked by rings of stone which were used to hold the edges of the tent down. Because the winter villages were composed of snowhouses, the only evidence of these may be increased concentrations of organic matter and, possibly, some artifact concentrations; obviously no surficial evidence would remain of the winter villages on sea ice. Sometimes two or more houses were joined, both in the cases of summer and winter houses; this could result in adjoining stone rings (Jenness 1922). Small stone rings may have served to hold down drying skins (Jenness 1922).

Other types of structures commonly constructed of rocks included hunting blinds, caches, traps, graves and signal rocks or inukshuit. Hunting blinds were semi-circles of large rocks or boulders, often formed by propping up large, flat slabs (cf. Jenness 1922). Hunters would lie on their bellies and peek through the cracks between the rocks or over the top edge to sight game. Traps were made by piling rocks or snow blocks and providing a small doorway into the inside. A flat slab was balanced at the entrance on a stick which was attached to a piece of blubber or meat at the far end of the interior opening. When the animal (usually a fox) entered the opening to get at the bait, it dislodged the stick and brought the roof down on itself (Jenness 1922). Jenness (1922) suggested that traps were a fairly recent development, linked to the fur trade.

Caches were locations where meat and/or extra winter clothing or other gear were temporarily stored (Jenness 1922) noted caches of blubber on the mainland coast). The meat was usually wrapped in skins and covered with moss or driftwood; this could be placed in a crevasse or on top of a steep incline or simply on the ground if there was no more suitable protective feature, then, large rocks would be piled on top so that animals could not get at the meat. Non-food caches could simply be skin covered goods placed on the ground and weighed down by a circle of stones to hold them in place (Jenness 1922).

During early contact times, graves built by Copper Inuit were apparently very simple. The body was usually wrapped in skins and placed on the ground, and may or may not have been surrounded by a circle of stones or snow blocks, or left inside the person’s tent (Jenness 1992). Some of the person’s possessions, or reasonable facsimiles were placed beside the body (Rasmussen 1932). More elaborate graves covered by stone cairns (that is, piles of rocks) that were found across the central Arctic were assumed to be from earlier times (Jenness 1922; see also McGhee 1972).

Lines of rock cairns were also sometimes constructed for funnelling caribou towards waiting hunters. The well known inukshuit, that is, rocks piled in a formation to look like a person, could also be constructed for this purpose, or they were used singly to mark locations or as guideposts; simpler signal rock formations were also used (Jenness 1922).

### 10.3.4 Previous Archaeological Investigations

Prior to 1995 (Bussey 1995a), there were no archaeological investigations conducted in the inland region immediately east of Bathurst Inlet. On the mainland coast, some previous work was carried out west of Bathurst Inlet, both on the coast and in southern regions of the inlet with particular focus on the Burnside River, as well as along the Back River south and east of the BHP study area. In addition, several studies have been conducted on Victoria Island and Banks Island, north of the project area.

Mathiassen (1927) conducted the first archaeological investigations within the Central Eskimo region, as part of the Fifth Thule Expedition. His excavations were carried out east of the Copper Inuit area (in Repulse Bay, Southampton Island and King William Island). No systematic work had been conducted in the region prior to that time and he was investigating the Central Eskimo with his ultimate aim being to examine problems relating to the origins of Inuit culture in general. Jenness (1922) mentions some archaeological work by Capt. Bernard at Cape Krusenstern, at the western end of Coronation Gulf, where a number of houses in several different villages were excavated. This is said to have extended the limits of the known range of semi-subterranean wood and sod houses (Jenness 1922).

Later archaeological investigations within the Copper Inuit region include survey and excavation by McGhee (1970, 1971, 1972) in the western portion of the Coronation Gulf area, Taylor (1967, 1972) on Banks and Victoria Islands, Hickey (1979) on Banks Island, and Stevenson (1992) in Amundsen Gulf, at the western limits of Copper Inuit territory. Slightly closer to the area of interest in this study, Morrison’s (1978) survey at the southwest end of Bathurst Inlet resulted in the recording of 61 archaeological sites. On the Back River, south and east of the immediate study area, Stewart (1996) recorded features and related oral history concerning five traditional Inuit campsites; investigations of one site resulted in the recording of information on 61 features. A site survey conducted by Damkjar (1994) which extended into the southern and western portion of Copper Inuit territory resulted in 52 archaeological sites being recorded. These studies have provided data on the entire time period of probable Inuit occupancy in the region and provide the basis for the culture history sequence developed thus far.

There are few archaeological sites known in the study area east of Bathurst Inlet, virtually none recorded prior to the 1995 study for BHP (Bussey 1995a). The only previously recorded site in the immediate area is NaNi-1 which is an undetermined site on the northeast shore of Hope Bay, almost directly west of the south end of Roberts Bay.

The 1995 study involved the excavation of a stone circle site south of Boston camp (MjNh-1) and preliminary survey of the island and peninsula in Roberts Bay (Bussey 1995a). A large, reported site near the Boston Property was also examined and preliminarily recorded (MjNh-2). In Roberts Bay, survey resulted in the recording of thirteen archaeological sites (NbNh-1 to -13), nine of which were found on the island. The sites comprised rock features including circles of various sizes and shapes, traps and caches. Only a few artifacts were found at one site, and they represented historic period use. The remaining sites could not be assigned to a period of occupation, although some had features suggestive of earlier use and/or were partially buried or exhibited considerable lichen growth, suggesting some antiquity.

Numerous archaeological and/or traditional sites in the surrounding region have been reported by local residents to the Nunavut Planning Commission Transition Team (NPCTT 1996), by local residents. The NPCTT report identifies a number of campsites and inukshuit on eskers within 10 km east and 20 km south of Spyder Lake and local residents reported that this area was extensively used for caribou hunting in the early 1900s or earlier (NPCTT). It is certainly conceivable that some hunting was also conducted north of that area, and/or that people travelling to the coast (either to the west or north) passed through the study area. There are also a number of archaeological sites plotted on the Nunavut Atlas map for the northern portions of the study area, that is, along the Hope Bay and Melville Sound coast and some distance inland (Riewe 1992). These sites were reported by local residents who were asked to mark locations on maps which were known hunting and fishing areas, travel routes, campsites and archaeological sites (Riewe 1992) and the Koignuk River is indicated to be of considerable importance in resource gathering and is identified as the location of a year-round camp.

### 10.3.5 Culture History

The culture history for this section of the central Arctic region is in the initial stages of development. Fairly detailed culture history sequences have been developed for the northern, western and eastern Arctic areas but, because so little archaeological research has been conducted in this region, there is considerable debate about cultural developments in the central Arctic and its relationships with adjacent areas. There is no doubt that this is a complex subject, and there are currently two main schools of thought. McGhee (1972) hypothesized a preliminary sequence based on environmental changes, while Stevenson (1997) has postulated a variation based more on social factors. Whatever the reasons for the movements of people and the cultural and technological changes exhibited in the archaeological record, a basic sequence of events can be identified.

The earliest time possible for human occupation of this region was after 9,000 years ago, when the large glacial ice sheet that covered much of North America is thought to have retreated from this region. South of the study area and west of Hudson Bay, a Plano Indian culture is known between about 8,000 and 6,000 years ago. Besides this, little evidence of occupation of this region is known for the period between glacial retreat and 3,500 years ago.

The earliest dated archaeological sites within the Copper Inuit territory relate to the Paleo-Eskimo period, beginning approximately 3,500 years B.P. At that time, a cooling climate appears to have prompted a southward movement of a culture known as pre-Dorset (which is thought to have developed in the western Arctic and gradually moved eastward across the High Arctic at a slightly earlier time period). This pre-Dorset group followed a mixed terrestrial-marine subsistence pattern and used small stone tools and therefore pre-Dorset manifestation is known as the Arctic Small Tool Tradition (Maxwell 1984). It is characterized by the use of small stone tools, small oval tent rings and fire boxes formed of stone slabs (Maxwell 1984). The Paleo-Eskimo sites recorded closest to the study area occur on southeast Victoria Island (Buchanan) and on the mainland at the western end of Coronation Gulf (Bloody Falls and Dismal Lake).

There is a gap in the mainland central Arctic archaeological record between approximately 2,500 and 1,000 years B.P. at a time when the Dorset culture was flourishing in the Eastern and High Arctic (Maxwell 1984). Approximately

1,000 years ago, another eastward expansion resulted in the establishment of Thule settlements across most of the Arctic. McGhee (1984) has postulated that two waves of Thule expansion occurred, the first through the High Arctic islands, following the distribution of whales which provided the economic base of early Thule. The second westward expansion occurred approximately 100 to 200 years later, along the coastline through Coronation Gulf, and south from the High Arctic along Baffin Island to the Hudson Bay area. This second expansion is thought to have included a diversification of the economic base which permitted inland penetration. Consequently, some regional variations are recognizable (McGhee 1984). Whaling was the primary economic activity of Thule in most Arctic regions (emphasized by the extensive use of whale bone in house construction), but in the Coronation Gulf area, Thule subsistence appears to have been based primarily on ringed seals, caribou, and fish, as stated by McGhee (1984) as “the absence of whalebone house ruins in the central Arctic regions strongly suggests that whaling was never an important activity to populations in the area.” It has been suggested that Thule people hunted seals from boats and on ice edges to accumulate stores to last the winter, in contrast to the breathing-hole sealing carried out by the later Copper Inuit (Stevenson 1997). This subsistence strategy fits with the identification of winter dwelling sites on the coastal shores. The Thule sites of most relevance to this study have been identified along the southern shore of Victoria Island and along the southern and western shores of Coronation Gulf.

Canadian Thule stone dwellings were generally round to oval in shape, with sleeping platforms of gravel or stone slabs; walls were heavily built of boulders or stone slabs and there was often an entry tunnel. These stone structures and semi-subterranean wood and sod house remains have been classified as autumn and winter dwellings (McGhee 1972). The technology consisted largely of bone and antler implements, and soapstone lamps were used for heat and light (Maxwell 1984). In the central Arctic, copper was an important part of the tool assemblage. Certain stylistic artifact attributes have been classified as Thule (cf. McGhee 1972); however, given the sparsity of artifacts found in this area to date, it is not deemed necessary to discuss specific artifact details at the present time. Furthermore, most Thule artifacts have been defined on the basis of variations in harpoon head styles (cf. Mathiassen 1930), and such a sequence is obviously of questionable utility in inland sites. Certainly, a more in depth study of artifact attributes will become necessary if future archaeological investigations in this area uncover artifact assemblages.

Because McGhee (1972) believes that Copper Inuit evolved directly out of Thule, he has defined an “Intermediate Interval,” in which he placed sites which do not seem to fit within the identified patterns of typical Thule culture or historic Copper Inuit culture. All sites that he has thus far identified as belonging to this period occur in the western portion of the Copper Inuit territory. The primary characteristic of these sites is an almost total lack of artifacts and bone, thereby creating problems in determining their placement within the cultural historical framework. Because of this lack of artifacts, the sites are identified largely on the basis of structural features. These structures include semi-subterranean houses without internal construction and heavy stone rings with stone platform edges (McGhee 1972). No sites assigned to this period have been definitely dated, but McGhee places them loosely within the “interval” between the latest Thule dates (about 500 years ago) and the beginning of the historic period, which he identifies as A.D. 1771 (Samuel Hearne’s visit to Coppermine). It should be emphasized that this “Intermediate Interval” is a hypothesis that is not yet generally accepted. As Arnold (1983) has noted:

> Archaeological sites dating to the period during which the Thule to Copper Inuit transition is thought to have occurred have not yet received much attention. Here, too, the relationship between the culture of the historic Inuit and that represented by earlier Thule sites in the area remains speculative.

McGhee (1972) noted that no spring or summer Thule sites have been identified. Because the summer subsistence pattern is postulated to require more travel to follow caribou and other game resources, it is anticipated that summer sites would be occupied for shorter periods of time and, consequently, fewer artifact and bone remains would be left behind. It is, therefore, considered conceivable that the sites McGhee classifies as “Intermediate” may, in fact, represent summer Thule occupations, since the construction techniques of the dwellings are quite similar to those described as classic Thule. In any event, a resolution of this issue obviously requires more detailed research on these “Intermediate” sites.

Stevenson (1997) has postulated a third migration from the west into Coronation Gulf during late prehistoric times which he suggests was prompted by a need to find more resources to maintain trading networks with people to the west.

The climate began to deteriorate into a climatic stage known as the Little Ice Age (dated about A.D. 1650 to 1850), and the High Arctic whaling subsistence pattern became untenable. It is during this period that the different historic Inuit groups are thought to have developed from the various Thule variants: "There seems to be little doubt that [the culture of the Copper Inuit] can be traced back to the maritime oriented Thule peoples" (Arnold 1983). However, the mechanism of this development is currently being debated. While McGhee (1972) and Morrison (1983) believe in a direct, *in situ* evolution based on environmental changes, Hickey (1997, pers. comm.) and Stevenson (1997, pers. comm.) have postulated a movement of late Thule people away from the coast to inland areas, then another migration of people back to coastal areas in the early 18th century; Stevenson suggests that these movements were due to a combination of environmental, economic and social factors. Jenness (1922) also saw evidence to suggest to him that "Copper Eskimo were an inland people until a few centuries ago." Regardless of what factors may have prompted the developments, the economic base of people in the central Arctic shifted towards exploitation of a mix of terrestrial and marine resources, and the subsistence pattern exhibited by the Copper Inuit became established.

## 10.4 Archaeological Investigations

This section provides details of the archaeological field work completed in 1996 and the results of the investigations of specific development areas within BHP's Hope Bay Belt Project. Work within each development area is described, beginning at the south end of the study area, and results presented; general site locational information relative to proposed developments will be noted within each discussion, but details of site features are provided in Section 10.5, where each site is described individually. To maintain the continuity of the text, site maps and photographs have been placed in Appendices 10-1 and 10-2, due to the high number required.

As noted earlier, the visit with Elders John Akana and Steve Anavilok to site NbNh-3 resulted in the identification of some features not observed last year; these were items difficult to identify, particularly given the preliminary nature of, short time available for, and adverse weather conditions during the island investigations. The 1996 trip to the island was conducted under ideal conditions with beautiful sunny, calm weather. The items pointed out by the Elders consisted of boulders set up to form kayak supports (subsequently observed at other sites) situated a short distance south of the tent rings, several wooden sticks which served as hide stretching pegs and a wooden scoop or bowl (similar to a bowl illustrated by Stefansson 1919) which was partially buried and filled with vegetation (Appendix 10-1, Photos 1 and 2). The site form was updated to note these new findings. The Elders also made some general comments about the island's use, suggesting caribou and seal hunting (the latter probably off the north end of the island in the summer), and confirmed that the stone traps on the island were for fox: "it was too hard to build traps strong enough to hold a wolverine or bear" (Akana 1996, pers. comm.). They also pointed out that circular tent rings probably predated the 1920s, when square canvas tents began to be used in the area.

### 10.4.1 Boston Project Area

The project map supplied by BHP was used to provide the focus for archaeological investigations. The map showed two possible air strip locations, the presently planned bulk sample area, and a larger surrounding area in which development or peripheral disturbance may occur (Figure 10.4-1). The entire outlined area was examined, mainly by foot traverse, and the remainder by helicopter.

The perimeter of the peninsula on which Boston camp is currently situated was subjected to foot traverses and ground examination (Figure 104-1). In addition, traverses crossed the width of the landform at several points, in order to examine landform rises and any other areas with some possible archaeological potential. In this manner, ground examination of the entire landform north of Stickleback Lake was virtually complete. Such complete coverage of this area was deemed necessary because, at the present time, it is the focus of development.

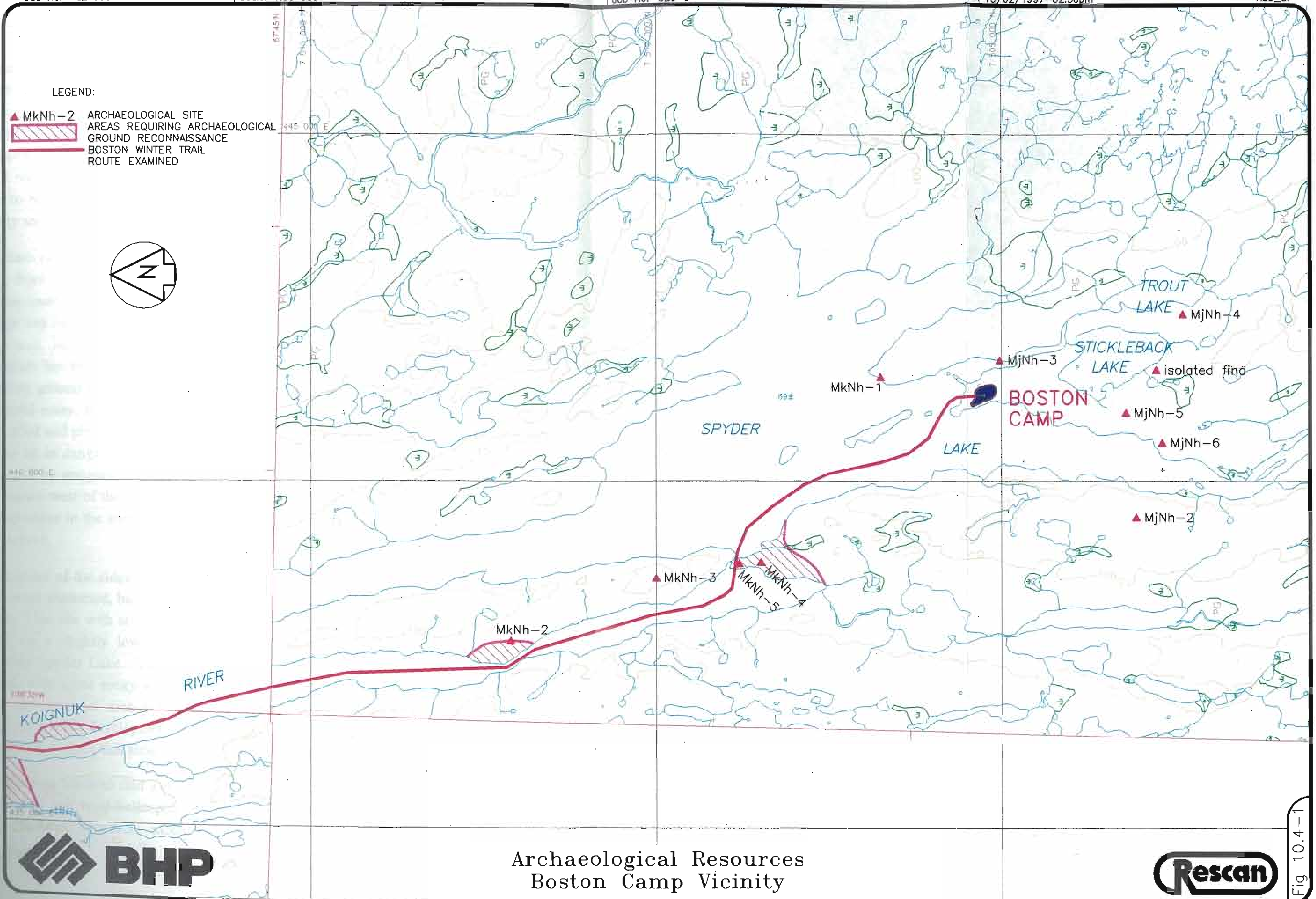
South of Boston camp, the surface of this landform is undulating and rocky with some wet portions in the interior of the landform. The western edge is fairly high with a substantial drop to the beach level, while the eastern edge slopes toward the lake/river channel which creates a swampy edge. The portion north of Boston camp is a low gravel beach. Ground exposure was generally good. No archaeological sites were found.

The large peninsula to the east of Boston camp (across the lake/river channel) was also subjected to foot traverses of the perimeter (Figure 10.4-1). The central portion of the landform may be used for an airstrip. The western edge of this landform is fairly high, but it slopes toward a gravel beach along the lake/river channel. The eastern edge is lower and has a wide swampy border. The northern end is more rocky and drops sharply to a rocky/gravel beach. The interior of the landform comprises mainly tussocks interspersed with wet areas and some landform rises. The rises were also examined and were found to be gravelly or rocky. Ground exposure was generally excellent in those portions with archaeological potential.

Two archaeological sites were found. One site (MjNh-3), a stone circle, is situated on the western side of the peninsula. The other site (MkNh-1), also a stone circle, is located on the northern tip of the peninsula, on the northern edge of the height of land. No archaeological sites were found in the central portion of this landform, where the possible airstrip is proposed, and the potential for archaeological sites in this portion is judged to be low. MjNh-3 is not in direct conflict with the proposed northern air strip option, but MkNh-1 appears to be at or near the north end of the airstrip.

The perimeters of the two small lakes south of Boston camp were also examined. Foot traverses were conducted completely around Stickleback Lake, and the western edge of Trout Lake to the southeast was foot traversed; the landform between the two lakes was thoroughly examined. Site MjNh-1, which was mitigated last year (Bussey 1995a), is situated in this area. It was revisited this season and no new disturbance was evident.

The eastern edge of Trout Lake was visually inspected by low, slow helicopter overflight and found to be low lying and swampy for a considerable distance from the lake, consequently, the archaeological potential was judged to be low. The same is true of the land bordering the southern edges of both lakes, for at least that portion included within the delineated development area. It is low lying swamp with tussocks.




Archaeological Resources
Boston Camp Vicinity

Fig 10.4-1

The land between the two lakes was generally level, gently sloping down toward the lakes on both sides, and interspersed with some elevated rocky features and low lying areas characterized by tussocks. The edges overlooking both lakes and all elevated landforms were thoroughly examined. One stone circle site (MjNh-4) was recorded on the southwestern edge of Trout Lake. It is situated on an elevated rock outcrop, adjacent to the second possible airstrip location. The site appears to be out of the direct impact zone, but indirect impacts due to the close proximity are possible.

The western edge of Stickleback Lake is bordered by a high, rocky ridge, ranging in width from about 600 m in the southern portion to 200 m at the north end, and which descends on the other side to the long, southwestern arm of Spyder Lake. The ridge was ascended near the southwestern edge of Stickleback Lake, along an apparent trail. Near the eastern edge of the ridge top, an isolated artifact, a caribou antler which has been notched and grooved, was found lying on the trail. The surrounding ground was thoroughly examined and some of the surficial vegetation was scraped away, but no additional cultural remains were found. The location was recorded and photographed, and the artifact was left *in situ* because it was not judged to be in danger of impact at the present time (a Borden site designation number will be assigned to this location). A small lake and swamp occurred a short distance west of the location of the isolated find on the upper surface of the ridge; exposures in the surrounding area were inspected, but no cultural materials were observed.

The remainder of the ridge was traversed and all ground exposures and elevated portions were examined, but no additional sites were found on the rocky height of the ridge. One site with stone circles and a possible hunting blind (MjNh-5) was recorded on a slightly lower landform level on the west side of the ridge, overlooking Spyder Lake. This portion of the landform is fairly level and well vegetated, with some rocky and gravelly areas. The site occurs just inside the possible development area delineated on the project map and consequently, although no specific developments are planned there at the present time, if mining is expanded to include this area, this site may be in jeopardy.

An attempt was made to find a reported site south of the delineated development area. Several low level helicopter passes of the general vicinity failed to locate any site features; however, another site was observed north of the reported location. This multiple feature site (MjNh-6) is situated on a well vegetated, low level landform which slopes gently toward the eastern shore of Spyder Lake. Although it is outside the currently delineated development area, the site will require additional investigation if future development plans are in closer proximity. This site includes a cairn feature that is suggestive of a possible grave, but it could also represent a cache (see site discussion in Section 10.5) and its function can only be determined by test excavation.

A site had been reported on a high ridge on the west side of the southwestern arm of Spyder Lake (MjNh-2). It was briefly observed last year by Jean Bussey of Points West, and some preliminary recording was completed (Bussey 1995a). Because this initial viewing suggested that the site was fairly large, a revisit was included in the 1996 field plan, if time permitted. This year's visit confirmed that this site is indeed very large, consisting of a complex of stone circles and caches with substantial quantities of bone remains extending over a large area, indicating that it was a fairly important hunting location. There is also an inukshuk to mark the location. Because it was found to contain numerous features, and because it is not within currently planned development areas and time was limited, examination of this site was aimed at determining the extent of the site, identifying and recording the major features, and producing a sketch map. The site is in no danger of direct development impacts at the present time; however, indirect impacts from increased human activity in the area are possible. Further investigations will be necessary if the site is to be disturbed at some future time.

### 10.4.2 Winter Trail Route

According to the map supplied by BHP (Figure 10.1-1), the winter trail is proposed to run from Boston camp across Spyder Lake, up the northwest arm of Spyder Lake to the confluence with the Koignuk River (Figure 10.4-1), along the Koignuk River for about 7.5 km (Figure 10.4-2), veer to the east and pass over swampy areas and small lakes for about eight kilometres, join the Koignuk River again for approximately four kilometres, and then proceed south and east over a complex of swamps and lakes to the east-central portion of Doris Lake (Figures 10.4-3 and 10.4-4). After crossing to the north end of Doris Lake, the route follows the low ground along the stream draining Doris Lake to Roberts Bay. It will then cross the bay to reach possible port and barge locations on the west side of Roberts Bay.

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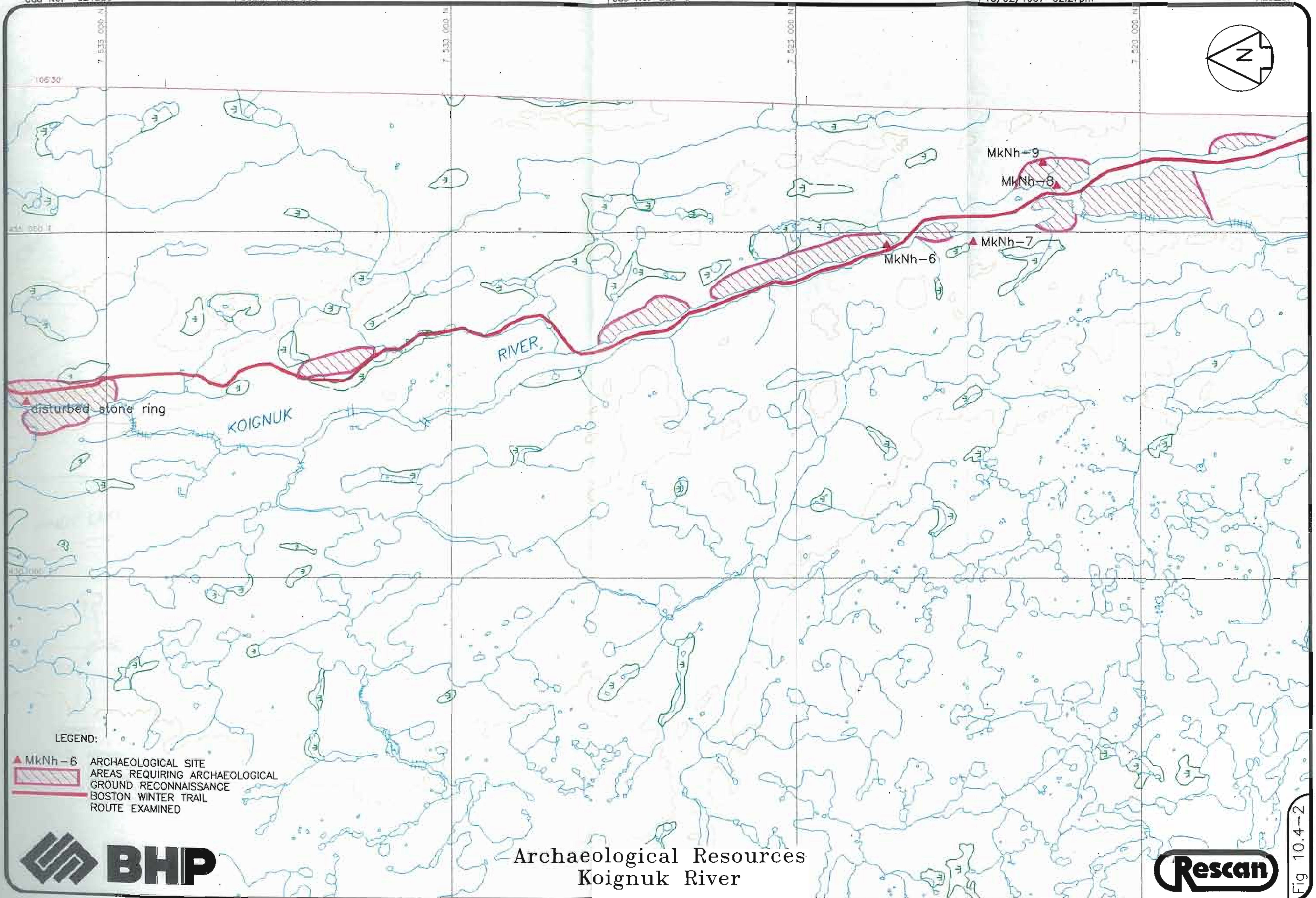

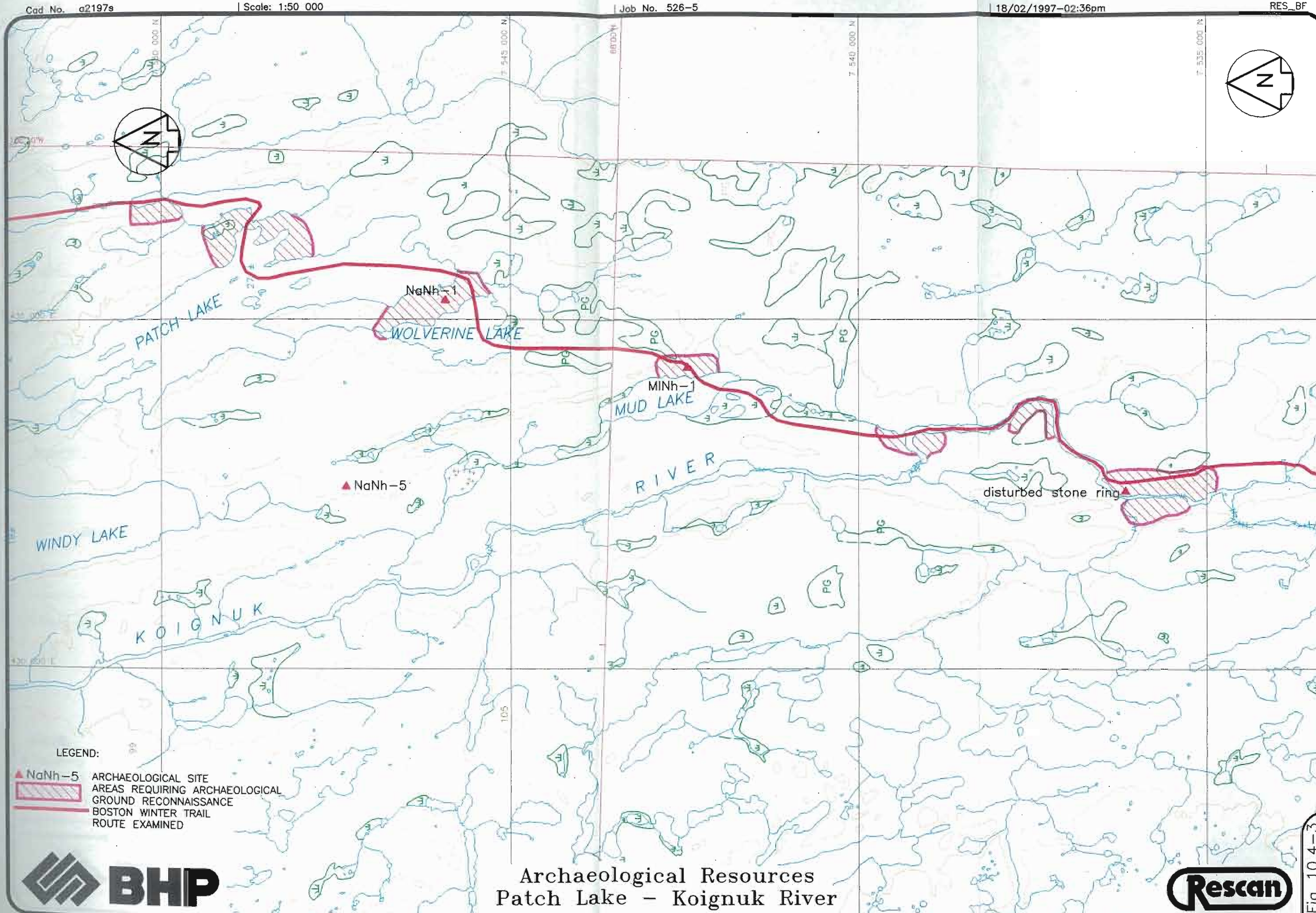


Archaeological Resources
Patch Lake – Koignuk River

Fig 10.4-3

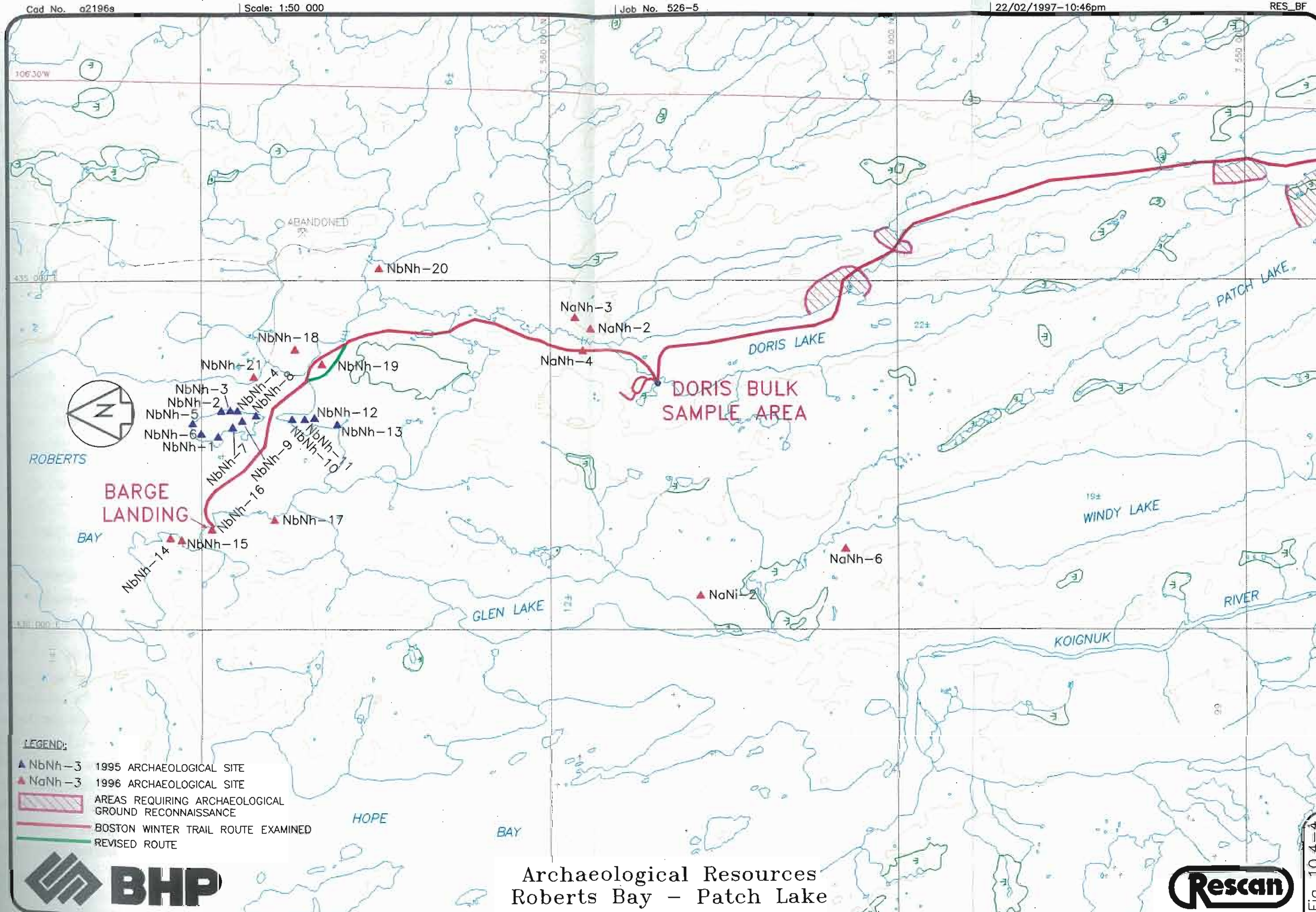


Fig. 10.4-4 Archaeological Resources Roberts Bay – Patch Lake

Two low level helicopter overflights were conducted of the proposed winter trail route from Boston to Doris Lake. At the request of BHP, the archaeological assessment of this section of the trail was preliminary because plans for the trail have not yet been finalized. The main intent of the archaeological assessment was to identify high potential areas along the route to assist in planning the trail so as to avoid as many of those areas as possible. In addition, sites that had been reported by the trail surveyors last year were to be recorded, as well as any sites that were observed during the overflight.

The section of the trail between Doris Lake and Roberts Bay was scheduled for use this winter; consequently, a more detailed assessment of this portion was conducted. The low level helicopter overflights were combined with foot traverses of all high potential landforms.

As it is presently planned, the trail will generally stay on low ground, following water courses and passing over swampy areas. Those portions of the proposed route on wet ground likely pose little direct threat to archaeological resources (although at least one site, OdPq-1, has been found in a bog on Victoria Island (McGhee 1972). The landforms with the highest archaeological potential are primarily the elevated ridges and knolls because these provide dry ground and good viewpoints. However, some lower landform levels are also known to contain sites, and therefore, such landforms with dry ground would have moderate potential for archaeological resources and would require some ground assessment. This is particularly the case in the vicinity of confluences, shallow narrows which would provide game crossings, or at good fishing locations.

Most of the sites observed and recorded during this inspection are situated on ridges or knolls adjacent to the waterbodies. Although the trail is not planned on those landforms, their close proximity presents the possibility of inadvertent or indirect impacts. All such landforms adjacent to the proposed trail route have been rated as having high archaeological potential and would require some ground reconnaissance. Low level landforms, although archaeological potential may not be as high, may be more prone to inadvertent or indirect impacts. Consequently, such landforms which provide dry ground adjacent to waterbodies, particularly confluences, would also require some form of field assessment. Low areas of particular concern along the proposed trail route are the southern point of land at the Spyder Lake narrows (Figure 10.4-1), both sides of the confluence between

Spyder Lake and the Koignuk River (Figure 10.4-2), and the land adjacent to the mouth of the creek at Roberts Bay (Figure 10.4-4). The first and third of these are to be crossed by the trail route, as currently proposed, and both those areas contain recorded archaeological sites.

This preliminary archaeological assessment resulted in the recording of ten new sites (MkNh-2-9, MlNh-1, and NaNh-1) adjacent to the trail route between Boston camp and Doris Lake. One isolated disturbed stone circle was observed from the air (Appendix 10-1, Photo 3) but not recorded due to shortage of time, degree of disturbance evident and the lack of other obvious features. This location should be examined on the ground during the detailed trail assessment. From Doris Lake to Roberts Bay, two sites were recorded immediately adjacent to or on the trail route (NaNh-4 and NbNh-19) and three more were recorded in the vicinity (NbNh-18, -20 and -21). The sites all consist of stone features including circles, caches, traps and blinds; most contain multiple features.

Three of the sites recorded are in direct conflict with the proposed trail route (MkNh-4, -5 and NbNh-19). Because NbNh-19 was on the portion of the trail planned for use this winter, steps were taken to re-route the trail to avoid the site features. A map and accompanying description were provided to BHP San Francisco, showing the location of the site and a suggested trail routing to avoid impacting the landform on which the site is situated. The suggested routing for the trail is over low, slightly wet ground which was examined and no cultural materials were observed.

The section of trail on which MkNh-4 and -5 occur is not finalized; routing the trail to avoid the sites is possible, but additional archaeological investigation is required once a final decision about the trail is made. It is particularly important to avoid site MkNh-4 since it contains a small biface and, thus, may represent the only Paleo-Eskimo site identified in the study area to date.

Because this phase of the archaeological work was preliminary, site locations and features were recorded and photographed, but detailed assessments were only conducted for those sites on the portion of the proposed trail north of Doris Lake. Assessments of other sites will be necessary when the remainder of the trail route has been finalized.

### 10.4.3 Doris Lake Project Area

Figure 10.1-1 shows a possible air strip, a camp location, and outlined a bulk sample area for the Doris Lake Project. One exploration area, known as Madrid, was identified as a possible area of interest during the field work and consequently, it was requested that it also be investigated.

The air strip location, on an esker with an undulating surface, in the interior portion of a high, large landform was crisscrossed by foot traverse. The ground surface was found to consist of wet, vegetated areas and tussocks, interspersed with small rocky outcrops and gravel patches. The frequent ground exposures were examined, but no cultural remains were observed.

An elevated landform between the air strip and the camp location was also examined. The camp is planned at the base of this high landform, and some impacts may be possible in the area between the air strip and the camp. Two sites, containing two features each, were recorded. Two rock traps occur near the western edge of the ridge, above the proposed camp (NaNh-2). Another rock trap and a stone circle are near the northern end of the landform (NaNh-3). Site NaNh-3 is less likely to be impacted since it is well north of the camp location, but NaNh-2 is within a direct line between the camp and the airstrip. Due to the steepness of the landform at that point, it is unlikely that such a direct route would be chosen. A much easier route of descent can be found at the south end of the landform. The vicinity of that possible route to the camp was also subjected to foot traverses and ground examination, but no cultural remains were observed.

The camp location and the vicinity of a small creek east of Doris Lake were also subjected to foot traverses (Figure 10.4-4). The camp is planned on a moderately sloping ground with low vegetation; examination of ground exposures revealed no cultural remains. Both sides of the eastern creek were examined, as was the northern end of the elevated landform south of the creek, and the shore of Doris Lake in this vicinity (Figure 10.4-4). The creek itself is in a valley between the two elevated landforms and the valley is characterized by wet ground and tall, thick vegetation. The archaeological potential of this site is judged to be low. The elevated landform surface was found to be similar to the one north of the creek examined previously, that is, rocky and undulating. Examination of exposures on the northern and western edges revealed no cultural remains. The west side of the landform provides a rocky descent to a gravelly, sparsely vegetated surface which slopes gently toward the eastern shore of Doris Lake. Inspection of the land adjacent to Doris Lake did not result in any cultural materials.

The bulk sample area, as delineated on the map (Figure 10.1-1), was subjected to foot traverses. The southern portion, where exploration drilling was ongoing during the archaeological investigations, is characterized by high, undulating rocky outcrops and ridges with occasional patches of sparse low vegetation. The rocks extend to the edge of the lake in much of this area. There has already been considerable disturbance due to the exploration activities, but the area has generally low archaeological potential. Examination of those portions considered to have the best potential for archaeological resources (albeit low) did not result in the discovery of any cultural materials.

The northern portion of the delineated area exhibited better archaeological potential. The land is less rocky, is covered by low vegetation, and gently slopes toward the lake and creek draining from the north end of the lake. A small knoll is situated on the west side of the creek, near some small rapids. Cultural remains were found on the knoll (NaNh-4), but ground examination of most of the remaining area did not reveal any cultural remains.

NaNh-4 is a multiple stone feature site which extends over most of the surface of the knoll. A cache or trap has already been disturbed by survey activities by having a stake driven through it and some of the rocks rearranged to support it. Not only is this knoll within the camp/bulk sample development area, but the winter trail route is proposed directly to the west of it. Due to the close proximity of the development areas and because the knoll is such an obvious feature on the landscape, there is considerable potential for continued impacts. Because of this potential for additional disturbance, a grooved wooden stick found on the surface was collected, a detailed scaled map of the site was completed and two subsurface tests were conducted, but these did not reveal any additional cultural materials. Refer to Section 10.5 for more details on NaNh-4.

The Madrid area was added to the field program at the request of BHP and the area of interest is sketched on the map (Figure 10.1-1). It is near the south end of Patch Lake, almost directly east of the present camp on Windy Lake. The areas immediately adjacent to the lakeshore were foot traversed. The land examined included low, wet areas, rocky ridges and knolls, and moderately sloped sections. The wet areas exhibit thick, relatively high vegetation, while much of the remainder has sparse vegetative cover. In general, the area would be rated as having low to moderate potential for archaeological resources. Ground examination did not result in the discovery of any cultural remains.

### 10.4.4 Roberts Bay Developments

Two possible port locations and two possible barge landings have been identified on the west side of Roberts Bay and are surrounded by a larger area of interest delineated on the map supplied by BHP (Figure 10.1-1). The port and barge landing locations were intensively covered by foot traverses, and the remaining area was viewed by low level helicopter as well as on the ground to provide virtually complete visual coverage of the area of interest.

The possible port locations are situated on high bedrock outcrops which extend into the ocean. Two sites were found within the northern port location, one (NbNh-14) on the highest level of the bedrock outcrop. This stone circle site contained an antler fragment carved into the shape of a sea gull adjacent to one of the circles. The artifact was collected because of the location within the proposed port and the close proximity of a barge landing which could be used this winter. The second site (NbNh-15) is an empty rock cache located within a crevasse below and south of NbNh-14. Both of these sites will require additional investigations if this port location is chosen.

The southern port location exhibits a more rocky, undulating surface, thus, providing lower archaeological potential. Thorough ground examination did not result in discovery of any archaeological remains.

Both barge landing locations are within gently sloping, horseshoe shaped bays between bedrock outcrops. They are characterized by wide expanses of gravel and grass covered, fairly level ground. Extensive ground inspection resulted in no cultural remains being observed on the level portions of the landings, but one stone circle site (NbNh-16) was found adjacent to the northern edge of the southern barge landing option. Because of the site's location within the rocks, together with the lack of obvious cultural remains, it is thought that the use of the area to the south as a barge landing is unlikely to result in direct impacts to the site.

The southern portion of the area of interest delineated on the Roberts Bay development map is a wide expanse of generally flat ground extending to the outlet of a small creek. It is partly vegetated, and the beach is gravelly. This area was covered by foot traverses, and visual ground inspection resulted in the discovery of an archaeological site (NbNh-17) containing two stone circles. At present, this site is a sufficient distance from currently proposed developments in this area to suggest little potential for direct impact.

### 10.4.5 Miscellaneous Reported Sites

Four additional rock feature sites (NaNh-5, -6, NbNh-21 and NaNi-2) were recorded. These localities had been reported by survey and geology crews working in the general area, both last year and this year. All occur in the general Doris Lake vicinity, from just south of Windy Lake to Roberts Bay. These sites were revisited because there was sufficient time remaining in the field schedule.

Although these sites are not in immediate danger of direct impacts, ongoing exploration activities in the general area could lead to direct or indirect impacts on archaeological sites it is important to record any sites found within the larger exploration area. In this manner, field crews could be made aware of the locations and of the importance of leaving all cultural remains where they are.

Two other reported sites were not relocated in spite of attempts to do so. One was a cache reported to be on the northern edge of the large unnamed lake on which NbNh-20 occurs, but intensive inspection of the rock outcrops in the area failed to reveal any cultural features. For the other reported site, only the location was noted, not the type of feature observed. Aerial inspection of the area did not reveal any obvious cultural features; there was an aggregation of very large boulders, but no pattern definitely suggesting cultural origin was apparent.

## 10.5 Archaeological Site Descriptions

This section provides a detailed description of each archaeological site visited during the 1996 field investigations for BHP's Hope Bay Belt Project. Photographs (Photos 1 to 57) and site maps (see Figures A through AB) can be found in Appendices 10-1 and 10-2.

### 10.5.1 Boston Project Area

MjNh-2 was initially recorded in 1995 following a brief inspection. Although it is not within the currently identified Boston development area, it is in relatively close proximity, and a revisit was planned in 1996, if time permitted, because it was suspected to be a fairly substantial site and a more complete assessment of the site extent was desired.

MjNh-2 is a large site on a high ridge, which represents the high point of land in this area, on the west side of the southwestern arm of Spyder Lake (Figure 10.4-2). The ridge is mainly exposed bedrock with much scattered rock and some patches of sparse vegetation and gravel. Site features recorded at MjNh-2 comprise at least four stone circles, five rock caches, and an *inukshuk* on the upper level of the ridge, extending over an area of about 150 m east-west (the full width of the ridge) by 300 m north-south (Figure A, Photos 4 and 5). More caches present on the lower slopes of the ridge. The circles occur on bedrock or gravel, average about three metres in diameter, and composed of angular rocks, fairly closely spaced (Photo 4). The caches average approximately one metre long by 80 to 90 cm wide, and are generally built in angular block outcrops, where only minor rearranging of rocks would be necessary to form the cache. One possible cache or hunting blind has rocks piled up to three courses on the west side. Several of the caches exhibit reddish discoloration, have some bone in the bottom and are up to 80 cm deep (Photo 5). The *inukshuk* is constructed of flat slabs and angular blocks piled up to a height of about 65 cm and is partially collapsed (Photo 6). There is much bone, mainly caribou, littering the entire site area, as well as some scattered shell. The site can be dated to the historic period on the basis of some scattered tin remains and a broken end of a wooden bow, although this location could also have been used earlier.

MjNh-3, a large stone ring, is found on a ridge which slopes gently down toward a narrow arm of Spyder Lake (Figure 10.4-1). It is situated about eight metres from the water's edge at a height of about four metres above the water. The ring is on a mostly gravel surface with some scattered patches of vegetation. The ring is composed of widely spaced rocks, approximately 5.5 m (E-W) by 4.5 m (N-S), with a smaller circle or horseshoe of rocks (about two metres in diameter) in the centre and an apparent opening facing south (Figure B, Photo 7). The surrounding ground provided excellent exposures which were thoroughly examined. Several tin cans were scattered about, and one wooden hide stretching stick was found beside the circle, suggesting a historic period use.

MjNh-4 is located on a knoll type landform on the west side of Trout Lake, about 20 m from the lake edge (Figure 10.4-1). It is covered with a thin layer of soil and sparse vegetation among a few exposed boulders. The site comprised (Figure C, Photo 8). of two possible abutting rings, one about two metres across and the second about one metre across. There is an apparent narrowing between the two rings that has no rocks; this may simply be the result of rock displacement, may imply some sort of interior spatial organization, or may suggest two adjoining structures (cf. Jenness 1922). The smaller ring seems more deeply buried which could suggest earlier use. All ground exposures were examined, but no cultural materials were found, consequently, period of use could not be ascertained. Soil and vegetal cover provides some potential for buried cultural remains.

MjNh-5 is located on a height of land between Spyder and Stickleback lakes (Figure 10.4-1). The site has thin soil and low vegetative cover with some gravel patches and scattered rocks. It consists of three stone circles, and a possible hunting blind (Figure D, Photos 9 and 10) extending over a distance of approximately 100 m. The central stone circle (about 2.5 m in diameter) and the possible hunting blind (about 1.8 m in diameter) are abutting and are constructed of large rocks, including one very large boulder, very close together (Photo 9). A small ring of rocks abuts the southeast corner of the stone circle. About ten metres southwest of these structures is a flat slab circle, about 3 x 1.5 m, with a possible partition through the centre (Figure D, Photo 10). This central slab partition is suggestive of Thule period stone circles. To the north, the third rock formation may be a large partial ring or a double rock alignment (about six metres north-south and four metres east-west) with a smaller (two metre diameter) central ring (Figure D). Approximately 3.5 m south of the possible hunting blind is a flat slab which has muskox hair and feathers under it and has some staining suggestive of burning. It is uncertain whether this represents a hearth/windbreak (see Damkjar 1994 for comment regarding placing a flat slab over a hearth area to keep it dry) or a small, specialized cache (materials possibly representing kindling). A thorough examination of surrounding ground exposures revealed no cultural material, but there is potential for buried remains.

MjNh-6 is located on a low, flat to gently sloping, well vegetated area adjacent to the eastern shore of the southwestern arm of Spyder Lake (Figure E). The site consists of a stone circle, a possible hunting blind and a cairn-type rock feature (Figure , Photos 11 and 12) spread over a distance of about 75 m. The stone circle is about three metres in diameter, and is composed of round rocks in an somewhat irregular arrangement, likely due to some displacement, and exhibits an apparent opening facing south. Just north of the circle is a rectangular depression (suggestive of human digging), approximately 2.2 x 1.65 m, containing a partially buried muskox skull. The hunting blind is situated about six metres west of the circle and comprises flat slabs, partially upright and in a slightly curved arrangement. About 50 m west (and approximately 50 m east of the lake edge) is the cairn feature composed of round rocks surrounding several centrally placed flat slabs, one of which has a tobacco tin under it. This feature is approximately two metres north-south by one metre east-west, and there are three partially buried muskox skulls in the vicinity. The function of this feature is presently unknown, but the size and configuration are suggestive of a possible grave, although it could also represent a cache. Stewart (1996) describes a definite grave of apparently similar construction. The presence of the tobacco tin and the squarish shape of the stone circle suggest that this site likely dates to the historic period. No other cultural material was observed but, due to the vegetative cover, there is good potential for buried cultural remains.

MkNh-1 is located on the northern tip of a point of land extending into Spyder Lake (Figure 10.4-1). It consists of one, possibly two, partial stone circle(s) and a possible exterior hearth (Figure F, Photo 13) covering about five metres. The back edge of the circle feature is about three metres from the edge of the landform, which drops about six metres to a rocky beach on the shore of the lake. It is constructed of relatively small rocks on exposed ground with some scattered rocks and sparse vegetation. It is approximately three metres in diameter with the southern side open; a short line of rocks inside the circle may represent a second circle or may simply be displaced rocks. Two metres directly south of the open side is a possible squarish hearth feature composed of four large rocks on an exposed bedrock slab (Photo 13, foreground). Several caribou bones are scattered about, but inspection of the surrounding ground surface revealed no other cultural material, however, there is some potential for buried cultural remains. Period of use could not be ascertained, although the possibly squarish shape of the stone circle is suggestive of the historic period.

An isolated artifact was found on the eastern edge of the ridge between Stickleback Lake and the southwestern arm of Spyder Lake, about 80 m southeast of MjNh-5 (this location will receive a Borden site designation number). It was found on a path leading from the lower wetlands around Stickleback Lake to the ridge top. It is a caribou antler fragment which has been notched at one end (Photo 14). The function of this item is presently unknown, in spite of some research in published sources (Mathiassen 1927, 1930; McGhee 1972; Rasmussen 1932; Stefansson 1919) and personal communications with other Arctic researchers; the only suggestion offered was a unique, stylized type of marrow extraction tool (Hickey 1996, pers. comm.). It is interesting to note that another such tool was found this season in a cache at site MkNh-3. The area around the isolated find was thoroughly examined and vegetation was scraped away, but no additional cultural material was found. Because it was not thought to be in any immediate danger of impact, the artifact was photographed, recorded and left *in situ*.

### 10.5.2 Winter Trail Route: Boston to Doris Lake

MkNh-2 consists of two stone circles on a bedrock slab near the eastern edge of a ridge on the east side of the northwestern arm of Spyder Lake (Figure 10.4-1). One ring, approximately three metres east-west by two metres north-south, is about 50 m from the southern end of the landform and is comprised of closely spaced, smaller rocks with some displacement and exhibits a possible opening facing west (Figure G, Photo 15). About six metres north is the second ring which is approximately 4 x 3 m in size. It consists of an outer circle of fairly widely spaced rocks, with an inner circle of more closely spaced, smaller rocks, about 3 x 2 m in size; both circles have the suggestion of an open side to the northeast, and a possible hearth/windbreak, about 0.75 m in diameter, occurs at the northern end of these rings. Examination of surrounding ground exposures revealed no cultural material, therefore, period of use could not be definitively established. There is some potential for buried cultural remains.

MkNh-3 is a large site consisting of three caches and five stone circles on a height of land between the two northern arms of Spyder Lake, covering a distance of about

100 m (Figure 10.4-1, Photo 16). Time was limited here because the helicopter was needed elsewhere and consequently, only a cursory examination and recording was possible. The circles are located on exposed bedrock or gravel patches and two of the caches are downslope from the upper landform (Figure  Photo 17 and 18). The stone circles all show some evidence of rock displacement. Beginning at the southern end of the upper portion of the landform, the first circle (about two metres north-south by 2.5 m east-west) is composed of round rocks and has a squarish rock feature (1.2 x 0.80 m) made largely of flat slabs in the northwest quadrant. This seems rather large for a hearth, and thus, it may represent some sort of interior division of space. The second circle is 2.5 x 2.5 m and seems to have an open side toward the southwest. It has a circle of rocks (about one metre in diameter) in the northwest corner; this, again, seems rather large for a hearth. The third circle, approximately two metres in diameter, shows the most disturbance of rocks and is composed of a relatively large number of smaller rocks. The fourth circle is fairly small (1.5 m north-south by one metre east-west), and is oval shaped and has the suggestion of openings at both ends of the oval, hence this could simply be the result of irregular rock arrangement or subsequent displacement (Photo 17). This circle could represent one of the smaller rock arrangements used for skin drying (Jenness 1922). The fifth circle is approximately two metres north-south by 2.5 m east-west and has an apparent opening to the southwest. One of the rocks in this circle has a caribou jaw under it.

The largest cache at this site (1.5 x 1.5 m) is about 30 m north of the smaller circle and is constructed within a frost heaved rock feature (Photo 18). It is shallower than the other two and contains several caribou bones, including a rib fragment with the same type of notching as that found on the antler isolated find, discussed above. The other two caches, both of which were empty, occur downslope, south of the rings. One is near the base of the landform and is approximately 125 x 65 x 60 cm deep. The other cache is 65 x 105 x ~ 60 cm deep. Caribou bone is scattered around the site, but no other cultural materials were observed. Although most of the site features occur on exposed bedrock or in rock outcrops, there is some potential for buried remains in limited vegetated patches. Period of use could not be determined.

MkNh-4 is situated on the southern point of land at the narrows between the main body of Spyder Lake and the northwest arm (Figure 10.4-1). The elevated portion of the landform containing features is approximately 25 m east-west x 35 m north-south. This site has a historic tent ring component and a probable prehistoric component (Figure I). The prehistoric component is near the southern edge of the elevated landform and is evidenced by a small, pressure flaked chert biface, a bone needle end, and a cut bone blade fragment (Photos 19, 20 and 21). The ground surface was thoroughly examined and two shovel tests were dug about six metres from the artifacts, but no additional cultural remains were uncovered, although soil and vegetative cover are sufficient to permit buried remains. The biface could suggest Arctic Small Tool Tradition (Paleo-Eskimo), since use of small stone tools was common during that period and much less common during subsequent cultural periods. If this does represent Paleo-Eskimo, the site could be as old as 3,500 years B.P. and would represent the oldest site identified in the study area to date.

The stone ring at MkNh-4 (Figure I, Photo 22) is located about eight metres north of the southern landform edge and consists of one large circle (six metres north-south by five metres east-west) of various sized, irregularly spaced rocks with an apparent opening toward the east, and a centrally located, smaller circle, about 2 m north-south x 1.5 m east-west. It is unclear whether these signify one or two occupations. A historic refuse area occurs downslope toward the east and contains glass and tin can remains; other remains scattered about the site include a carved wooden toy outboard motor, a saw blade fragment and a wooden stir stick.

MkNh-5 is located near the northern tip of the elevated portion of the landform on which MkNh-4 is situated, on the same point of land at the narrows of Spyder Lake (Figure 10.4-1). The site consists of two stone circles (Figure J, Photo 23) covering an area of about 15 $m^2$. The most northerly ring is composed of widely spaced rocks and is approximately five metres in diameter with a possible south facing opening. It has a partially buried half circle inside, the significance of which is unclear. A bone artifact, consisting of a flat round ended bone fragment with a central hole through which a bone dowel is inserted (Photo 24), was found adjacent to this ring. The second stone circle is composed of more closely positioned rocks and is about three metres in diameter. Inspection of the ground surface revealed no additional cultural materials. Site age is undetermined, but the more deeply buried rocks could suggest some antiquity.

The landform on which both sites MkNh-4 and MkNh-5 are located is thinly covered by soil and vegetation, with scattered gravel patches. This, together with the landform's prime location at the narrows (a location presently known as an excellent fishing spot) and the presence of the stone tool, would provide good potential for additional, possibly buried, cultural materials of some significance in defining the older aspects of the culture history of the area.

MkNh-6 is situated on a high ridge on the east side of the Koignuk River (Figure 10.4-2) and covers an area of about 50 x 25 m. It consists of four stone circles, all characterized by solid walls of large rocks; two of these circles have walls at least two courses of rocks high (Figure K, Photos 25 and 26). The most southerly circle is approximately 3.5 m north-south x 2 m east-west and is constructed of a combination of very large rocks, smaller rocks and flat slabs piled on top of each other. This circle it also has two lines of partially buried flat slabs crossing the circle, and cutting it into approximate thirds (Figure K). The second stone circle is about 2.5 m north-south x 2 m east-west and is also characterized by a solid wall of rocks, including some very large, apparently *in situ* rocks. Both these rings show evidence of rocks toppled off the wall. The third feature is a possible stone circle that is composed of a series of large rocks, a single course in height, with a possible attached smaller circle. The former is about two metres in diameter, while the latter is approximately 1.5 m in diameter. The final stone circle is about 1.8 m in diameter and is composed of large, partially buried rocks which form a fairly solid ring. An examination of surficial ground exposures did not reveal any cultural materials; however, there is some soil and vegetation cover, thus, there is good potential for buried remains. The heavily constructed walls and use of huge boulders are reminiscent of classic Thule characteristics and the partitioning is also suggestive of Thule period occupation. Consequently, this site may date to 800 years B.P.

MkNh-7 is a single stone circle on a bedrock slab on the west side of the Koignuk River (Figure 10.4-2). Due to a shortage of helicopter time, the ring was photographed from the air (Photo 27) and its location recorded. Ground examination was not conducted, but no other features were observed from the air. This site should be examined on the ground once the trail route is finalized.

MkNh-8 is a rock trap located on the east side of the confluence of the Koignuk River and the northwest arm of Spyder Lake (Figure 10.4-2). It is situated on a landform that is about 100 m east of the Koignuk River and is elevated about five metres above the river. The trap consists of a pile of rocks about 1.2 m long x 1.2 m wide and the opening extends the complete length of the trap and is about 20 cm wide and 30 cm high (Figure L). No other cultural remains or features were observed in the immediate vicinity, and age could not be determined.

MkNh-9 occurs on another height of land about 250 m east of the Koignuk River and 150 m northeast of the landform containing MkNh-8 (Figure 10.4-2). This is a stone circle, approximately 3 m north-south x 2.5 m east-west, and composed of evenly spaced, medium sized rocks on a gravelly surface (Figure M, Photo 28). There is a possible opening at the southern end and, just inside this opening, is a small square formation of flat slabs (central space about 30 x 30 cm), probably serving as a hearth/windbreak (see left side of Photo 28). In the northeast quadrant of the ring is an approximately 0.5 m square area of mossy growth indicating some enhanced organic base, probably resulting from some human related deposition. No cultural materials were observed, but vegetal cover is sufficient to permit subsurface remains. Period of use could not be ascertained.

MlNh-1 occurs on an elevated bedrock knoll, about 75 x 60 m in size, on the eastern shore of a lake known locally as Mud Lake (Figure 10.4-3). The site is approximately 40 m from the lakeshore and about 40 m above the water. Features consists of two squarish stone alignments on a smooth bedrock surface and two boat support structures located on a gravel surface (Figure N, Photos 29 and 30). The stone alignments are most likely canvas tent supports (Akana 1996, pers. comm.), consequently, the site probably dates to the historic period. The square stone features have one open side, and both are constructed of flat slabs. The southern one is about two metres square and the open side faces southwest. The other one is about 2.5 m across and the open side faces northeast. The latter has a central rock formation, about one metre in size, possibly signifying a hearth. The different facing directions may indicate different times of use. The boat supports are each constructed of four large boulders positioned in groups of two, about two metres apart (Photo 30). Their functions are interpreted on the basis of comments made by a local Elder (Akana 1996, pers. comm; see NaNh-3 discussion, Section 10.4). There was some caribou bone scattered around the site, and a bird bone was found in the northern stone ring, but no other cultural materials were observed and there is limited potential for buried remains.

NaNh-1 is located on a large, irregular bedrock ridge between two lakes known locally as Wolverine and Patch Lakes (Figure 10.4-3). Site features occur at about 25 m above the lake and cover an area close to 100 m long north-south. The site includes a large stone circle, two stone features suggestive of hunting blinds, a stone semi-circle abutting a rock face, and a rock cache (Figure O, Photos 31 and 32). The stone circle is about four metres east-west by three metres north-south and is constructed of medium sized rocks that are partially buried and re-vegetated (Photo 31). There is a central pile of rocks which may signify a hearth. About 55 m north of the ring is a hunting blind composed of large flat slabs propped up, approximately two metres across and facing west (Photo 32). Another, similar type of feature occurs two metres west, and is constructed of four large rocks encompassing an area about 1.5 m across. There is a muskox skull approximately six metres southwest of the hunting blind. About nine metres north of the hunting blind is a rock cache, approximately 142 x 92 cm in size, and constructed of several large slab rocks with numerous smaller pieces. The cache has caribou bone inside and more is scattered around the vicinity. Approximately 35 m west of the hunting blind is a half circle of rocks with a grassy interior surface, about 1.5 m across, abutting against a rock face which is about 0.75 m high; this could represent a possible shelter or a temporary cache. A thorough surficial inspection did not reveal any artifactual materials, but there are some areas of soil and vegetation which could provide opportunities for buried remains. Occupation period of the site is presently unknown, but the degree of vegetation growth in the stone circle could suggest some antiquity.

### 10.5.3 Doris Lake Project Area

NaNh-2 is located near the western edge of a high rocky ridge on the east side of the stream at the north end of Doris Lake (Figure 10.4-4). It consists of two rock traps approximately 24 m apart, constructed largely of angular blocks and flat slabs on rocky surfaces (Figure P, Photos 33). The southern trap is about ten metres from the edge of the ridge, is approximately 1.4 x 1 m in exterior dimensions, and has an interior opening that is 70 cm long, 20 cm wide and 14 cm high. The second trap is approximately 22 m from the edge of the ridge, has exterior dimensions of about 1.2 x 2.2 m, and the opening is 160 cm long, 33 cm wide and 33 cm high (Photo 34). Openings in both traps face south. No bone or other cultural evidence was observed in the vicinity of either trap, and due to the rocky surface, there is little potential for buried cultural materials. Site age could not be ascertained.

NaNh-3 is located near the northwestern edge of the same high landform on which NaNh-2 occurs, approximately 100 m to the northeast (Figure 10.4-4). It consists of a rock trap and a possible double stone circle (Figure P, Photos 35 and 36). The rock trap is constructed of angular blocks on gently sloping, undulating ground, and the west facing opening is approximately 140 cm long, 30 cm wide and 40 cm high. A possible double stone circle is about 60 m south of the trap and is composed of partially buried, medium sized rocks on level ground. It is covered by a thin layer of soil and vegetation. The larger circle is approximately 3 m north-south x 1.8 m east-west and a smaller circle, about 1.5 m north-south by 1 m east-west, abuts the south-east end of the larger circle. Both circles exhibit some rock displacement. A thorough ground inspection revealed no cultural materials, but there is potential for buried remains. Period of use could not be determined, but the degree of soil and vegetative cover around the circle could suggest some age.

NaNh-4 is situated on a small knoll on the west side of the creek draining Doris Lake (Figure 10.4-4). The level upper surface of the knoll is largely exposed bedrock and is about 30 m north-south x 25 m east-west; a lower level on the east side has some vegetative cover. The site consists of a stone circle and a cache or trap on the upper surface, as well as a half circle of stones and a hearth against a rock face on a small, lower ledge on the northeast side of the landform, directly opposite some small rapids on the creek (Figure R, Photos 37 and 38). The stone circle is positioned on a bedrock slab in the northwest quadrant of the upper knoll area, and it is about 4 m north-south x 3.5 m east-west in size. Approximately five metres south of the ring is a rock pile that was a cache or trap, but it has been largely disturbed by survey activities - a survey stake was placed within it and the rocks rearranged to support the stake (Photo 37). At the northeastern edge of the landform is a narrow shelf exhibiting lush vegetation growth, and a semi-circle of stones that abuts the one metre high rock face. There is an apparent opening to the north, and at that point, just inside the semi-circle, a small stick (about 13 cm long) with a groove at one end was found (Photo 39). Less than one metre north of the opening is a small slab lined hearth (approximately 50 x 40 cm) with evidence of burning and some burned bone fragments (Photo 40).

Because of the proximity of this landform to ongoing exploration activities, a detailed scaled map of the features was drawn and two subsurface tests were completed. The upper surface of the landform was thoroughly examined, but no cultural materials were found. One subsurface test was conducted inside the disturbed rock pile. Two central rocks were removed and the five to eight centimetres thick moss accumulation was scraped away to reveal a bed of small shale pieces. Some bits of bone were scattered about, but no cultural materials were found. Our Inuit assistant, John Franklin, mentioned that people might cover cached items with moss, then pile rocks on top; it did appear that the moss within the rock feature was significantly thicker than was apparent on the surrounding surface. Another subsurface, 40 x 40 cm square shovel test was conducted near the centre of the semi-circle stone feature, against the rock face. A ten centimetre thick layer of moss was removed to reveal a shale bed. No cultural remains were found within the test, but due to the vegetation cover, there is a possibility of buried remains. The heavy vegetation growth within and around this feature indicates some enhanced organic base, suggesting a cache, or shelter function (cf. Stewart 1994). Age could not be ascertained, but degree of vegetal cover of the semi-circle feature could suggest some age.

NaNh-5 was found by an exploration survey crew on the last day of archaeological investigation and consequently, the site was recorded that evening, and light conditions were not optimal for photography. It is a large site (covering an area approximately 100 m north-south x 50 m east-west) on a high ridge south of Windy Lake (Figure 10.4-4). The site comprises three stone circles, a possible hunting blind/shelter, possible signal rocks, and a small disturbed stone ring (Figure S). Bone fragments litter the entire site area. The two northerly circles are constructed of angular blocks on exposed bedrock slabs, and both have a small formation of upright slab rocks just inside an apparent entrance, which probably served as hearths/windbreaks. One of these circles, approximately 2.5 m in diameter, has two lines of rocks extending south from the body of the circle, creating the suggestion of an entry tunnel (Photo 41). This could indicate use during Thule times, when entry tunnels were most commonly used. The hearth/windbreak feature in this circle has evidence of burning. The second circle is about 4 m north-south x 3 m east-west and has an apparent opening facing east. Scattered around the vicinity are quantities of bone fragments and bits of cut/notched wood. About one metre north of this circle was a short drop in the landform that results in a rock face about 0.5 m in height; a possible hunting blind/shelter (1 x 1.3 m) was built against this rock face. It is facing northwest, has a grassy interior and was constructed by propping up several large flat slabs and angular rocks (Photo 42). This is interpreted to be a hunting blind because of the rocks used and the construction method. Jenness (1922) describes "a semi-circular stone shelter on top of a ridge near the camp which would command a wide view over the surrounding country; every day one or other of us would spend several hours there watching for caribou."

The third, southern circle at NaNh-5 is partially buried in a grassy area near the eastern edge of the landform. It is about 3.5 m north-south x 4 m east-west and has an apparent opening facing southeast. About five metres east of this circle, at the edge of the landform, are two upright rocks stuck in a crevasse, suggestive of signal rocks (Photo 43). The rocks are about 34 cm in height and would be very obvious when viewed from the east. Approximately three metres north of the signal rocks is a small, partially disturbed group of rocks which may have been a circle about 1.4 x 0.9 m in size; the small size of this features suggests that it could represent a hide drying structure (cf. Jenness 1922). A thorough examination of the ground surface of the entire site revealed no additional surficial cultural materials, but some areas of soil and vegetative cover provide opportunities for buried remains.

NaNh-6 is located on a grassy flat at the base of a small bedrock knoll, west of the river draining out of the north end of Windy Lake (Figure 10.4-4). It is a squarish rock circle, about three metres north-south by four metres east-west, with an apparent open end to the north (Figure T, Photo 44). Near the back, the southern wall of the structure, is a small squarish formation of slabs which is suggestive of a hearth/windbreak. No surficial cultural remains were observed, but the grassy surface provides potential for buried material. The square shape of the stone ring suggests a historic age for this site.

NaNi-2 is situated on a large, flat topped, grass covered knoll which is about 200 m east of a large lake known locally as Glen Lake (Figure 10.4-4). The site features extend over an area about 80 m north-south and consist of two stone circles, two possible hunting blinds and a possible cache (Figure U, Photo 45). Both stone circles are squarish with three sides of rocks and one open end. One is about 3 m north-south x 2.5 m east-west and has an open side facing northwest.

The other is about 1.5 $m^2$ with the open side facing east. The hunting blinds are ovals of large rocks, built in small depressions using some *in situ* boulders. One of them has huge flat slabs propped up on smaller rocks; inside dimensions are 2.3 m north-south x 1 m east-west (Photo 46). The other is located downslope; it is backed by large boulders, has flat slabs on the view side, and has inside dimensions of 1.6 m north-south x 1.4 m east-west. The possible cache is situated about half-way down the southern side of the knoll and is a 1.2 x 0.8 m sized hole among huge flat slabs, some of which have obviously been moved. Surficial inspection revealed no cultural materials, but the grass cover provides some potential for buried remains. The square shape of the rings suggests a historic period occupation.

### 10.5.4 Roberts Bay

NbNh-14 is located on a high bedrock promontory on the west side of Roberts Bay (Figure 10.4-4). It consists of two stone circles placed on shale gravel beds (Figure V, Photo 47). Some of the rocks seem somewhat displaced. One circle is about three metres in diameter, while the other is approximately two metres in diameter. A concentration of shell fragments (whether of natural or cultural origin is unclear) occurs south of the eastern ring, and a carved antler artifact was found southwest of the western ring (Photo 48). Some scattered bone was also noted on the site, but no other cultural remains were observed. Soil deposition is limited, consequently, potential for buried remains is low. Site age could not be determined. Following discussions with BHP camp manager, it was decided to collect the antler artifact, given that use of the general area as a barge landing may increase the chances of someone wandering among the rocks and finding the artifact (Flood 1996, pers. comm.).

NbNh-15 is located in a bedrock outcrop below and just south of NbNh-14 (Figure 10.4-4). It is a rock cache in a crevasse formed of fairly large rocks (Photo 49). The dimensions of the interior area are 1.2 x 1 x .5 m deep. The cache was empty, thus, age could not be ascertained.

NbNh-16 is located on a sheltered gravelly beach at the base of a high bedrock outcrop (Figure 10.4-4) approximately 30 m from the western shore of Roberts Bay. The site consists of what appears to be a double stone circle; one circle is about 3.5 m east-west x 2.5 m north-south, and abutting the south side is another circle about 2 m east-west x 1.8 m north-south (Figure W, Photo 50). Approximately centrally located in the larger circle is a small square of flat slab rocks which may have functioned as a hearth/windbreak; some apparently burned twigs were noted within the square. Thorough inspection of the surrounding ground revealed no cultural materials, and there is little potential for buried remains. The time period of use could not be determined.

NbNh-17 is located on a large, flat area on the west side of Roberts Bay, some distance south of the high bedrock outcrops on which the above sites occur (Figure 10.4-4). Two stone circles are situated about 75 m from the water's edge, on a pebbly beach with some sparsely vegetated patches. Both rings are constructed from well spaced, small rocks, and both have interior, squarish rock features made of flat slabs, suggestive of hearths/windbreaks (Figure X, Photo 51). The northerly ring is approximately 3 m north-south x 2 m east-west, and the interior rock feature is 60 x 48 cm; the latter is located near the northern wall of the ring. About nine metres southwest is the second circle, which is approximately three metres in diameter; the interior hearth/windbreak feature is about 90 x 30 cm and is placed near the southern wall, just inside a gap in the wall which could represent an opening. Surficial examination of the area revealed a piece of wood about five centimetres long, with a small half circle in one edge, lying within the northern ring could represent a piece of a wooden handle. This may suggest a historic age for this site. There is some potential for additional cultural remains in the vegetated patches.

NbNh-18 is located on the east shoreline of Roberts Bay, immediately north of the mouth of the creek that drains Doris Lake (Figure 10.4-4). The area is generally a flat gravel beach with some sparse vegetative cover back from the shoreline, interspersed by small, low bedrock knolls and rock outcrops. The surface of the bedrock is undulating and there is some vegetation growth in the shallow depressions. The site consists of three stone circles and a cache, on two bedrock outcrops (Figure Y). The remains of a very recent camp (occupied on the day of the overflight with the Elders), signified by a rectangular stone ring and assorted modern garbage, are located adjacent to the creek mouth.

The cache and one stone circle are situated on a bedrock knoll about 50 m from the shore of Robert's Bay and the recent camp is on the flat immediately to the south of this knoll. The cache (1 m north-south x 1.4 m east-west) is a simple pile of rocks on a fairly flat portion of the knoll. The stone circle (about 2.5 m north-south and 1.5 m east-west) is on a flat slab of bedrock, and the south half is constructed of abutting rocks, while the north half exhibits some spacing between rocks; a considerable amount of lichen growth is evident on the rocks. There is some scattered seal bone in the vicinity. The other two stone circles are situated on a lower rock outcrop about 150 m east. The more easterly ring is approximately 3 m north-south x 1.5 m east-west, is constructed of large abutting rocks with some lichen growth, and there is some evidence of disturbance of the southern rocks. Approximately three metres west, the second ring is about 2.5 m in diameter and is constructed of large rocks with some spacing between. The east side includes a section of protruding bedrock (Photo 52). A nearby rock outcrop has two small depressions containing shell remains, but it could not be determined if these were natural or cultural accumulations. No definite cultural remains were observed, but the vegetal cover presents some potential for buried materials. Site age could not be definitively established, although the degree of lichen growth on the rocks could suggest some antiquity; in addition, the use of large, closely spaced or abutting boulders in oval rings could suggest a Thule time period (up to 800 years B.P.)

NbNh-19 is a large site located on the south side of the creek draining Doris Lake (Figure 10.4-4). Features extend over an estimated area of 150 $m^2$. The site is situated mostly on a large, low bedrock knoll, the north end of which begins about 40 m from the creek; the landform is about 1.5 m above sea level. There are four stone circles on the bedrock knoll and two, possibly three, on the flat just to the west of the knoll (Figure Z). The circles on the elevated landform are round, while those on the flat are square (with one exception), possibly suggesting different periods of use. The one stone circle on the flat which is oval is partially buried, suggesting some antiquity. The circles range from about 1.5 m in diameter to 6 x 5 m in size (Photo 53). On the flat, a possible small circle could represent a skin drying structure. On the bedrock knoll, there is a small square hearth (about 50 cm across) constructed of flat blocks of stone, a structure of propped and stacked rocks (Photo 54) which may represent a meat or fish drying rack (Franklin 1996, pers. comm.; see also photos in de Coccola and King 1986 and Jenness 1922) and a trap. The interior measurements of the trap are approximately 90 x 30 cm. The site features are generally situated on gravel, but there are some patches of vegetated ground, providing potential for buried remains. Considerable quantities of bone and historic debris are scattered about, including tin (some modified), canvas, sawed bone and wood. Of particular note were a wooden stick smoothed and thinned at one end for marrow extraction and one leather mitten. These artifacts and the square stone rings indicate historic use of the area, but the presence of circular stone rings may suggest use during earlier times as well.

NbNh-20 is located near a stream outlet on the west side of a large lake known locally as Tail Lake, north of Doris Lake (Figure 10.4-4). It consists of one, and possibly two, stone circles on top of a high bedrock knoll, another ring at the southern base of the knoll and a fourth further south on the flat bordering the lake (Figure 10.4-4). One ring on the upper landform is approximately two metres in diameter and is composed of large, abutting rocks on a shale like surface with some vegetation and the interior is slightly depressed (Photo 55). About one metre east of this circle is a squarish rock arrangement on an exposed bedrock surface with well spaced rocks on three sides and an open side toward the west. This could represent a more recent tent ring. There is some scattered bone in the vicinity of these features.

The stone circle at the base of the knoll is approximately 1 m north-south x 1.5 m east-west and is constructed of abutting large rocks (Photo 56). It is on an undulating, well vegetated bench which is about six metres wide. There is some scattered caribou bone around the ring, and the vegetation cover presents the possibility for buried cultural remains. The small size of this ring could suggest that this may have served as a cache, and the degree of vegetation growth provides some support for such an interpretation.

The final stone circle is about 55 m southeast of the base of the knoll. It is situated on gravelly ground that slopes gently toward the lake. It is about 2.5 m north-south x 3 m east-west; a short distance east is an oil drum rim which may have served as a fireplace, and there is evidence of wooden tent pegs and scattered tin cans. NbNh-20 provides definite evidence of use during historic times, but it may also have seen earlier use, as suggested by the ring with large, abutting rocks.

NbNh-21 is on a rocky outcrop on the east side of Roberts Bay (Figure 10.4-4). The maximum height of the outcrop is about 20 m above sea level at the south end, and it slopes down gently toward the north, forming several slightly different levels of land. The site consists of two stone features on the top of the landform and a possible cache or trap on the southwest side, near the base of the landform (Figure AB, Photo 57) The two stone features occur in a gravelly area with some surrounding scattered vegetation patches. One is approximately 2 m north-south x 1.5 m east-west; about 3.5 m south is a three-sided stone alignment (~ 1.8 x 1 m) with an open side facing northeast. There is another possible ring about 100 m north of these, and in between is much scattered caribou, seal and bird bone and some historic debris including tin cans, a fragment of a leg hold trap, a wooden handle fragment and rubber boots. In addition, the remains of an abandoned boat are located on the beach. The cache or trap is a pile of rocks, approximately 1.4 x 0.7 m, showing signs of rock displacement to expose the centre. This site was used during historic times, and there is some potential for buried cultural materials.

### 10.5.5 Site Summary and Preliminary Analysis

Almost all of the 30 archaeological sites for which information was recorded during the 1996 field investigations for the Hope Bay Belt Project have multiple features (Table 10.5-1); consequently, some extend over fairly large areas. Total site size ranges from about three metres for some of the single feature sites up to 300 m for the largest sites.

Stone circles range in shape from round to oval to square; considerable variation in the size of individual rings is evident, from less than one metre in diameter to about six metres. Some of the very small ones may represent skin drying structures, as observed by Jenness (1922). Some double rings were also recorded which may indicate adjoining residences, such as shown by Jenness (1922), or possible storage areas, in the case of the smaller attached circles.

**Table 10.5-1**
**Summary of Site Features**

| Features | Site |
|---|---|
| Single stone circle | MjNh-3, MjNh-6, MkNh-4, MkNh-7, MkNh-9, NaNh-1, NaNh-4, NaNh-6 |
| Double stone circle | MjNh-4, NaNh-3, NbNh-16 |
| Multiple stone circles | MjNh-2, MjNh-5, MkNh-1, MkNh-2, MkNh-3, MkNh-5, MkNh-6, MlNh-1, NaNh-5, NaNi-2, NbNh-14, NbNh-17, NbNh-18, NbNh-19, NbNh-20, NbNh-21 |
| Hearth/windbreak | MjNh-3, MjNh-5, MkNh-1, MkNh-2, MkNh-3, MkNh-9, MlNh-1, NaNh-4, NaNh-5, NaNh-6, NbNh-16, NbNh-17, NbNh-19 |
| Shelter/cache | NaNh-1, NaNh-4 |
| Hunting blind | MjNh-5, MjNh-6, NaNh-1, NaNh-5, NaNi-2 |
| Cache | MjNh-2, MkNh-3, NaNh-1, NaNh-4, NaNi-2, NbNh-5, NbNh-18, NbNh-20, NbNh-21 |
| Cairn | MjNh-6 |
| Rock trap | MkNh-8, NaNh-2, NaNh-3, NbNh-19 |
| Signal rocks | MjNh-2, NaNh-5 |
| Kayak supports | MlNh-1 |
| Meat drying support | NbNh-19 |
| Artifacts | MjNh-2, MjNh-3, MjNh-6, MkNh-4, MkNh-5, NaNh-4, NaNh-5, NbNh-14, NbNh-17, NbNh-19, NbNh-20, NbNh-21 |
| Animal bones | MjNh-2, MjNh-6, MkNh-1, MkNh-3, MlNh-1, NaNh-1, NaNh-5, NbNh-14, NbNh-18, NbNh-19, NbNh-20, NbNh-21 |

Several interesting variations in construction of the stone circles are evident, some of which allow preliminary suggestions concerning possible age. The square configurations are interpreted to represent historic use, on the assumption that the use of square canvas tents beginning in the 1920s resulted in this change in shape (Akana 1996, pers. comm.). Such rings were found at 12 sites which have, therefore, been tentatively assigned to the historic period (Table 10.5-2). Some of these sites also contain round or oval rings, suggesting possible use during other times as well. Five sites contain stone circles with structural evidence suggestive of possible Thule construction, that is, round to oval rings with heavily built walls, partitions, and/or entry tunnels (Table 10.5-2). It must be emphasized that these are preliminary interpretations, based on surficial structural evidence only, which need to be investigated through excavation to recover additional structural details and, possibly, diagnostic artifacts.

Some of the stone circles have apparent openings; although these openings may

**Table 10.5-2**
**Possible Time Periods Represented**

| Time Period | Site |
|---|---|
| Paleo-Eskimo | MkNh-4 |
| Thule | MjNh-5, MkNh-6, NaNh-5, NbNh-18, NbNh-20 |
| Historic | MjNh-2, MjNh-3, MjNh-6, MkNh-4, MlNh-1, NaNh-6, NaNi-2, NbNh-17, NbNh-18, NbNh-19, NbNh-20, NbNh-21 |
| Undetermined | NbNh-14, NbNh-15, NbNh-16, NbNh-19, NbNh-20 |

have been caused by rock displacement, most are assumed to represent doorways in the absence of obvious evidence of disturbance. A tabulation of facing directions of these openings, shown below, indicates that south facing openings are dominant, and when south, southwest and southeast facing directions are grouped, they by far out number those with a northern orientation (that is, 16 to six).

| S | SW | SE | W | E | N | NW | NE |
|---|---|---|---|---|---|---|---|
| 7 | 6 | 3 | 4 | 3 | 2 | 2 | 2 |

A preliminary explanation for the southerly directional dominance could relate to wind direction. Since prevailing winds are most often northerly or westerly, it seems logical to face a doorway away from the wind, particularly in this area where winds are often very strong. This suggestion is supported by a perusal of the locational situations for the northerly facing rings which indicates that they are generally situated at the base of knolls, in the lee of elevated landforms or are facing lake or river views, probably for game spotting (possibly on days when winds were light or bugs were fierce). Another possible explanation is that southerly facing doorways may permit more warmth within the dwelling from the sun during the period of the day when it is at its warmest.

A number of the stone circles have associated hearth/windbreaks, most characterized by upright, flat slabs. The majority of the slab-type hearths/windbreaks (eight) were located just inside the rings, with only a few situated a short distance outside (two definite, two possible). This type of structure is common in sites found in this region and is illustrated by Jenness (1922), however, other studies have found that these types of hearths/windbreaks more commonly occur outside the rings (cf. Morrison 1978; Damkjar 1994). Jenness (1922) has noted, “In fine weather cooking takes place out of doors, but whenever it is cold or windy a hearth is made just inside the doorway." Whether the predominance of these features inside the circles apparent in this study represents a regional, functional or temporal difference (or is weather related) is unclear at this time, but it is certainly worthy of further consideration. Two or three exterior hearths/windbreaks have a flat slab placed on top of the central area (NaNh-4, NbNh-19, and possibly MjNh-5) and this was apparently meant to keep the centre dry for future use (Damkjar 1994). Several stone circles contain small circles or semi-circles of round rocks which were placed centrally within the rings. The determination as to whether these features are hearths requires further investigation, but they have been provisionally identified as such.

Three of the multiple feature sites include half circles of rocks placed against a rock face. Two of these (NaNh-1 and NaNh-4) could represent expedient shelters or caches. The third (NaNh-5) is almost certainly a hunting blind/shelter (see site discussion in Section 10.5-3). A hunting blind function is unlikely for the other two similar features because the rocks used are not of sufficient height. At site NaNh-4, the cache suggestion is supported by enhanced vegetation growth, although the shelter possibility is supported by the close proximity of a hearth. The similar feature at NaNh-1 does not contain such obvious enhanced vegetative growth; it simply has an interior of low grass cover, consequently, neither suggested function is supported or eliminated. Some excavation may assist in determining functions of these features.

All the caches found this season were opened and mostly empty (a few bones were found in some). Some exhibited discoloration of the bottom rocks. At least one (NaNh-4) seemed to have an interior mossy layer thicker than surrounding areas. It is possible that this (and perhaps the few bones found in other caches) represents a base layer on which meat was placed, or a moss covering over the meat (Franklin 1996, pers. comm.; Damkjar 1994).

Several interesting stone features were recorded this season. One site (MlNh-1) contains kayak support structures similar to those identified by the Elders at NbNh-3 (see also Stewart 1994). Site NbNh-19 has a boulder alignment identified by Franklin as a possible meat or fish drying rack; similar structures are shown in use in de Coccola and King (1986) and Jenness (1922). Several sites exhibited possible marker stones or signal rocks, generally not large or elaborate enough to be considered true *inukshuit*, with one exception (MjNh-2 contains a possible partially collapsed one). The hunting blinds recorded this year were generally of a fairly standard construction, that is, a semi-circular arrangement of large boulders or flat slabs propped upright. Similar structures have been recorded by several ethnographers (*e.g.*, Jenness 1922).

Most of the sites have little associated surficial artifact material; only a limited amount of subsurface testing was conducted, and there is some potential for buried cultural material at most sites because of soil and vegetation cover. However, “sterile” sites (sites with no artifacts) are well documented in this area (cf. Morrison 1978) and it is possible that cultural material will not be found in association with some sites. Not many artifacts are expected in most sites because this area it is thought to have been exploited largely during the summer months (see Section 10.3.3), when people were at their most mobile following caribou or travelling in search of other game. Consequently, a particular camp spot may have been occupied only for a night or two, thereby not resulting in much cultural material accumulating. In addition, because of the high degree of mobility, people would probably choose to only carry necessities with them, and may have left many items behind at wintering locations. This practice has been ethnographically documented (*e.g*., Jenness 1922), and it is possible that prehistoric residents followed a similar practice. However, this is a theory that needs to be tested by excavation, and some of the larger sites with soil and vegetative cover are likely to produce some artifacts.

It is not yet possible to adequately address the issue of site location patterns, since research has been restricted to specific limited development areas. Prior to 1995, no archaeological work had been conducted in the region east of Bathurst Inlet. In 1996, as predicted by Bussey (1995b), the majority of sites were found on elevated, dry landforms near rivers, lakes and the coast. However, a number of sites were found in lower elevation topographic situations, some distance from significant waterbodies. Consequently, such areas cannot be dismissed, particularly since so little archaeological field work has been conducted in the region to date. It should also be noted that the high number of sites found in a relatively restricted area suggests a high degree of use of the region, possibly well into the past, and may refute the opinion that this area has had low populations densities throughout time (Maxwell 1980).

Detailed analysis of the spatial distribution of feature types is not yet possible. Various stone circle types seem to occur throughout the study area, as do the sites which possibly represent different time periods. Consequently, no temporal patterns are yet discernible. However, one apparent pattern seems to be that no rock traps were found in the vicinity of the Boston Project area or Spyder Lake. The Koignuk River/Spyder Lake confluence area seems to be the southern extent of this feature. However, given that little archaeological research has been conducted in the area thus far, this is a very preliminary suggestion.

The results of this study present some tantalizing possibilities for contributions to the culture history of the central Arctic region. For example, thus far, all definite Thule sites seem to occur in close proximity to the coast line. If sites MjNh-5 and MkNh-6, in the vicinity of Spyder Lake, are indeed Thule, then the known range of Thule sites may be expanded some distance from the coast. In addition, the inland sites tentatively identified as Thule may present opportunities to elucidate Thule summer activities, hitherto unknown.

Of equal interest is that this area may provide opportunities to better define the relationships between Thule and modern Copper Inuit. The area east of Bathurst Inlet from the coast to the tree line may hold the key to understanding the development of the Copper Inuit culture (Hickey 1977, pers. comm.). Much can be learned from investigations of sites in this area, in spite of the sparsity of artifacts; for example, if some of these sites could be dated, this would provide a better chronological basis for defining cultural developments in the Copper Inuit region (Hickey 1977, pers. comm.).

## 10.6 Conclusions And Recommendations

The archaeological investigations conducted in the Hope Bay Belt Project area in 1996 resulted in the recording of information on 30 archaeological sites. Many of these sites have multiple features and include stone rings, rock caches, traps, hearths/windbreaks, boat supports, drying rack supports and possible signal rocks. Some artifacts were also found, consisting of wooden and bone/antler implements, one stone tool, and various historic tin and glass remains. Only two artifacts, endangered by their proximity to proposed development, were collected and will be submitted to the Prince of Wales Northern Heritage Centre.

### 10.6.1 Project Summary

In the Boston Project area, five new archaeological sites (MjNh-3 to -6 and MkNh-1) and one isolated find were recorded; in addition, one large site (MjNh-2) on a nearby landform was revisited and site information updated. Two sites (MjNh-4 and MkNh-1) occur on the edges of the two possible air strip locations and some mitigative work will likely be necessary once one of the two options is chosen and the exact location is identified. MjNh 6, although not directly within the currently delineated development zone, has a potentially sensitive feature (possible grave) which will require additional investigation if development encroaches on the vicinity of the site. The remaining sites are not in danger of immediate, direct impacts, but will require continual re-assessment as development plans evolve. The archaeological inventory of the Boston Project area, as defined during the summer of 1996, is complete. If new development areas are identified, these will require additional inventory work and possible assessment and/or mitigation if any sites are found.

A preliminary assessment of the currently proposed winter trail route between Boston camp and the south end of Doris Lake resulted in the recording of ten new archaeological sites (MkNh-2 to -9, MlNh-1 and NaNh-1). One disturbed ring was also observed from the air, but was not recorded. These sites represent features reported by trail surveyors last year as well as stone features observed from the air during the helicopter overflight. The preliminary archaeological assessment was designed primarily to identify areas with significant archaeological potential because BHP had indicated that the route had not been finalized and would not be required for at least one year. It must be emphasized that no detailed inventory of the trail route has been completed; a detailed inventory will be necessary once the final route is identified.

The sites recorded in the section of the proposed trail between the Boston and Doris Lake properties occur on elevated landforms (with a few exceptions) adjacent to the trail, which generally passes over low lying waterbodies and wet areas. Consequently, the potential for direct impacts to these recorded sites is minimized, with two exceptions. Sites MkNh-4 and -5 occur on a knoll which the trail is proposed to cross, thus, direct impact is possible. MkNh-4 may be of particular significance, since it is the only site containing a stone tool found thus far, and the tool is suggestive of a Paleo-Eskimo occupation (that is, might be as old as 3,500 years ago).

With regard to the assessment of archaeological potential along this section of the proposed trail route, all elevated landforms, particularly those adjacent to waterbodies, have been rated as having high potential and would require ground reconnaissance (see Figures 10.4-1 to 10.4-4). Although these landforms may not be directly impacted by trail development and use, indirect impacts are quite possible due to the close proximity. Lower elevation, dry ground immediately adjacent to waterbodies would have sufficient potential to also require examination. In addition, documentation has suggested that portions of the Koignuk River provide resource gathering areas of some importance (cf. Riewe 1992; NPCTT 1996) and since much of the proposed trail route follows the Koignuk River, potential for sites is enhanced.

A detailed inventory and impact assessment was completed for the portion of the trail between Doris Lake and Roberts Bay because it was to be used this winter. Two sites (NaNh-4 and NbNh-19) were recorded, both of which are in danger of direct impacts. In the case of site NbNh-19, consultation with BHP personnel resulted in a revision to the proposed alignment so as to avoid the landform on which the site is located. NaNh-4 is also within the Doris exploration program area and is adjacent to the proposed camp location; therefore, potential for impact is increased. The archeological inventory of the portion of the winter trail between Doris Lake and Roberts Bay, as identified on the plans supplied by BHP in July 1996, is complete.

Three sites (NaNh-2-4) were recorded within the Doris Lake project area. As discussed above, one site (NaNh-4) is in direct conflict with development. NaNh-2 and -3 are adjacent to planned developments and may be subject to indirect impacts. The inventory of the Doris Lake Project area, as defined for 1996, is completed provided there are no changes to its boundaries.

On the west side of Roberts Bay, examination of two possible ports and two proposed barge landings resulted in the recording of four archaeological sites (NbNh-14 to -17). Two of these (NbNh-14 and -15) occur within the proposed northern port location and additional archaeological work will be required if this location is chosen. One site (NbNh-16) occurs adjacent to the northern edge of the southern proposed barge landingand it is felt to be sufficiently removed that direct impact will not likely occur. Although indirect impact may be possible, it is considered relatively unlikely due to the site's location within a rocky outcrop, as well as the fact that no artifacts were observed, thus reducing the potential for illegal collection. The final site (NbNh-17) is not within any currently planned developments, but is included within a potential development area and may require additional investigation in the future. No archaeological remains were found within the southern port option or the northern barge landing. Consequently, these locations present no further archaeological concerns. The inventory of this development area in Roberts Bay of the trail route has been completed provided no revisions are identified.

Five sites (NaNh-5, -6, NbNh-20, -21 and NaNi-2) that had been reported by survey and geology crews were also recorded. These all occur in the general vicinity of the Doris Lake exploration area, from south of Windy Lake to Roberts Bay. Although they are currently in no danger of direct impacts, continued and/or increased exploration activities could increase the potential for impacts, both direct and indirect. The discovery of these sites was not part of a systematic inventory and there is potential for additional archaeological sites outside of the areas examined in 1996.

The sites recorded in 1996 appear to represent the full time range of occupation known for the central Arctic. One site (MkNh-4) may contain a Paleo-Eskimo component which could date as old as 3,500 years B.P. Five sites (MjNh-5, MkNh-6, NaNh-5, NbNh-18 and -20) contain structural features which could represent Thule occupation, dated from about 1,000 to 400 years ago. Twelve sites contain historic components (see Table 10.5-2), based on the square shape of the stone rings as well as the presence of historic artifacts such as metal and glass. A number of these sites could also contain older occupations, generally suggested by more deeply buried features. Because of the inventory nature of the 1996 field work, the majority of the sites contained features whose ages remain undetermined; additional investigations at those sites may assist in establishing time of use.

In summary, most of the sites recorded in 1996 are not in direct conflict with identified development. Seven sites may be in direct conflict with specific proposed developments (MkNh-4, -5, NaNh-4, NbNh-14, -15, -16 and -19), but are generally avoidable by development re-design. Another eight sites occur peripherally, that is, just within or immediately adjacent to possible development areas, one on Roberts Bay (NbNh-17), two near the Doris Lake Project (NaNh-2 and -3), and five in the Boston area (MjNh-3, -4, -5,- 6 and MkNh-1). In addition, once a final trail route has been selected, it is possible that additional sites could be in conflict. One of the sites found during the 1995 field reconnaissance is also located near a proposed development, one of the airstrip alternatives. However, MjNh-1 was mitigated in 1995 and no further archaeological investigation is recommended. The other 1995 sites, MjNh-2 and NbNh-1 through -13, are not threatened by direct impact at the present time.

### 10.6.2 Recommendations

All recorded archaeological sites should be plotted on development and exploration plans and avoidance should be stressed. Any sites that cannot be avoided will require more detailed assessment, possibly including systematic surface collection and/or test excavation, to evaluate significance and to recover data. All revisions to proposed development or exploration areas should be reviewed by an archaeologist to determine the need for additional inventory work.

*Boston Project*

When an air strip location has been finalized, the sites adjacent to the chosen location (which may be any of sites MjNh-3, -4 or MkNh-1) should be re-examined in order to determine if potential for impact has increased. If so, those sites should be evaluated and mapped in greater detail.

If the Boston project area is revised, additional inventory and impact assessment could be required and the potential for impact on all recorded sites should be re-evaluated. If development plans are extended to the south, the cairn feature at site MjNh-6 should be investigated to attempt to determine its function.

*Winter Trail Route*

All elevated and dry ground adjacent to or crossed by the current proposed trail route, as indicated on Figures 10.4-1 to 10.4-4, should be examined. The portion of the route along the Koignuk River, especially the vicinity of the confluence of the Koignuk River and Spyder Lake, is of particular significance, as is the Roberts

Bay area. If the trail route is revised, similar areas adjacent to any new route would require ground reconnaissance. It is recommended that selected portions of other, lower potential areas also be examined, to ensure that assumptions of archaeological potential are valid and that no sites are missed. Any of the recorded sites that remain in close proximity to the final trail route selected should be revisited for detailed assessment.

MkNh-4 should be subjected to some test excavation to attempt to determine its temporal significance. In addition, the vicinity of the landform should be thoroughly examined to find a route for the trail which would not impact features at MkNh-4 and MkNh-5 and to ensure that no other unrecorded archaeological resources are impacted.

With regard to the portion of the trail route between Doris Lake and Roberts Bay, NaNh-4 and NbNh-19 should be re-examined to see if construction and use of the nearby ice trail this winter has caused any damage to the site features. It must be emphasized that winter trails are known to have damaged archaeological sites elsewhere in the past, consequently, some monitoring of activity and effects is considered necessary. It is understood that use of the winter trail in 1996 - 1997 will be monitored by an archaeologist. If this re-examination results in an assessment of increased impact potential, these sites should be evaluated and mapped in more detail.

*Doris Lake*

NaNh-4, discussed above in association with the trail route, is also within the Doris Lake development area and could be in conflict. Any changes to the boundaries of this development area or any increased activity would require a re-assessment of nearby archaeological sites and could require additional inventory.

*Roberts Bay*

The sites in the vicinity of the barge landing used during the winter of 1996 to 1997 should be revisited to monitor impacts on the archaeological sites. If the potential for disturbance of NbNh-14, -15, and -16 appears to be enhanced, more detailed mapping and site evaluation is recommended.

*General*

It has been suggested that a number of the sites threatened by impact may require evaluation. This is partially intended to assist in the identification of site significance, but also to help in the determine of the level of mitigation required if the site can not be avoided. More intensive examination would likely involve a combination of exploratory subsurface testing and/or intensive surficial examination and collection. However, because little is known of this region it is suggested that a number of sites that are in close proximity to development areas, or could fill information gaps, should also be tested. Of particular significance are sites suspected to represent Thule occupation, the testing of which may reveal structures such as sleeping platforms as well as diagnostic artifacts. In addition, sites with animal bone could provide valuable dates for developing a chronological framework. This strategy is recommended for several reasons that are listed below:

- Development plans can be revised on very short notice, and sites which may not have appeared to be in direct conflict with development may suddenly be within impact zones.
- The archaeological field season is so short in this region that field work must be planned well in advance.
- The results of such work would be of great interest to local Inuit residents by helping to elucidate their history and would demonstrate BHP’s commitment to sharing the benefits of their projects.
- It could be of considerable significance from a scientific perspective to examine sites which could hold the key to defining the culture history of the Copper Inuit traditional territory and provide a cultural historical framework within which archaeological sites recorded in the future can be evaluated.

Sites for which some subsurface testing and intensive surficial inspection/collection is recommended are: MjNh-5 (possible inland Thule), MjNh-6 (possible grave), MkNh-4 (possible Paleo-Eskimo), MkNh-6 (possible Thule), NaNh-4 (possible development impacts), NbNh-19 (multiple occupation, possible development impacts). These sites represent a selection of the known sites in the project area which are in close proximity to possible development and/or could provide opportunities for examination of various feature types and the recovery of cultural materials and/or dateable materials which could assist in establishing a temporal framework for the prehistory of the study area. It is suggested that this degree of additional work may assist in mitigating conflicts between development and archaeological sites in the future as well as provide a better basis for evaluating sites and the overall potential for impacts.

Every effort should be made to have potential exploration areas examined for archaeological resources. Exploration activities, in particular but not restricted to, drilling activities and associated camps, can cause considerable damage to archaeological sites. All such areas should be investigated as much in advance of exploration as possible. It is acknowledged that it is impractical to cover the entire region potentially to be explored, but it is recommended that some level of archaeological survey be conducted prior to intensive exploration activities which involve ground disturbance.

Some form of crew education is recommended, to stress the importance of leaving in place all rocks, bones and artifacts within and around archaeological sites, as well as not building new rock features such as inukshuit. This should apply to BHP personnel as well as any subcontractors working for them and may require an orientation lecture.

It must be acknowledged that the possibility exists that some archaeological remains may have been missed. It is impossible to cover every inch of ground within possible development or exploration areas and there could be some small or buried sites which escaped detection using methods designed to cover large areas, but this is an unlikely possibility, given the generally good visibility in this region. Further, it is very unlikely that any large or intensively utilized sites exist within the portions of the development areas that have been subjected to ground reconnaissance. However, if any cultural or human remains are encountered during development, all activities in the vicinity should cease and the Prince of Wales Northern Heritage Centre should be contacted.

Further inventory in this area will likely yield similar types of archaeological sites to those already discovered. However, it is also possible that different site types, possibly including those without surface features, could be located. Because traditional knowledge has already contributed to the archaeological study, it is suggested that further consultation would be of value.

This inventory phase is only the first step in dealing with the archaeological resources of this region. As development plans are revised, the possible effects on recorded sites will require ongoing evaluation. Consultation with the Prince of Wales Northern Heritage Centre and the Inuit Heritage Trust with regard to further investigations, site assessments and mitigation measures will be necessary. Avoidance is the preferred mitigative strategy; however, threatened sites must be assessed and tested or excavated if avoidance is not feasible. Further, some evaluative testing of sites is desirable to assist in assessing the archaeological resources of this little known region. Where avoidance is possible, site protection measures will need to be considered and periodic monitoring may be necessary.

# 11. Traditional Knowledge, Community Consultations and Socioeconomics

# 11. TRADITIONAL KNOWLEDGE, COMMUNITY CONSULTATIONS AND SOCIOECONOMICS.

BHP Minerals became a partner in the Naonayaotit Traditional Knowledge Study being conducted by the Kugluktuk Angoniatit Association on behalf of the Kitikmeot Hunters and Trappers Association (KHTA), in May of 1996, to provide an overview of local indigenous knowledge for the Hope Bay Belt projects. This study provides a step toward working more closely with the hunters of Cambridge Bay, Omingmaktok, and Bathurst Inlet through their local Hunters and Trappers Organizations (HTO's) by accepting that their experience on the land has an important role in planning development.

The geographic scope of the Naonayaotit study is very large. It will provide an overview of traditional and modern Inuit land use of the west Kitikmeot mainland by people from Kugluktuk, Bathurst Inlet, Omingmaktok, and Cambridge Bay. It extends from the west Nunavut boundary east to the Perry River and south from the Arctic coast to the southern boundary of Nunavut.

Within this large study area, particular attention will be given to the Hope Bay Belt south of the Kent Peninsula, Lac de Gras, the area between Tahikyak and Imaokatalok, and the Hood River region. These areas contain mineral deposits under exploration by BHP, Lytton, Echo Bay, and Diavik Diamond Mines. Traditional knowledge of these areas will assist in planning, monitoring and mitigating the impact of exploration and perhaps in some instances mining. The study also provides traditional knowledge to the Department of Resources, Wildlife and Economic Development's (DRWED) grizzly bear study, and Parks Canada's History of Nunavut Project.

The Kugluktuk Angoniatit Association is conducting the study. BHP Diamonds, BHP Minerals, Lytton, Diavik Diamond Mines, Echo Bay Mines Ltd., DRWED and Parks Canada are partners in the Project. The partners acknowledge that the KAA owns the interview data. This database will provide the people of the Kitikmeot with a valuable planning tool to help manage their lands.

Interviews and transcription/translation for the Naonayaotit Traditional Knowledge project is nearly complete. Proofed and corrected transcripts are expected in April of 1997. BHP and the other industrial partners are currently working on a pilot with the KAA to digitize the map overlays from the interviews into the GIS program *Arch View*. The final report for the Naonayaotit project is due in the summer of 1997. To accommodate BHP Minerals' Hope Bay Belt projects, the Kugluktuk Angoniatit Association's principal investigator has indicated that he will work with BHP Minerals on integrating traditional knowledge with biophysical data sets as material becomes available in the late winter of 1997. At the request of elders who visited the region during the summer of 1996, emphasis will be given to wintering by Victoria Island caribou, the calving grounds of the Bathurst and Queen Maud Caribou herds, water quality and fish in the Koignuk River, and marine mammals around Roberts Bay.

The KHTA project will provide a useful data set for comparison with the older Inuit Land Use and Occupancy Studies and more recent work done by the Nunavut Planning Commission. Analysis of regional level patterns will provide BHP Minerals with the background to work with local Inuit on more specific problems associated with the Hope Bay Belt project. Topics currently under discussion include management of heritage sites and caribou. Subsequent studies will be designed in consultation with the Inuit to examine specific questions.

## 11.1 Community Consultation

From the onset of exploration in 1991 until 1995, at least one community meeting per year has been held in Cambridge Bay and Omingmaktok. Beginning in 1996, two community meetings were held in each of these communities and annual elders' visits to the Hope Bay Belt were instituted. These gatherings dealt with a range of issues including, but not limited to, jobs, training, business opportunities and environmental protection.

Starting in April 1996, the BHP Minerals Hope Bay Belt projects have been active participants in the community mobilization component of the NWT Job Development Strategy. BHP Minerals is currently participating in job shadowing programs for people from the surrounding Arctic communities, associated with the strategy's pre-mine employment training.

Consultation has occurred with the Hamlet of Cambridge Bay on a yearly basis. BHP Minerals has been closely working with Kitikmeot Inuit Association since the proclamation of the Nunavut Land Claim, on a variety of land use issues. The Kitikmeot Hunters and Trappers Association, and community hunters' and trappers' organizations have been consulted on traditional knowledge, use of BHP facilities by Inuit corporations for communal caribou hunting, and potential land use conflicts between Inuit land users and mineral exploration. BHP Minerals has worked with the Nunavut Tunngavik Inc. on the lease of mineral concessions. Since early 1996 BHP Minerals has been cooperating with the New Nunavut land and water organizations - Nunavut Planning Commission, Nunavut Impact Review Board, and the Nunavut Water Board. Discussions with these councils, boards and agencies will in turn create the need for further rounds of community consultations.

As BHP Minerals undertakes mine feasibility studies for the Boston Project, the frequency of community visits will increase as new issues arise that require local updates and discussion. To accommodate the increased need for community consultation, BHP Minerals is assigning specific staff to handle community consultation and traditional knowledge. This staff is shared with BHP Diamonds in order to provide a more uniform approach to BHP operations in the Northwest Territories.

## 11.2 Socioeconomics

A limited evaluation of socioeconomic conditions was conducted in 1996. It is customary to reserve detailed socioeconomic assessment until such time as a decision is made to proceed to apply for development approvals. This is to ensure that the data collected for socioeconomic input assessment and management purposes is sufficiently current to reflect, as best as possible, conditions that are likely to be experienced at the time of project development. The ultimate objective of the study will be to generate sufficient socioeconomic data to allow for project planning to maximize the benefits and minimize any disruption that may result to local Inuit people and northerners more generally.

In addition to socioeconomic studies that will be instituted, important and relevant data will also be garnered from the traditional knowledge and community consultation programs. BHP's involvement in the community mobilization and NWT Job Strategy will also provide useful information for a socioeconomic analysis. As mentioned above, broader and longer term socioeconomic studies (*e.g.*, employment levels, demographics, infrastructure and services availability, *etc.*) will follow the successful completion of exploration activities and the decision to proceed to full feasibility studies.

Socioeconomic impact assessment involves identifying population and income effects on the region and any communities where mine employees or suppliers/contractors may settle. Company policies on workforce shift schedules, recruitment, transportation, accommodation, and native involvement will be reviewed to delineate specific impact issues.

Not only benefits but also potential negative impacts of project development would be critically reviewed when a more extensive socioeconomic review is called upon, within the categories of social tensions, racial interactions and demographic considerations. The aim would be to organize and operate the project so as to maximize socioeconomic benefits to the region and minimize any social disruption.

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