Appendix V5-4C

Hope Bay Belt Project: Environmental Baseline Studies Report 1996

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

HOPE BAY BELT PROJECT

1996 ENVIRONMENTAL BASELINE STUDIES REPORT

February 18, 1997

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Prepared for:

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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.

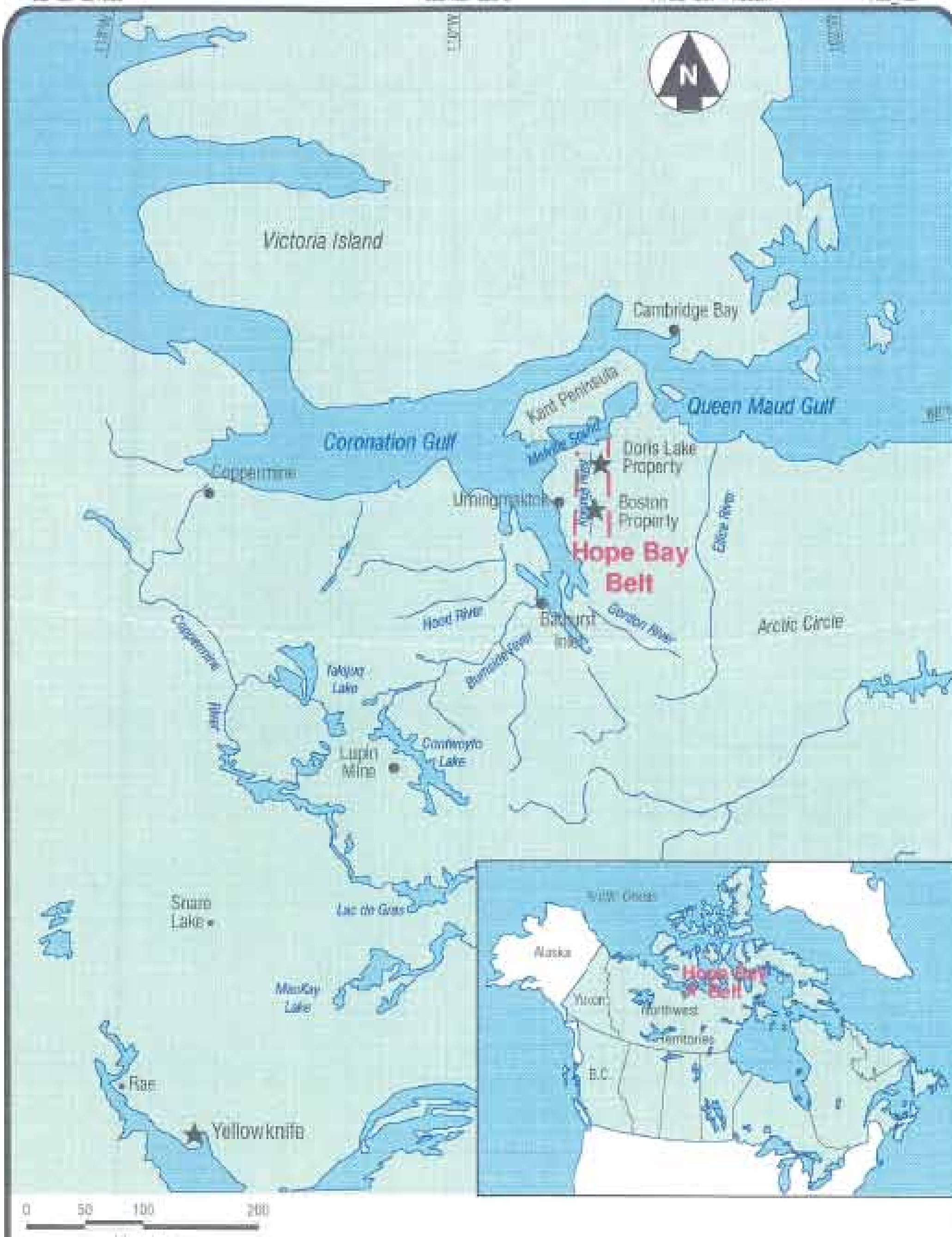

FIGURE 1-1

BHP **Project Location Map** Rescan

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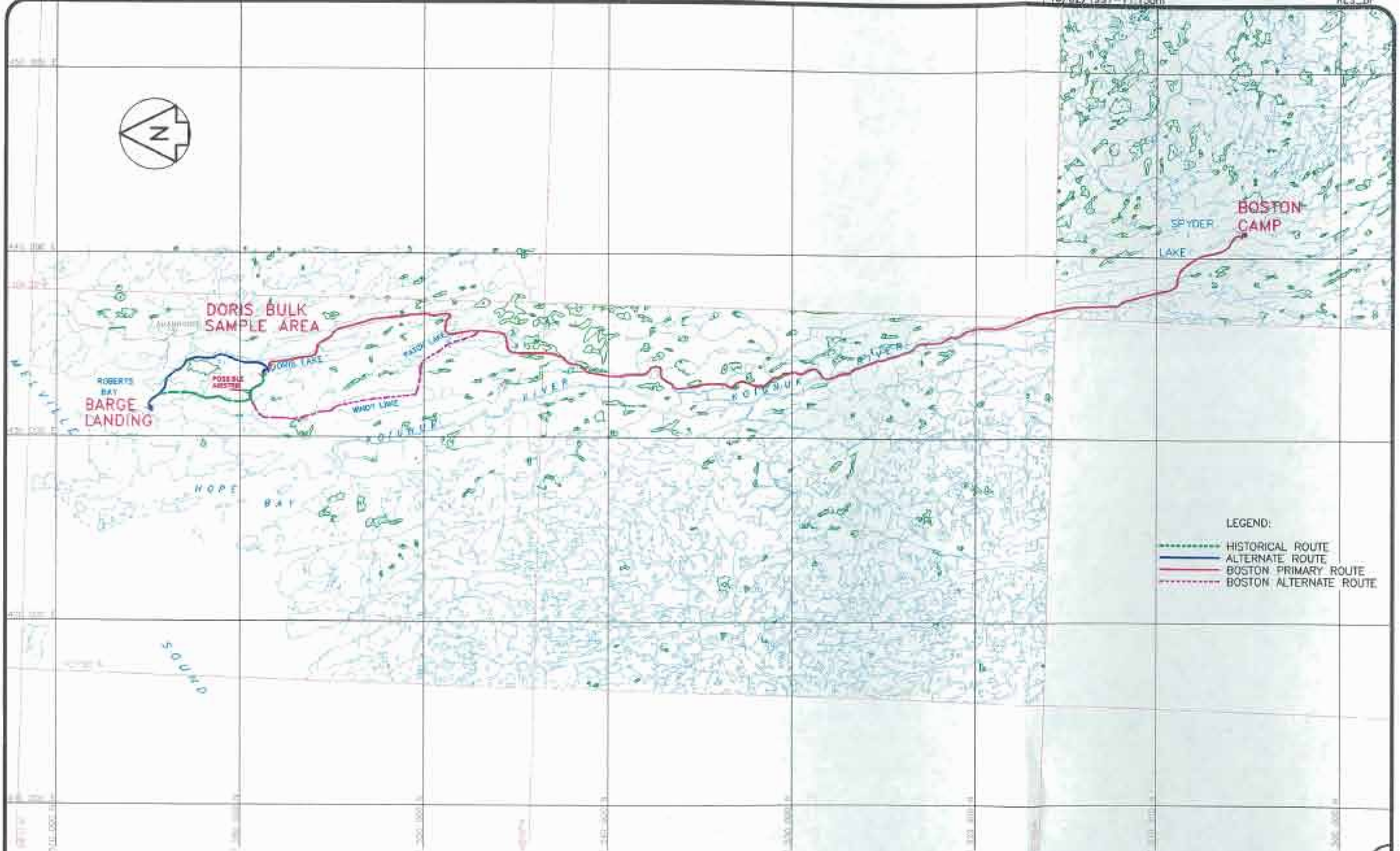

BHP

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.

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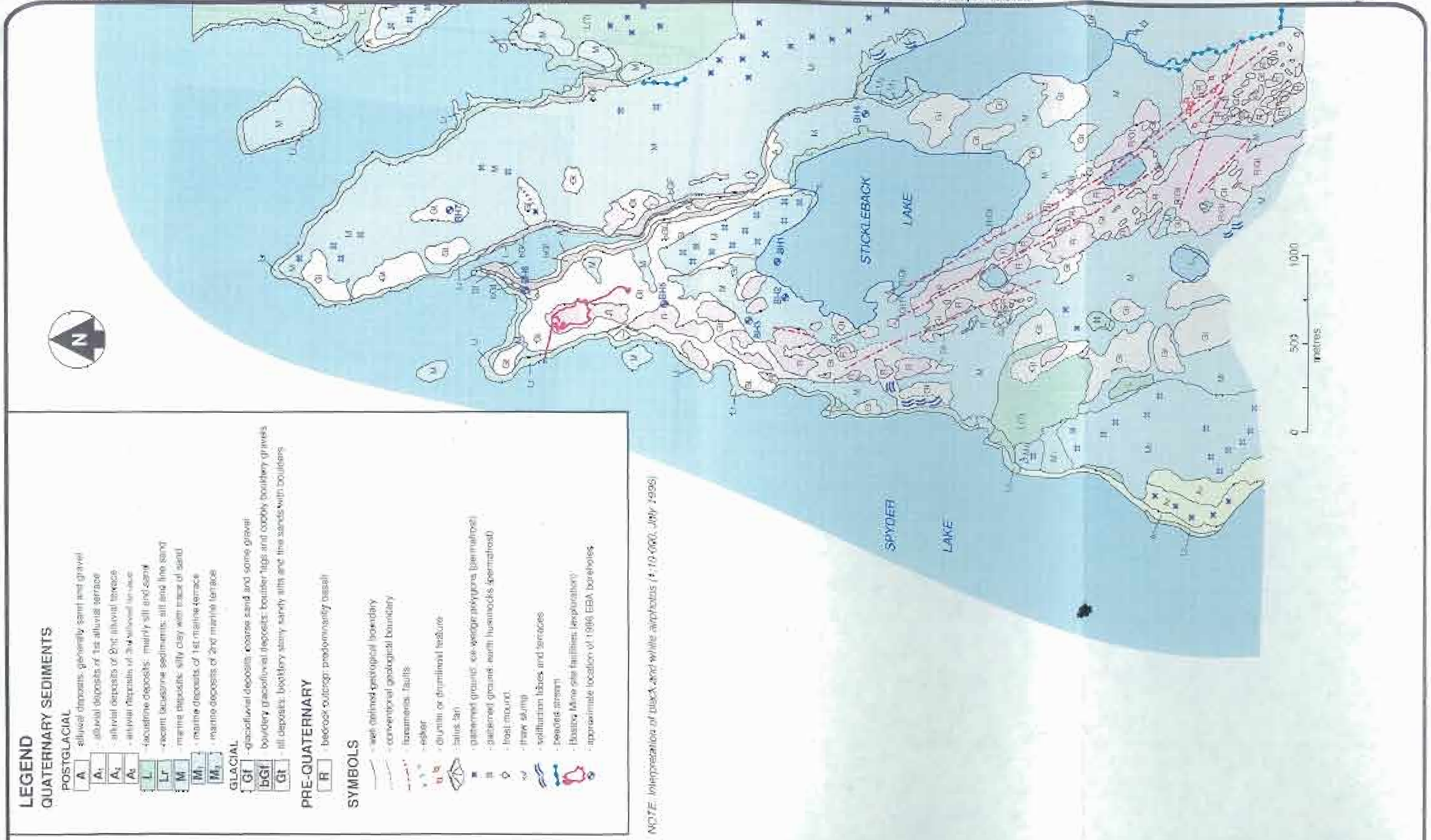


Surficial Geology and Permafrost Features
Boston Project Area, Spyder Lake, NWT

Source: EBA Engineering Consultants Limited 1996 101-42659/L02C

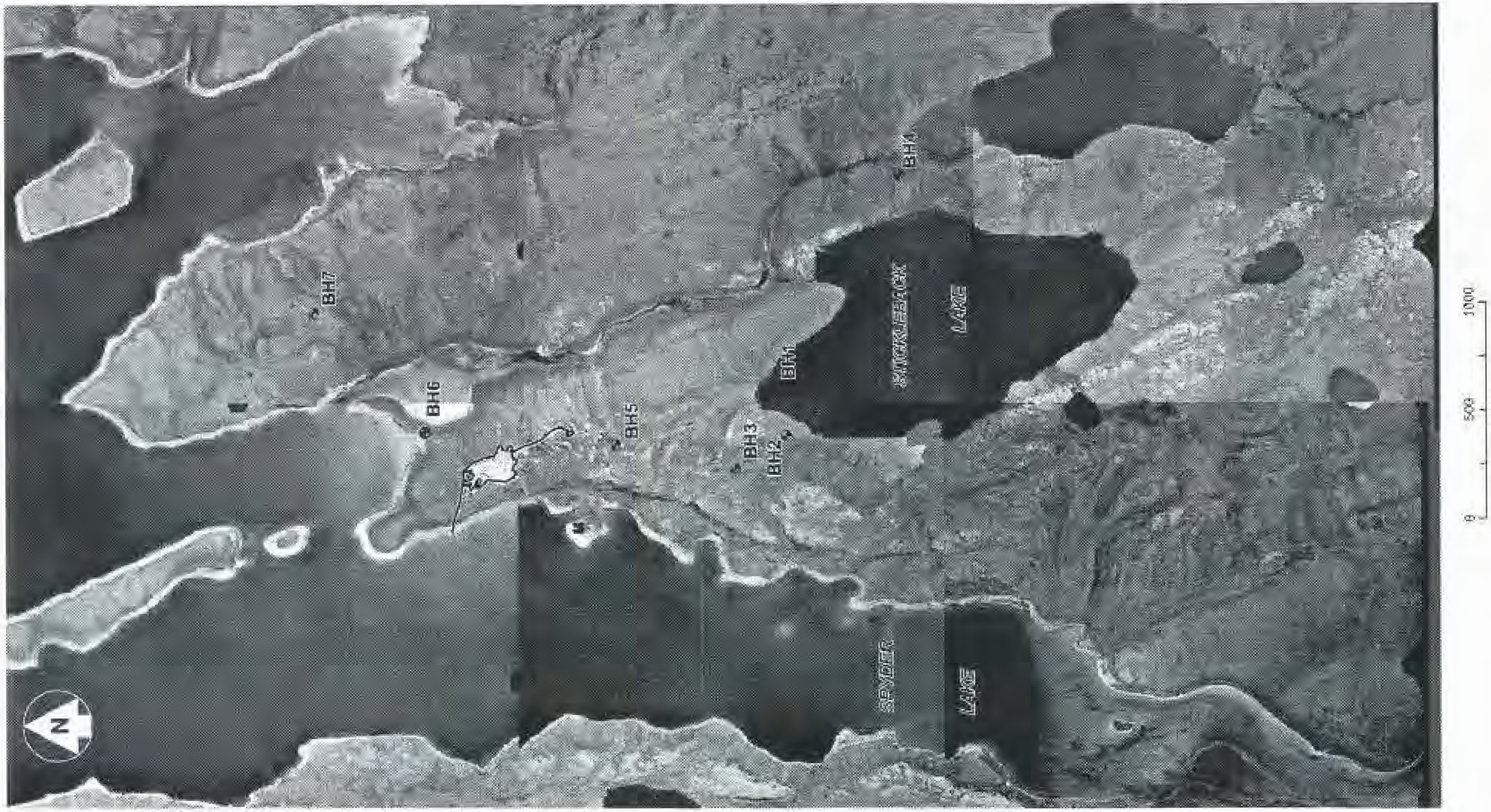


FIGURE 1.2-2

BHP

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

Rescan

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.

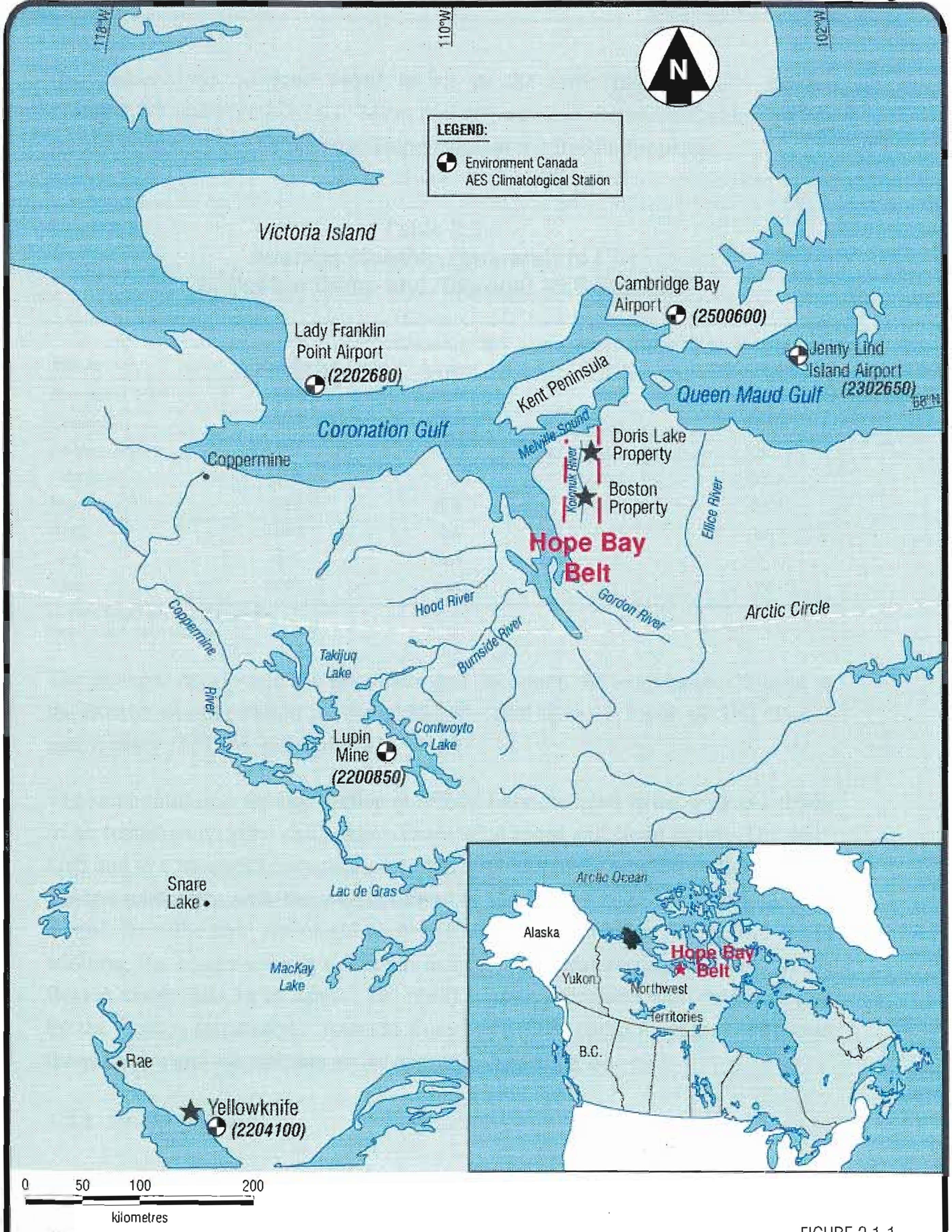
To obtain the requisite verification of the on-site data for an environmental impact statement, the climatological databases for the Boston and Doris Lake projects are augmented with government data collected by Environment Canada Atmospheric Environment Service (AES). The locations of the AES and BHP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



BHP

Location of Regional Climate Stations

FIGURE 2.1-1

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

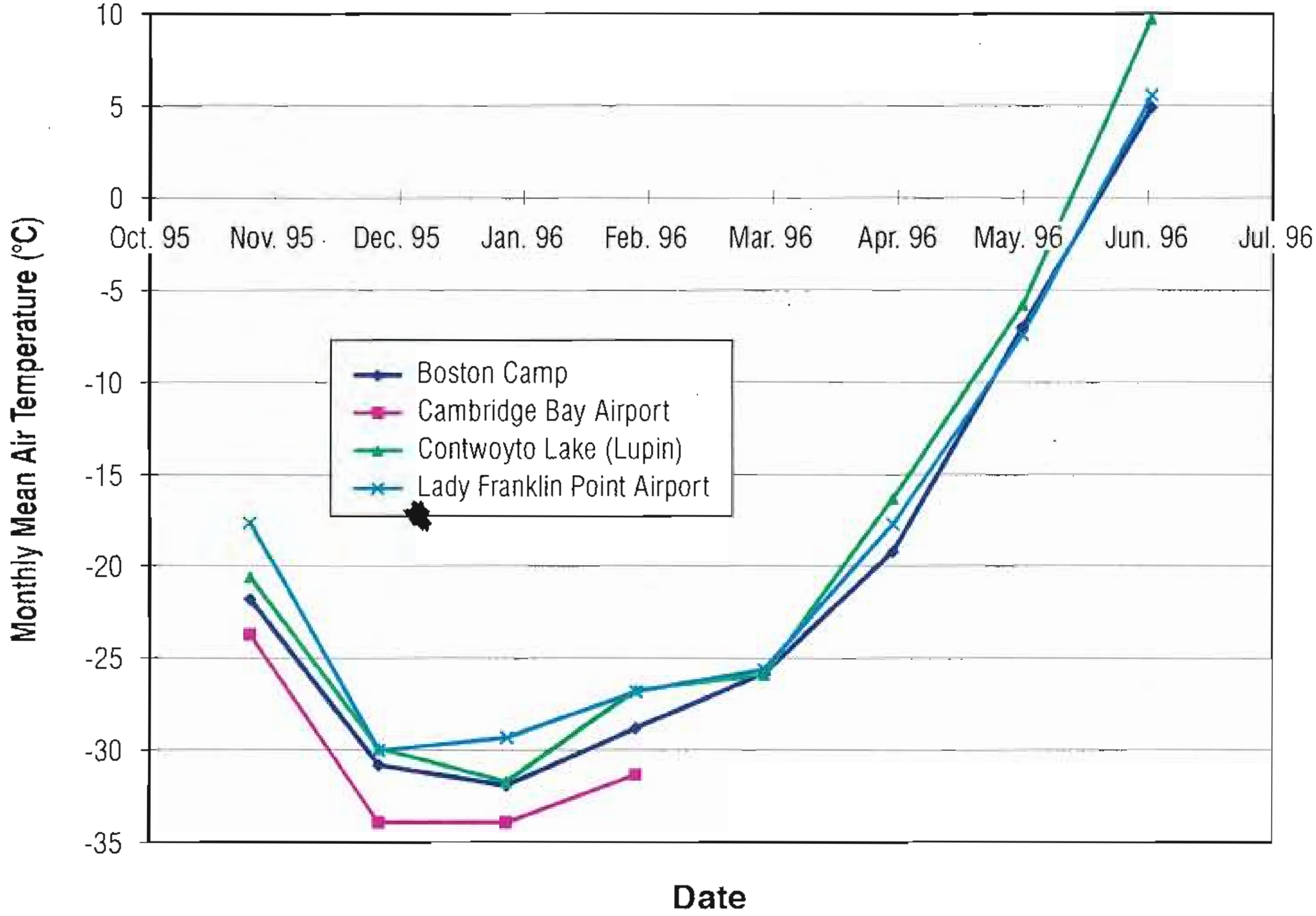


FIGURE 2.2-1

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

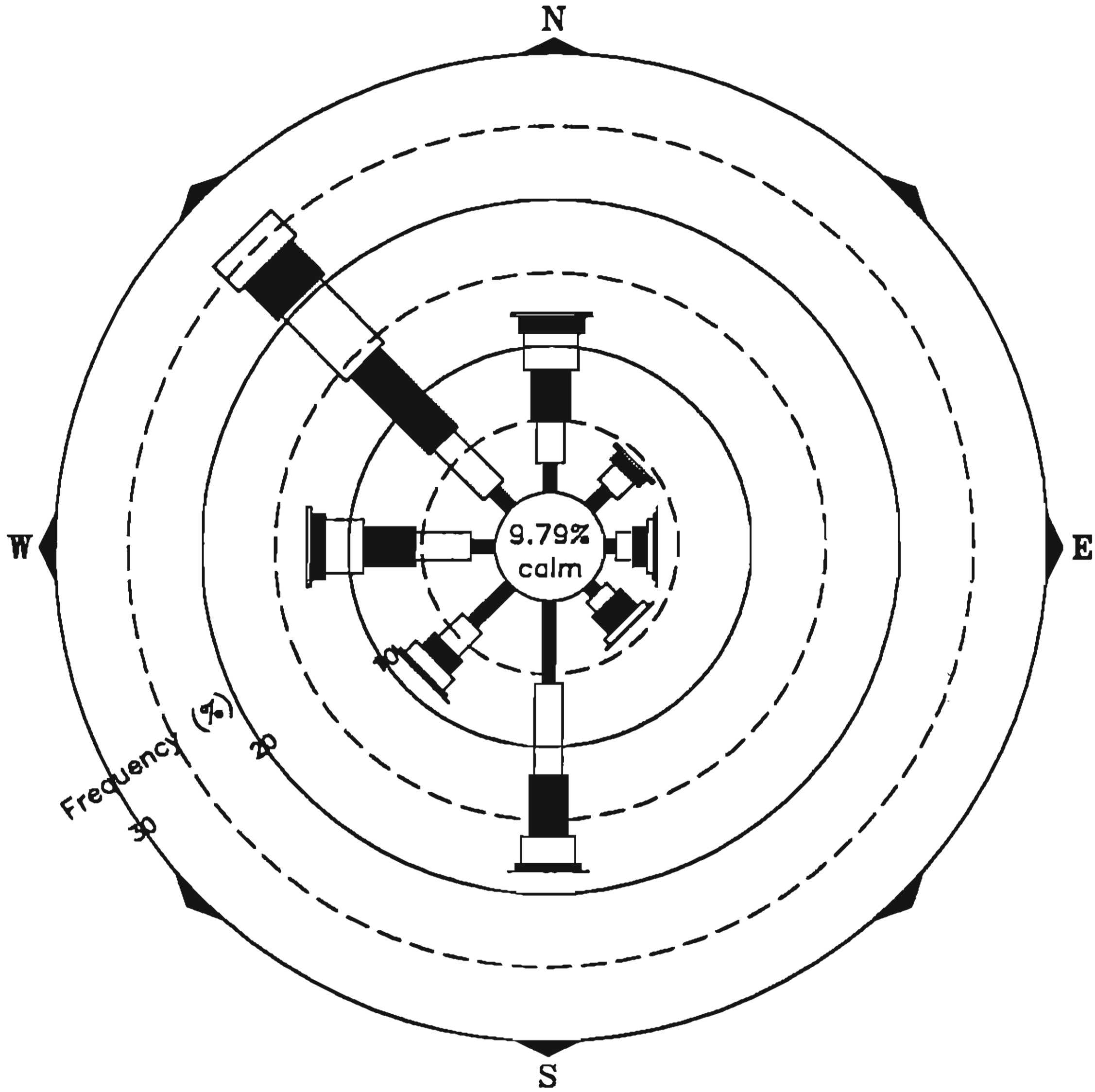
Evaporation data were collected from a Class A evaporation pan located at Windy Lake adjacent to the exploration camp. The on-site staff were trained to collect the hook gauge readings on a daily basis. The evaporation pan was installed June 14 and was monitored daily until September 4. Several of the 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.

BHP

Wind Rose for Boston Weather Station

FIGURE 2.2-2

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 ± 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 (µg/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 µg/Nm^3, the criteria for PM10 (United States Environmental Protection Agency) is 150 µg/Nm^3.

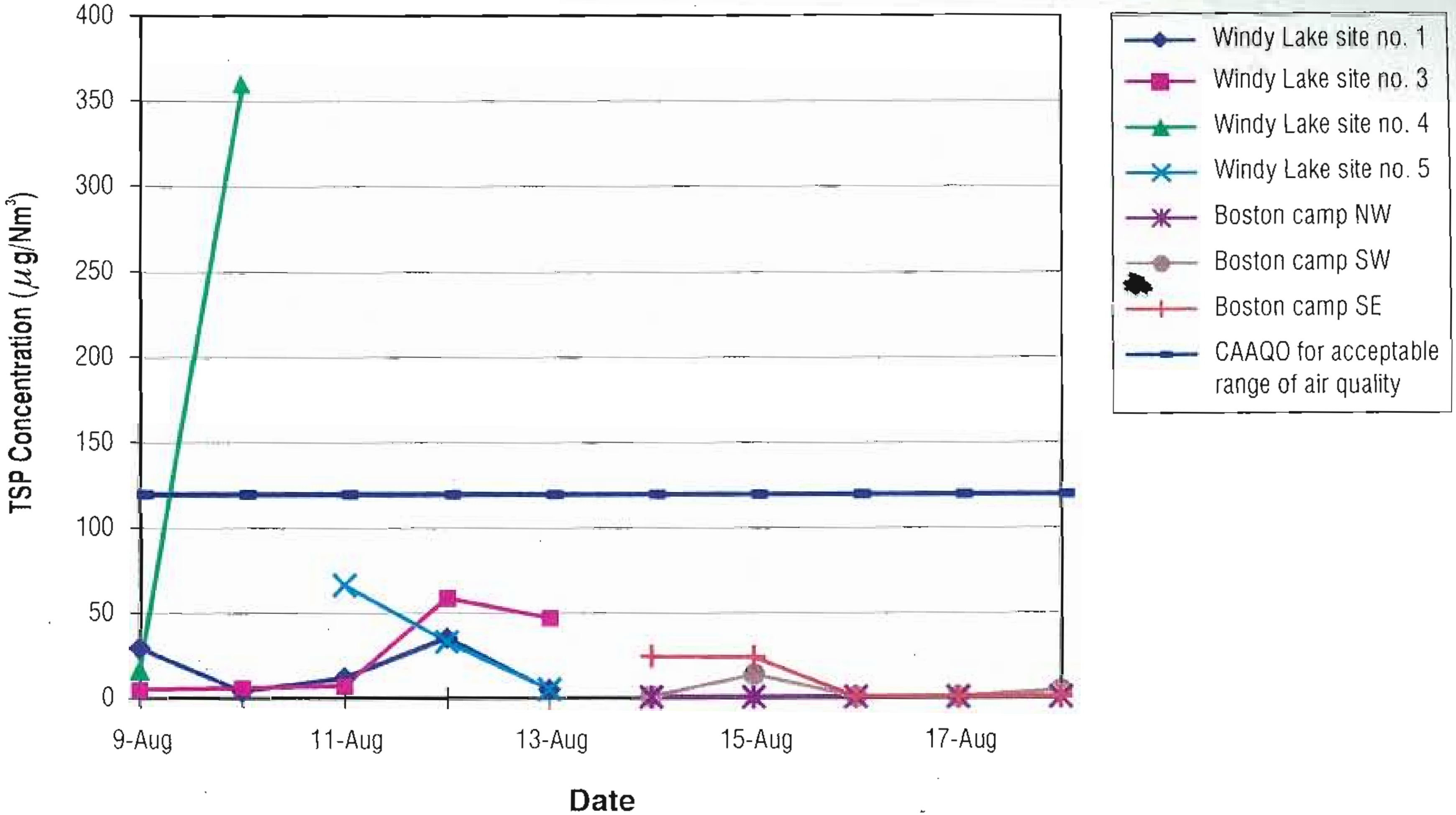


FIGURE 3.2-1

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

BHP Rescan

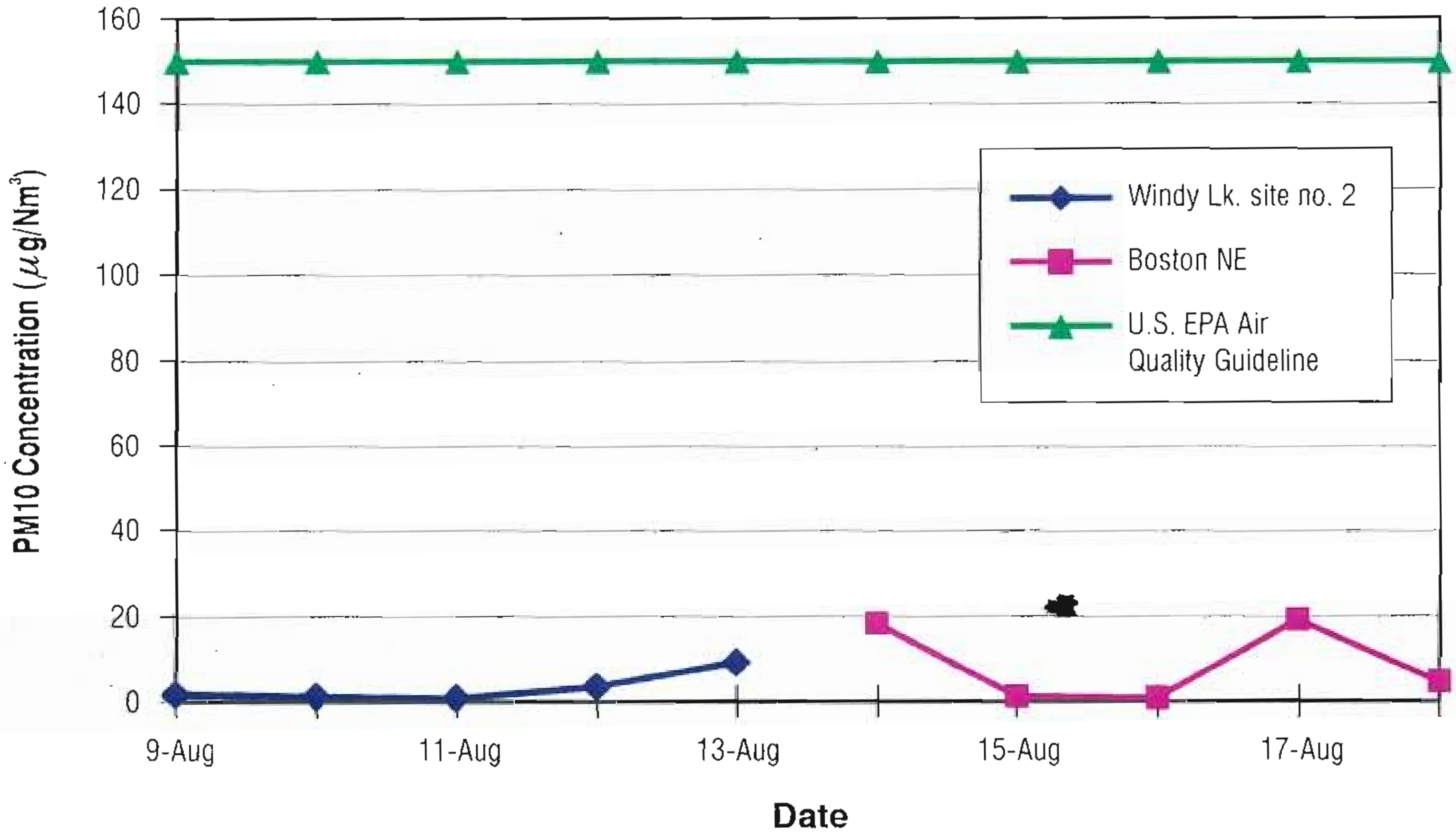


FIGURE 3.2-2

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.	1.3×10^{-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.	6×10^{-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

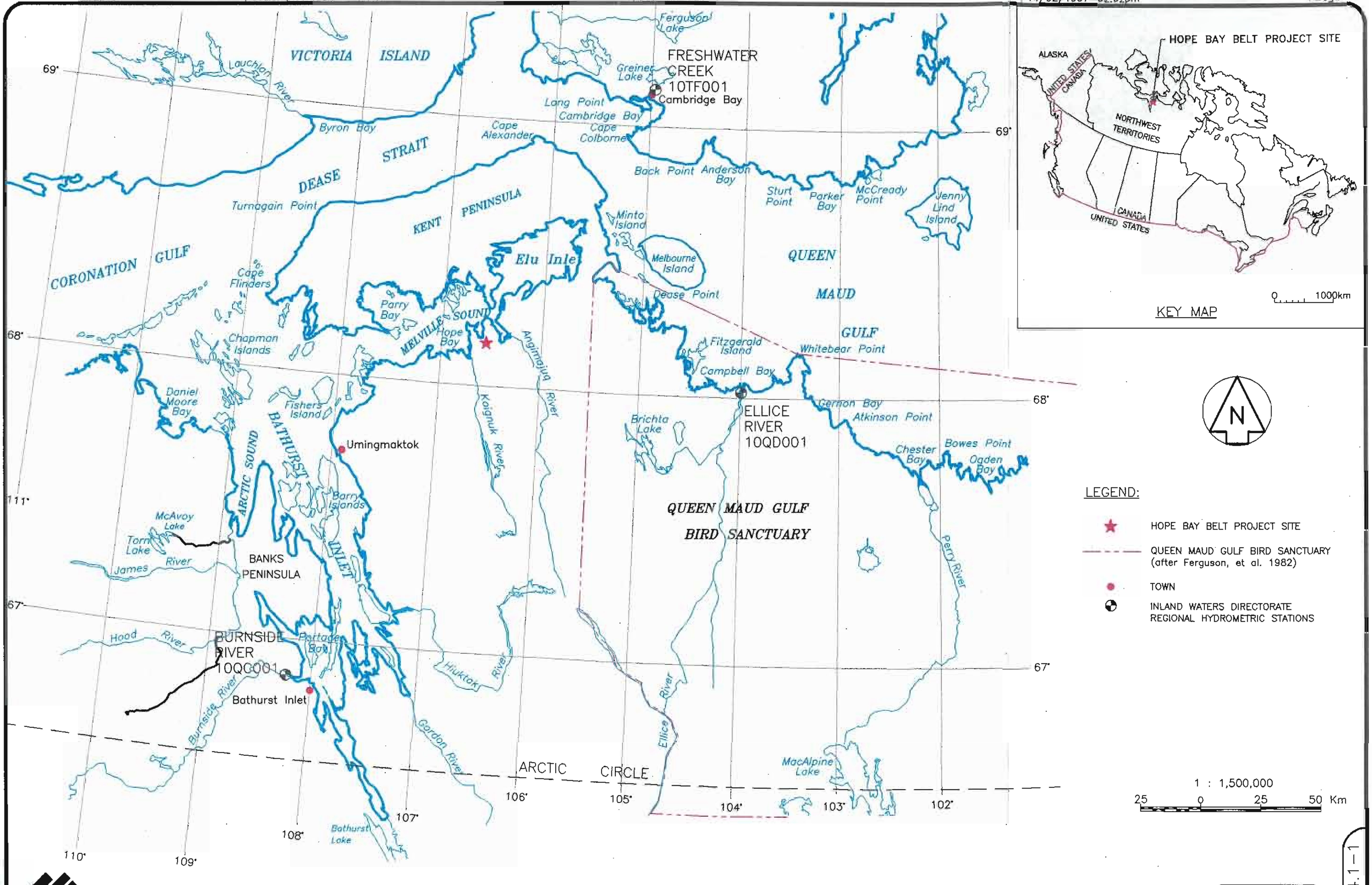
Within the project area four stations were monitored continuously for water levels using a staff gauge, pressure transducer and automated datalogger setup. These stations included the Koignuk River upstream of the entrance to Spyder Lake, and the outlets of Ogama, Doris and Glenn lakes. Water levels 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



Locations of Regional Hydrometric Stations

Fig 4.1-1

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

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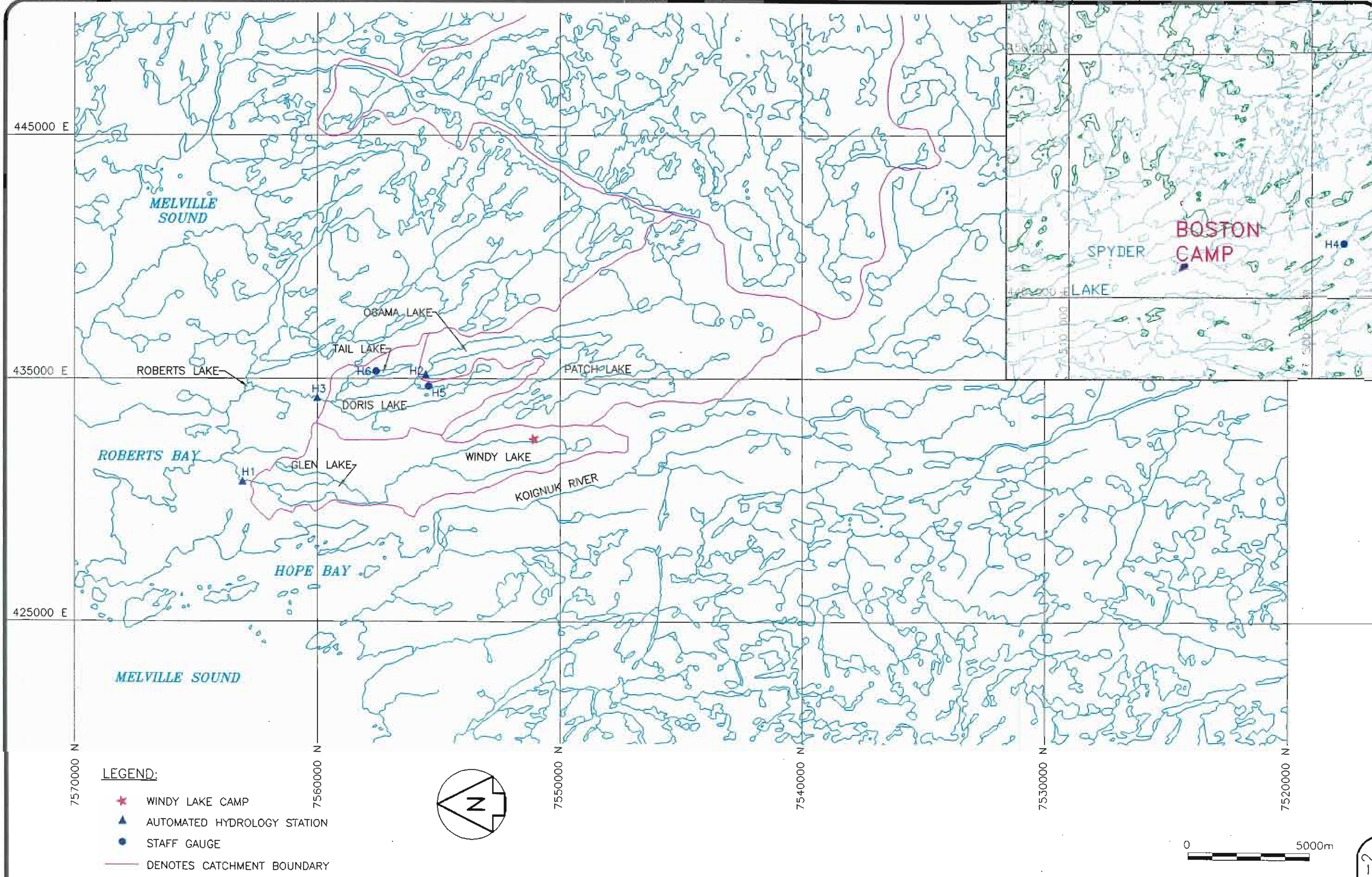

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Locations of Site-Specific Hydrometric Stations

Rescan

Fig 4.1-2

Source: Klohn-Crippen, 1995

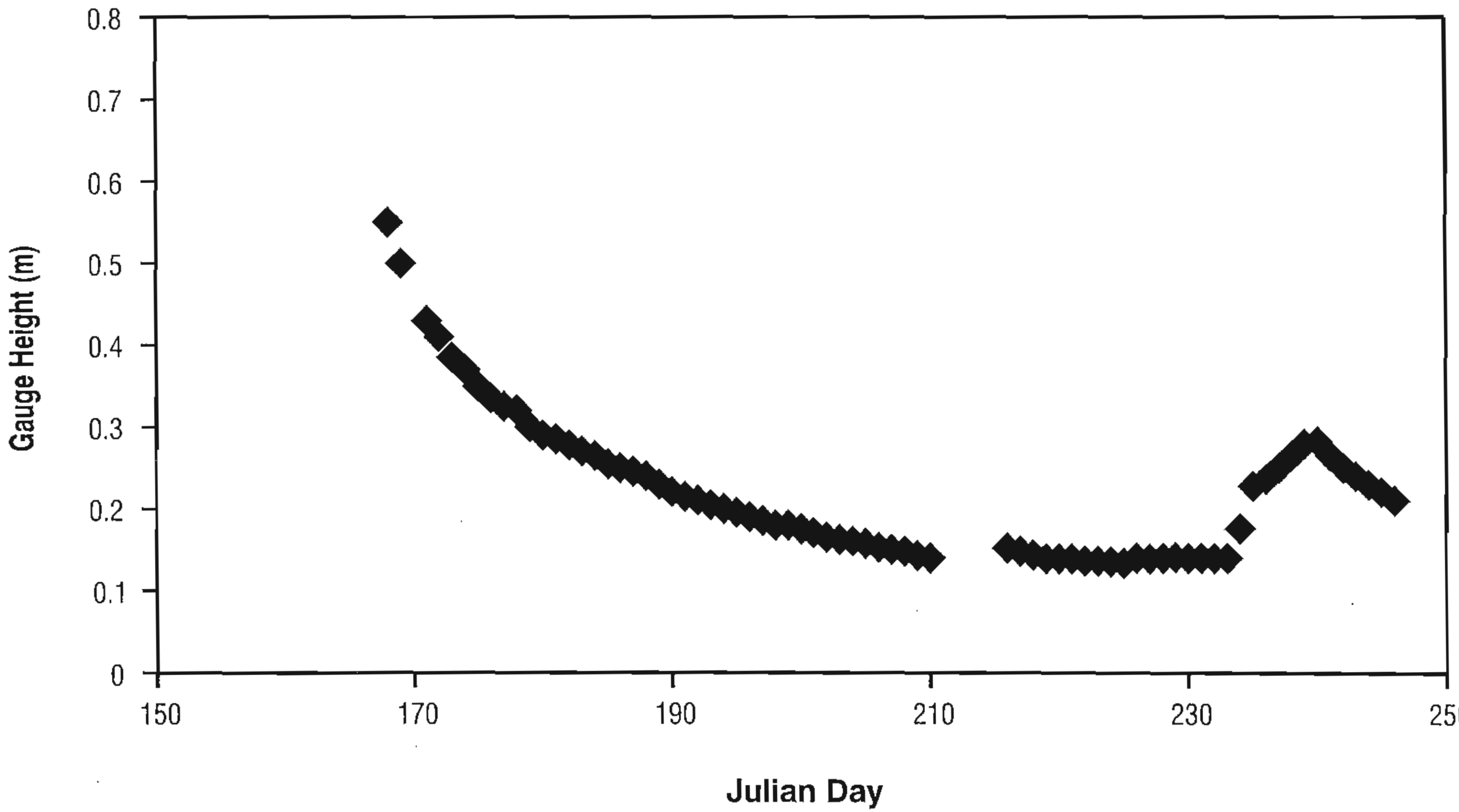

FIGURE 4.1-3

1996 Mean Daily Water Levels Glenn Lake Outlet

BHP

Rescan

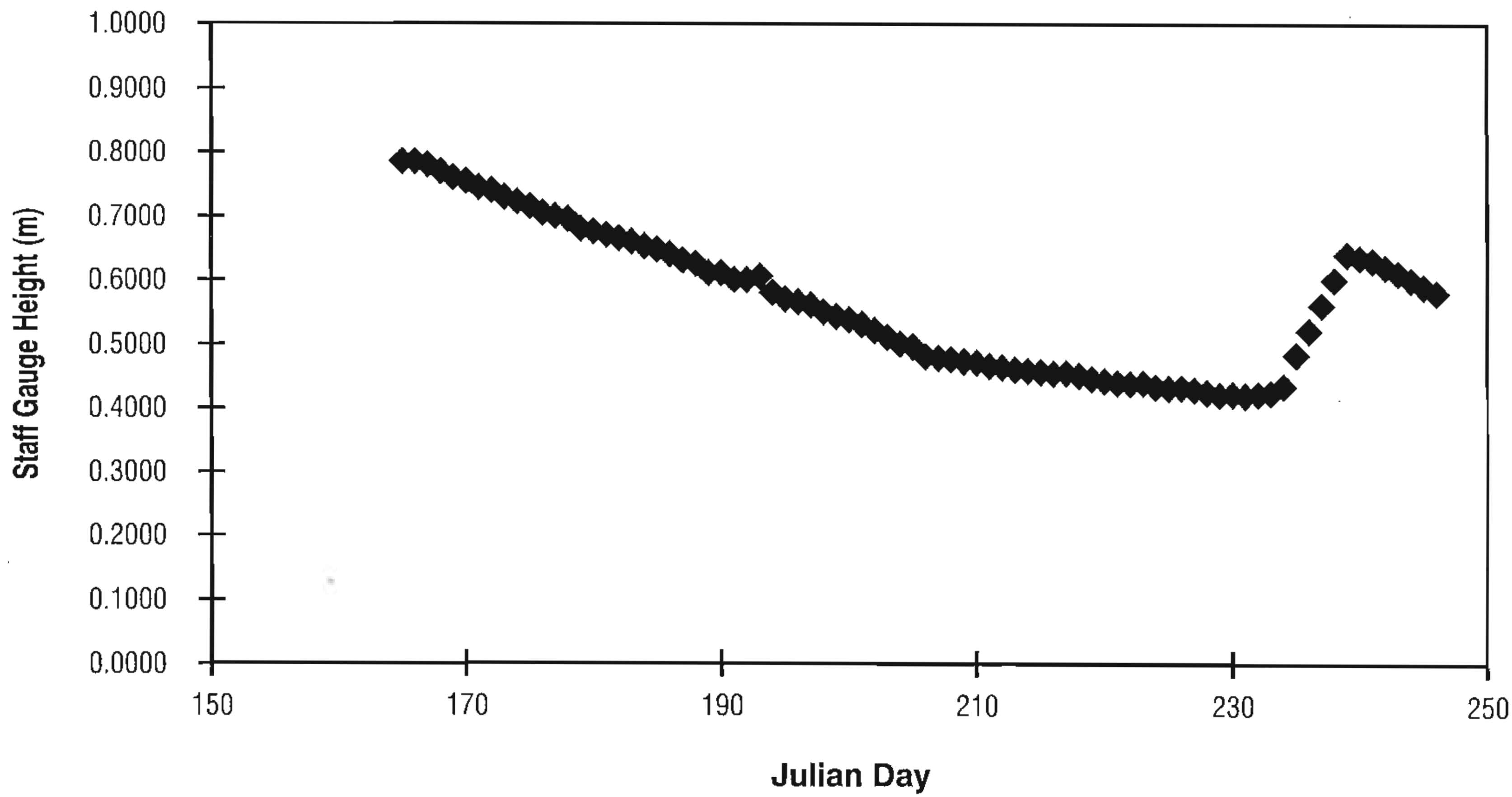

FIGURE 4.1-4

BHP

1996 Mean Daily Water Levels
Ogama Lake Outlet

Rescan

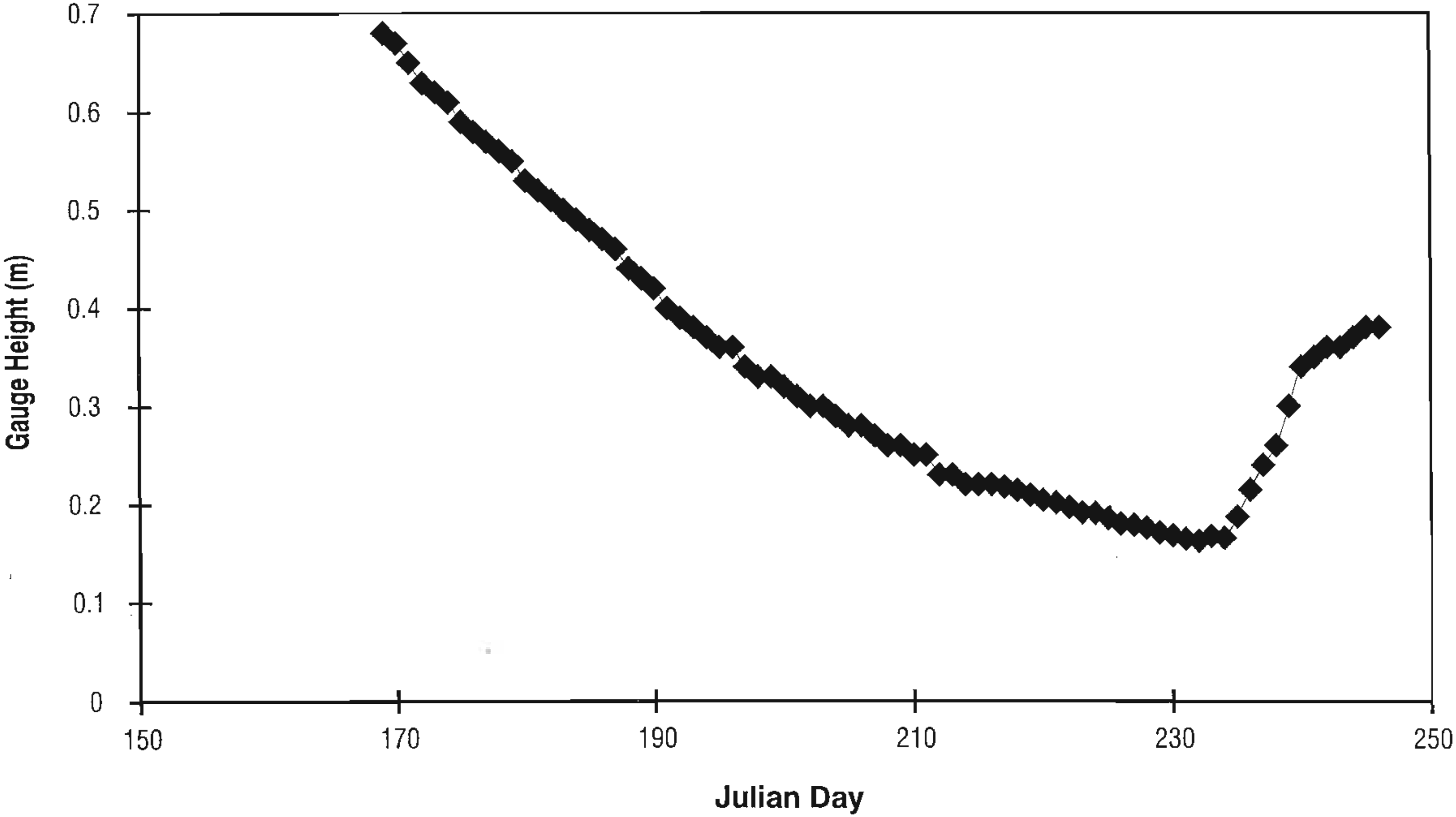

FIGURE 4.1-5

BHP

1996 Mean Daily Water Levels
Doris Lake Outlet

Rescan

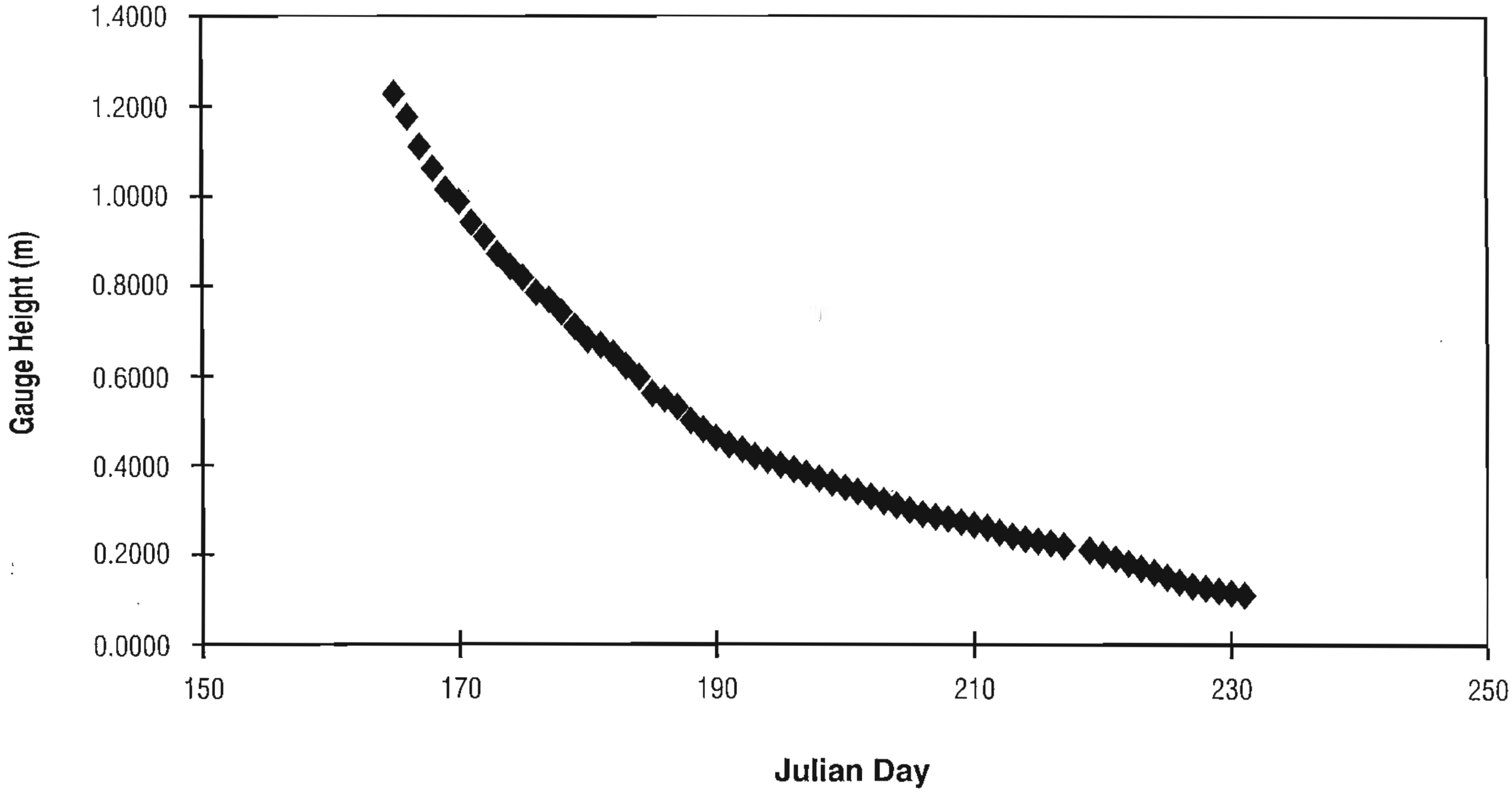

FIGURE 4.1-6

BHP

1996 Mean Daily Water Levels
Koignuk River Upstream of Spyder Lake

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

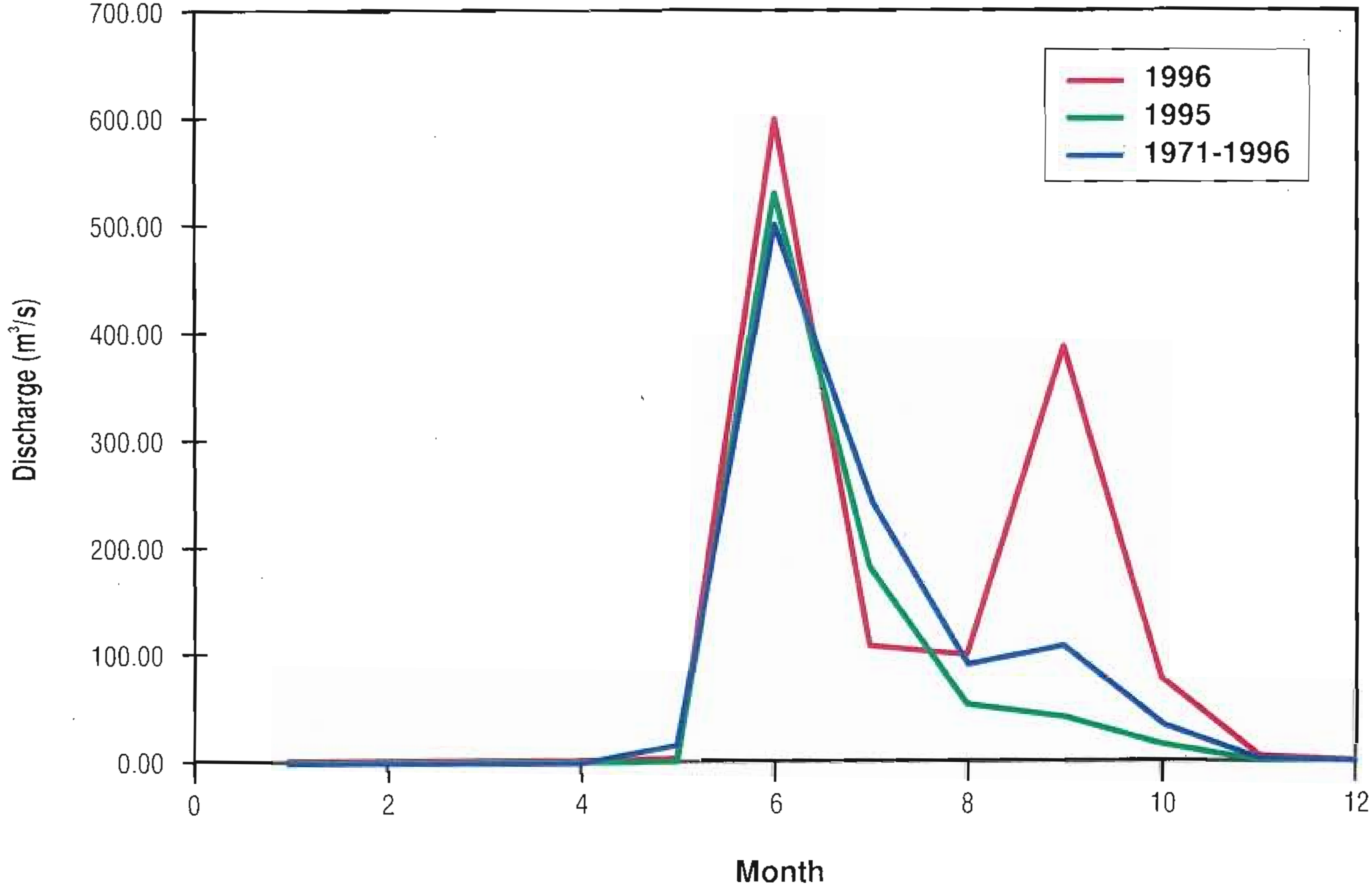

FIGURE 4.2-1

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Mean Daily Discharge
Ellice River Near the Mouth

Rescan

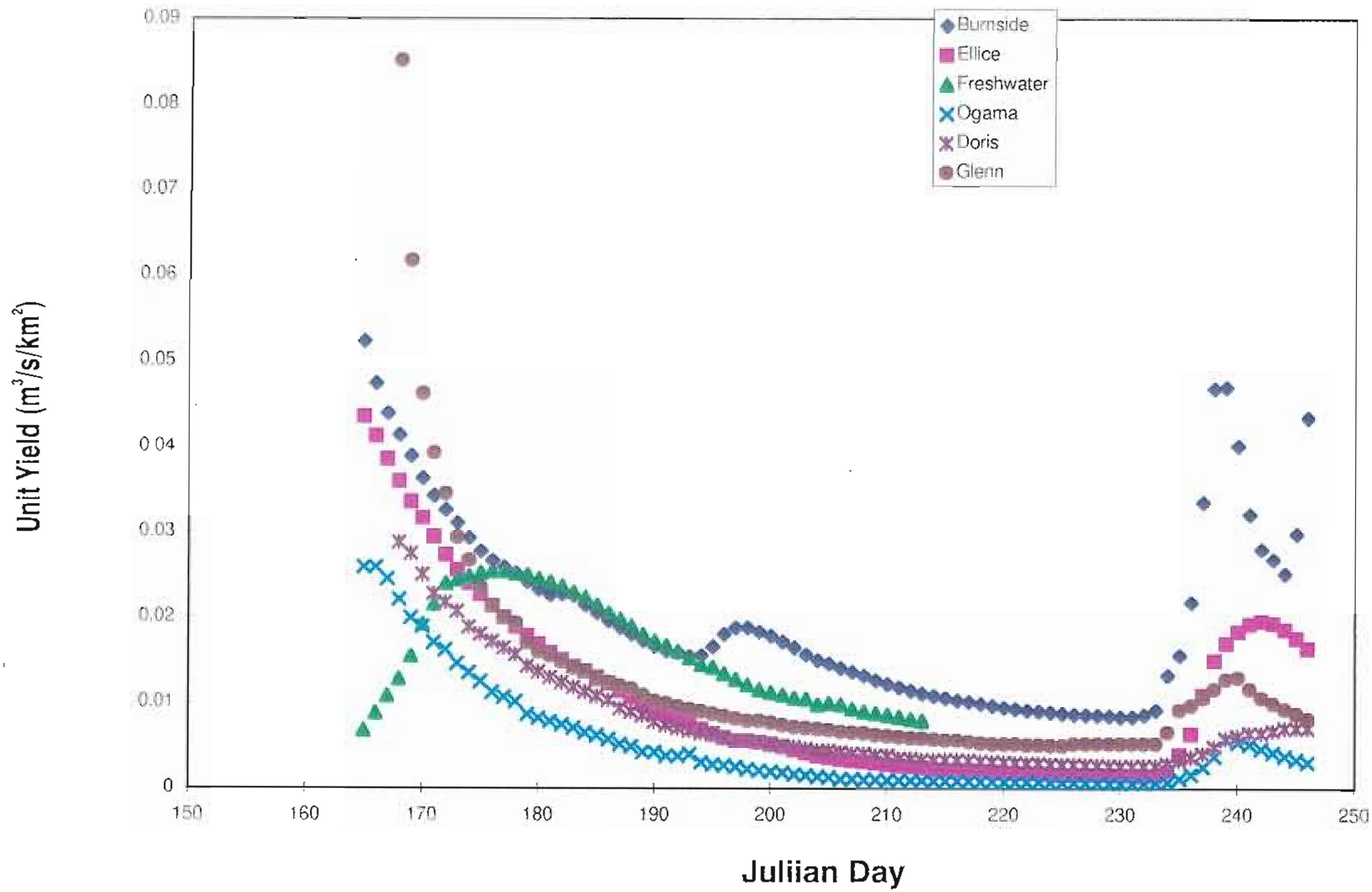

FIGURE 4.2-2

BHP

Unit Yield for Site Specific and Regional Catchments

Rescan

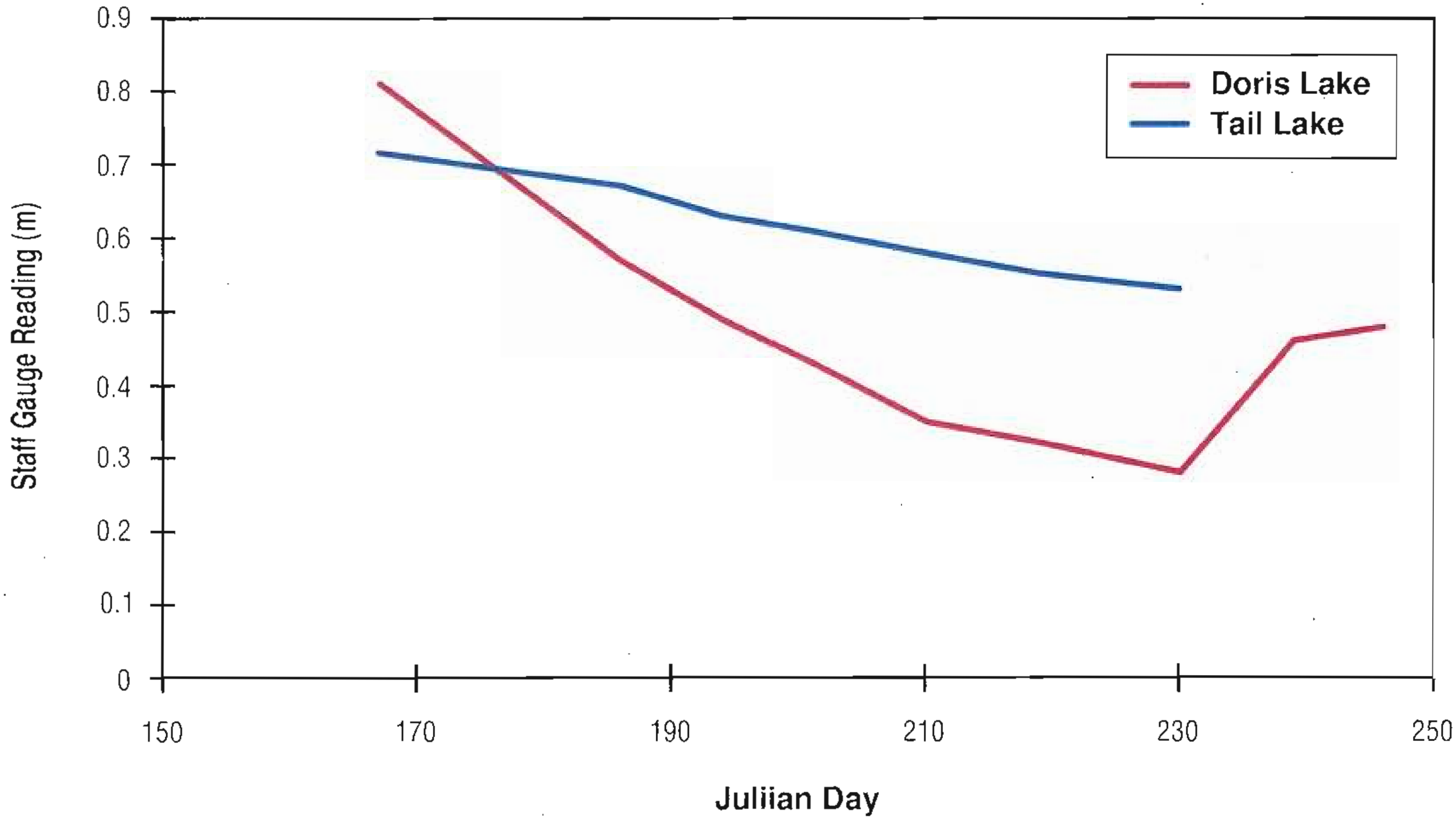

FIGURE 4.2-3

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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)

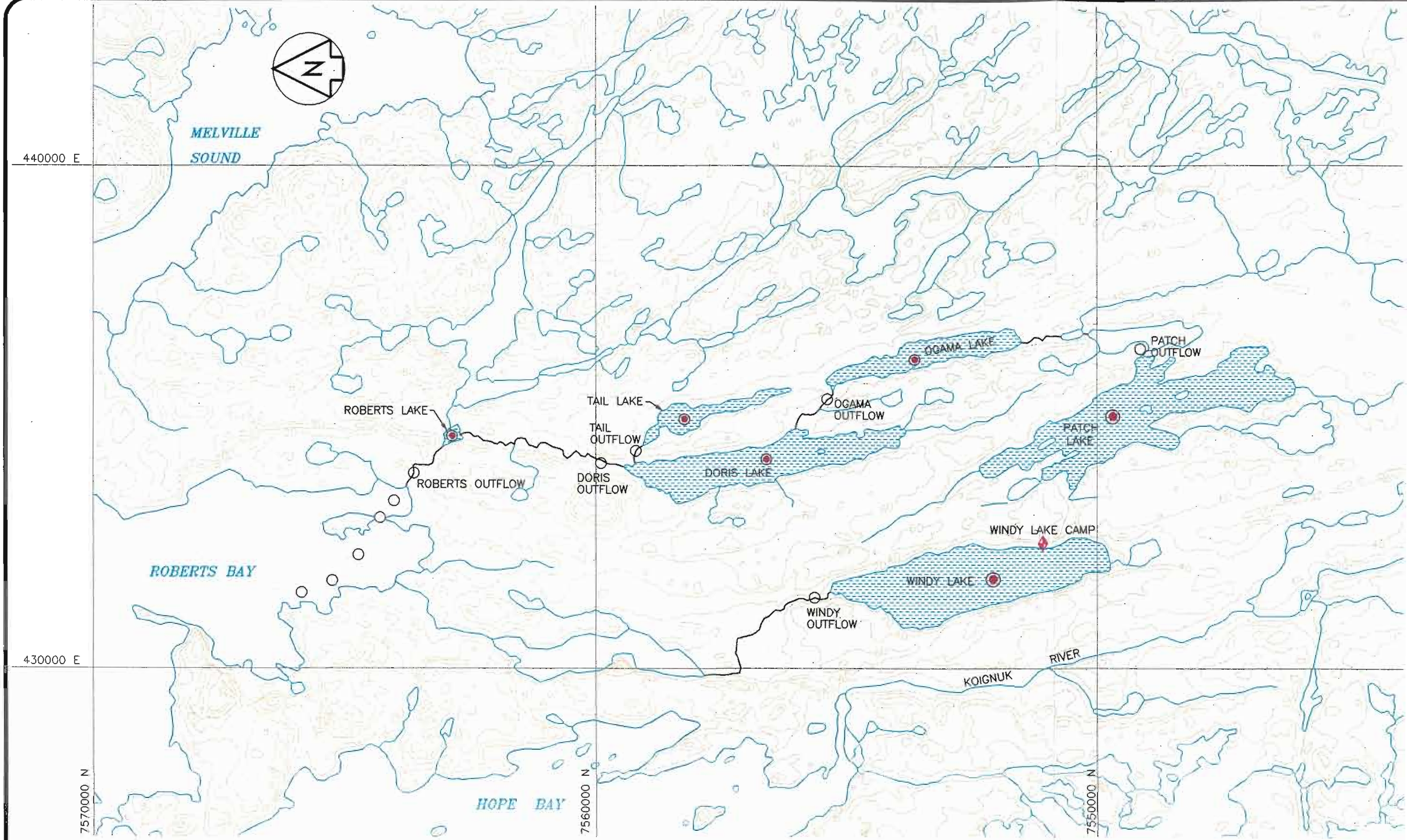
Parameter	Trout Outflow June 22	Trout Outflow Aug. 5	Trout Outflow Aug. 25	Stickleback Outflow June 22	Stickleback Outflow Aug. 5	Stickleback Outflow Aug. 25[1]	Northeast Spyder Inflow Aug. 5	Northeast Spyder Inflow Aug. 25
pH (pH units)	7.1	7.0	7.2	7.1	7.3	7.6	7.0	6.9
TSS (mg/L)	1.0	74	18	<1.0	2.0	2.0	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.



NOTE:
CONTOUR INTERVAL 20m

LEGEND:
SEDIMENT SAMPLING STATION
WATER QUALITY SAMPLING STATION
CAMP SITE

0 2500m

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).

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

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 1,350°C 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

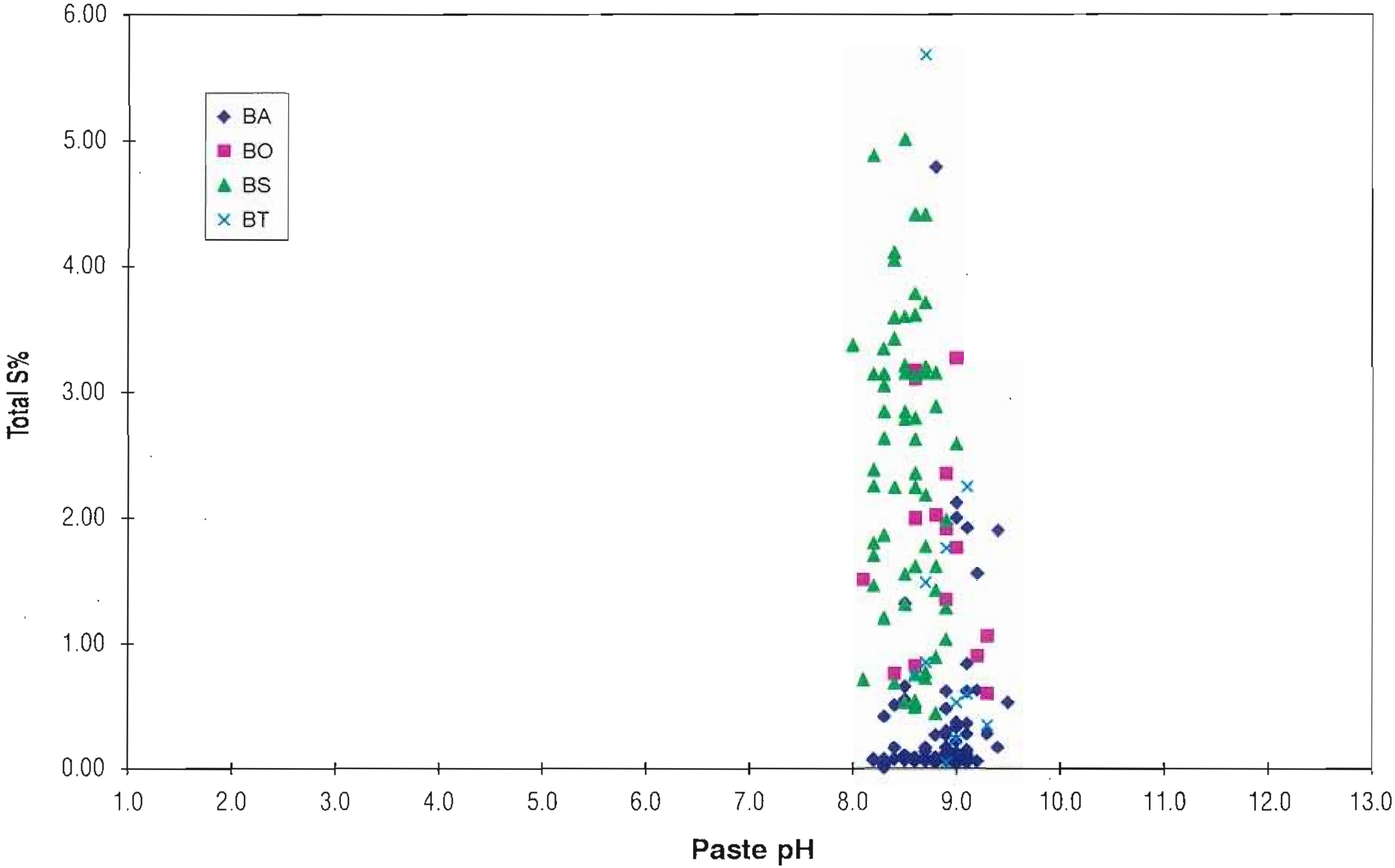


FIGURE 5.3-1

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.

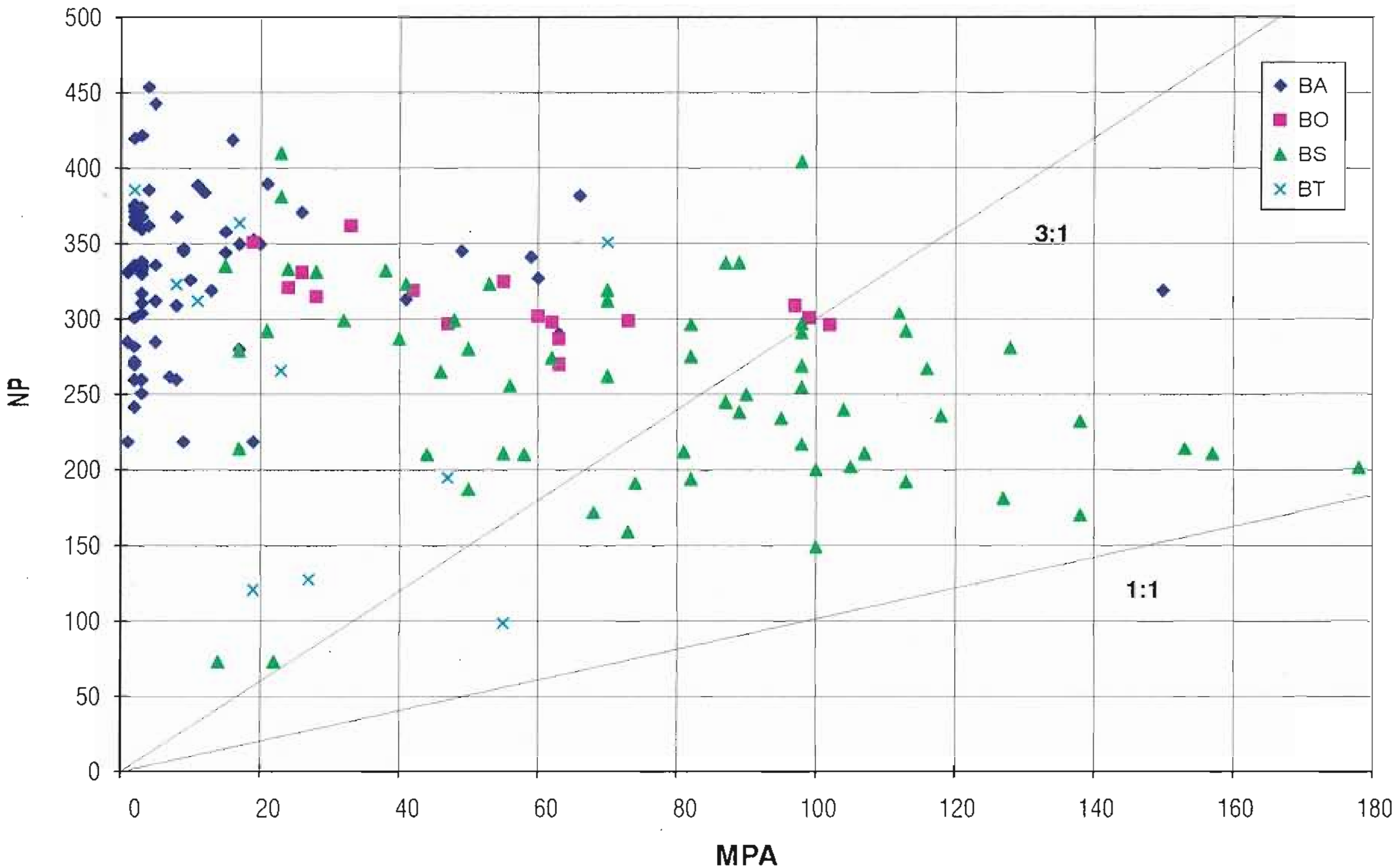


FIGURE 5.3-2

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Boston NP vs MPA

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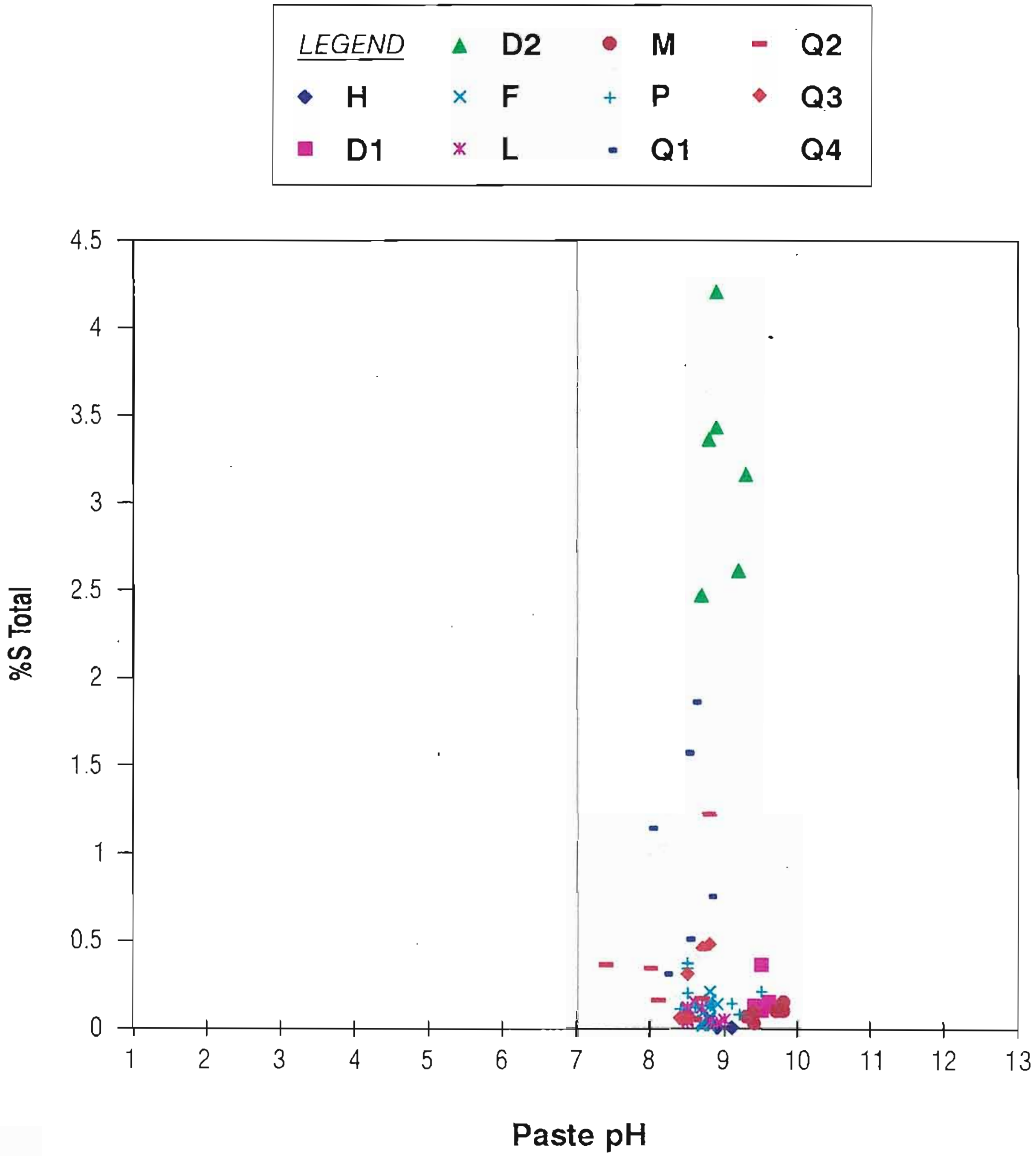
Boston Bulk Sample ARD Potential

Rescan

Fig 5.3-3



Doris Lake Percent S vs Paste pH

FIGURE 5.3-4

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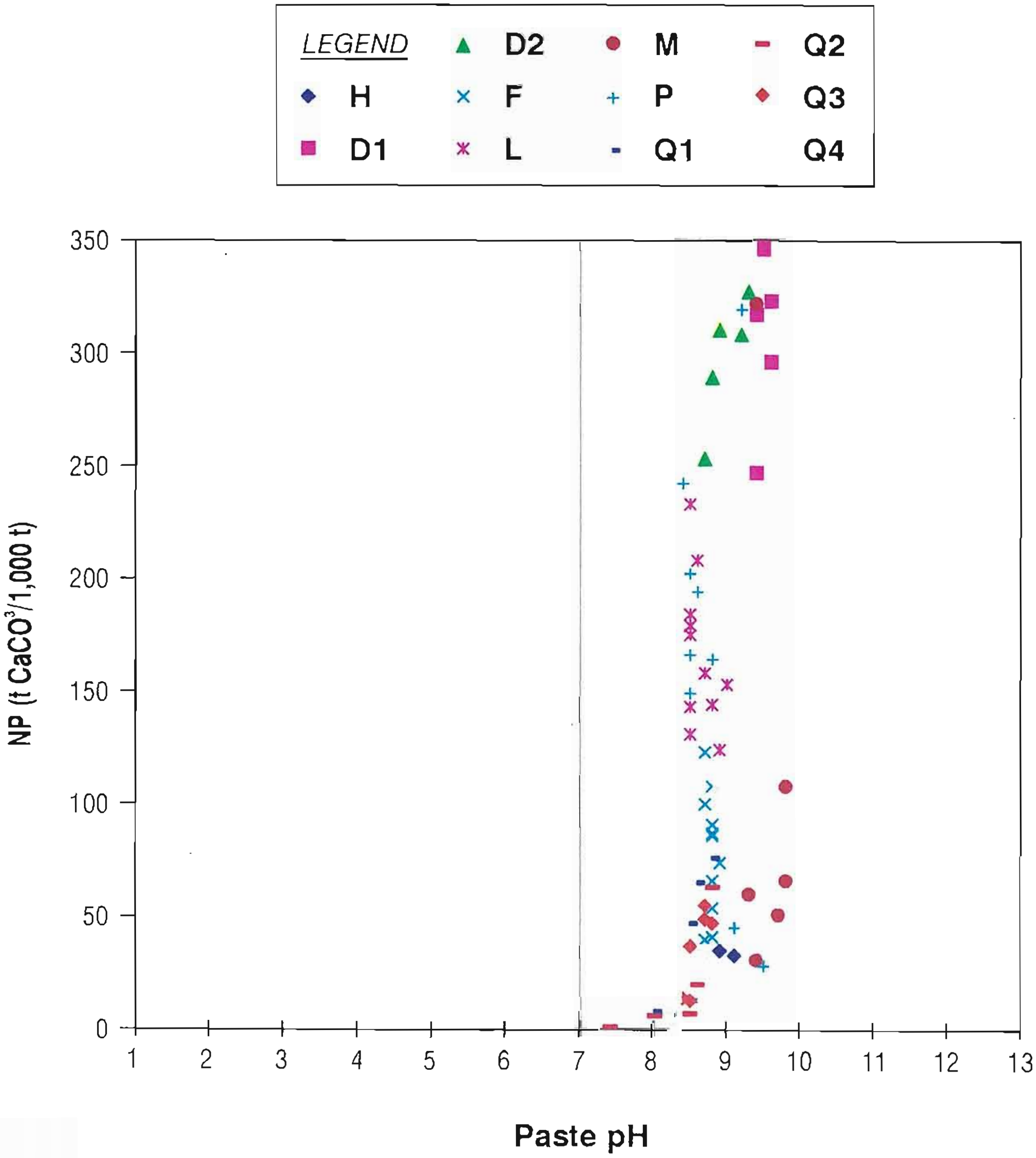

Doris Lake NP vs Paste pH

FIGURE 5.3-5

BHP

Rescan

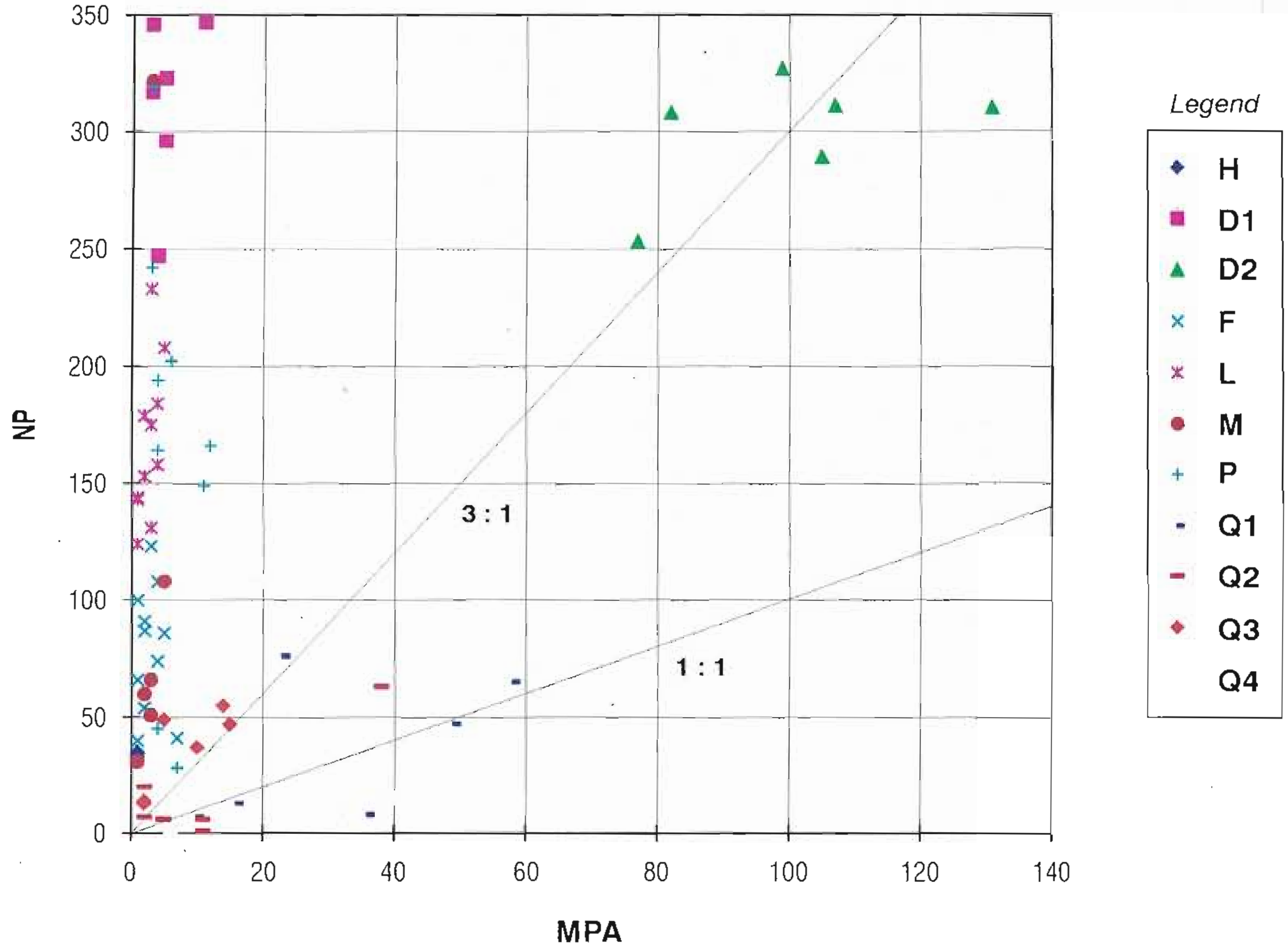

FIGURE 5.3-6

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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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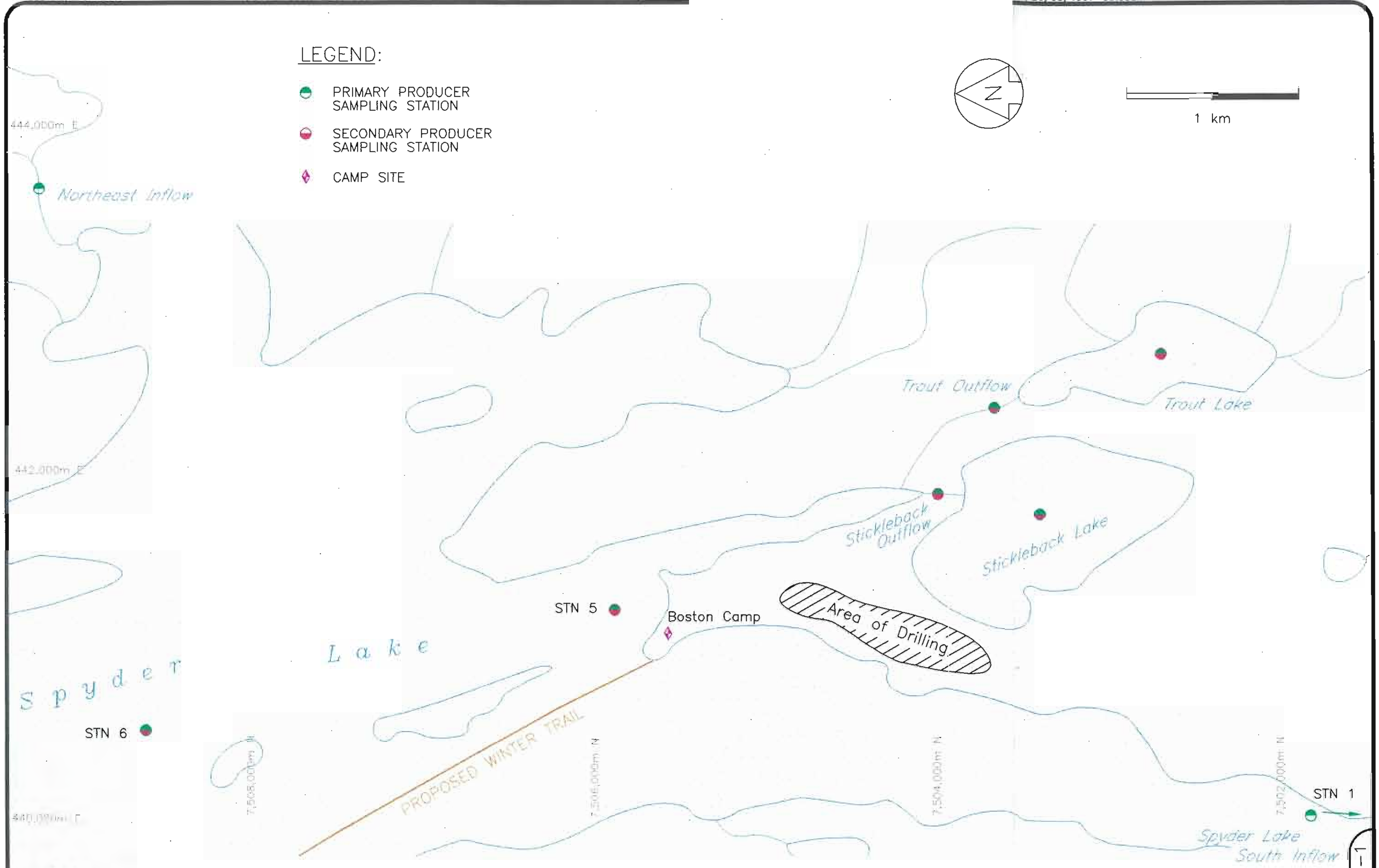

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Aquatic Biology Sampling Stations
Boston Property, 1996

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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).

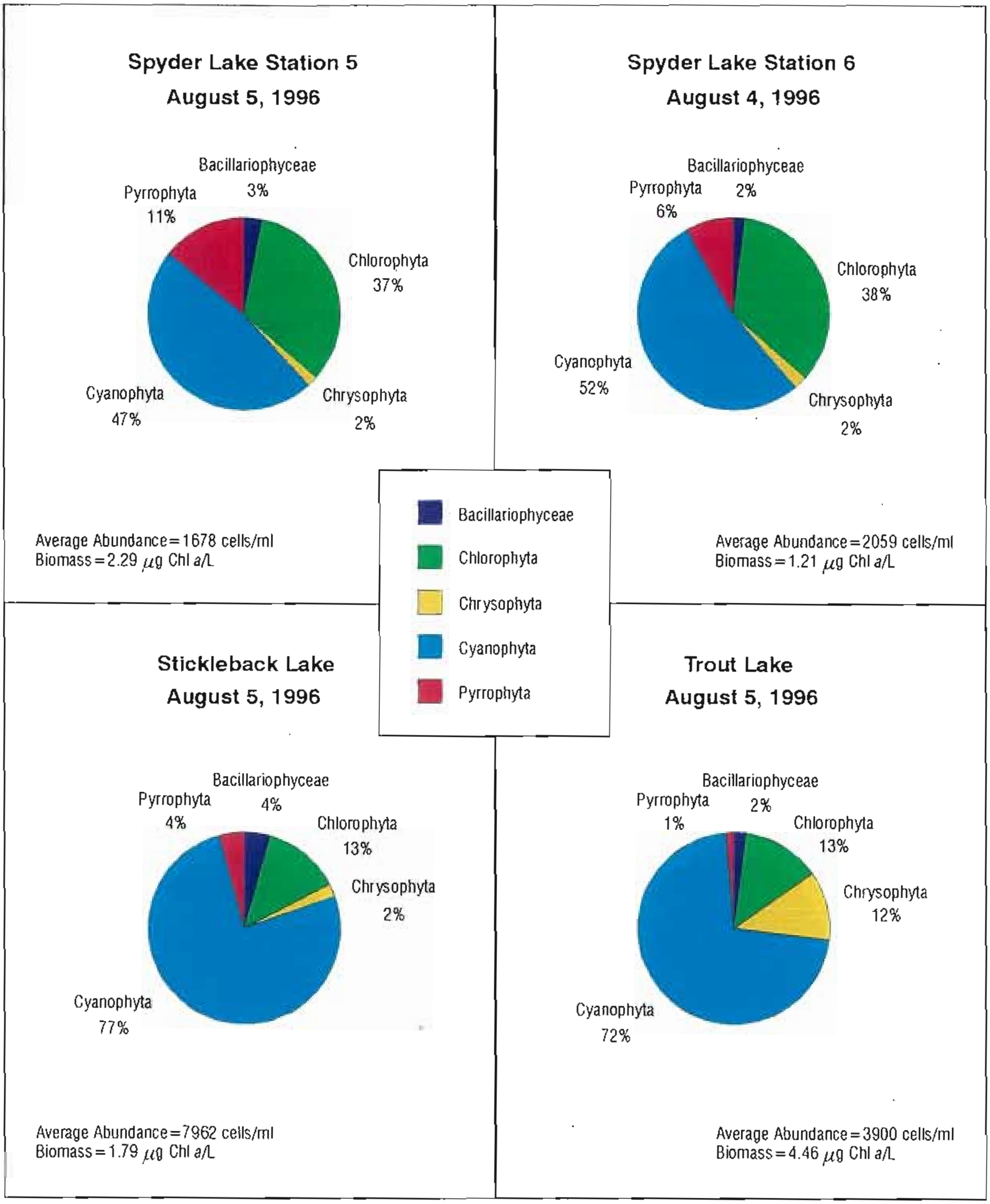
During the second sampling period (August 24, 25), the phytoplankton assemblage in Trout Lake was still dominated by cyanobacteria (77%; Figure 6.1-2b). The assemblage of Stickleback Lake, however, consisted of nearly equal proportions of diatoms (Bacillariophyceae), green algae, and cyanobacteria (~27% 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).



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

FIGURE 6.1-2a

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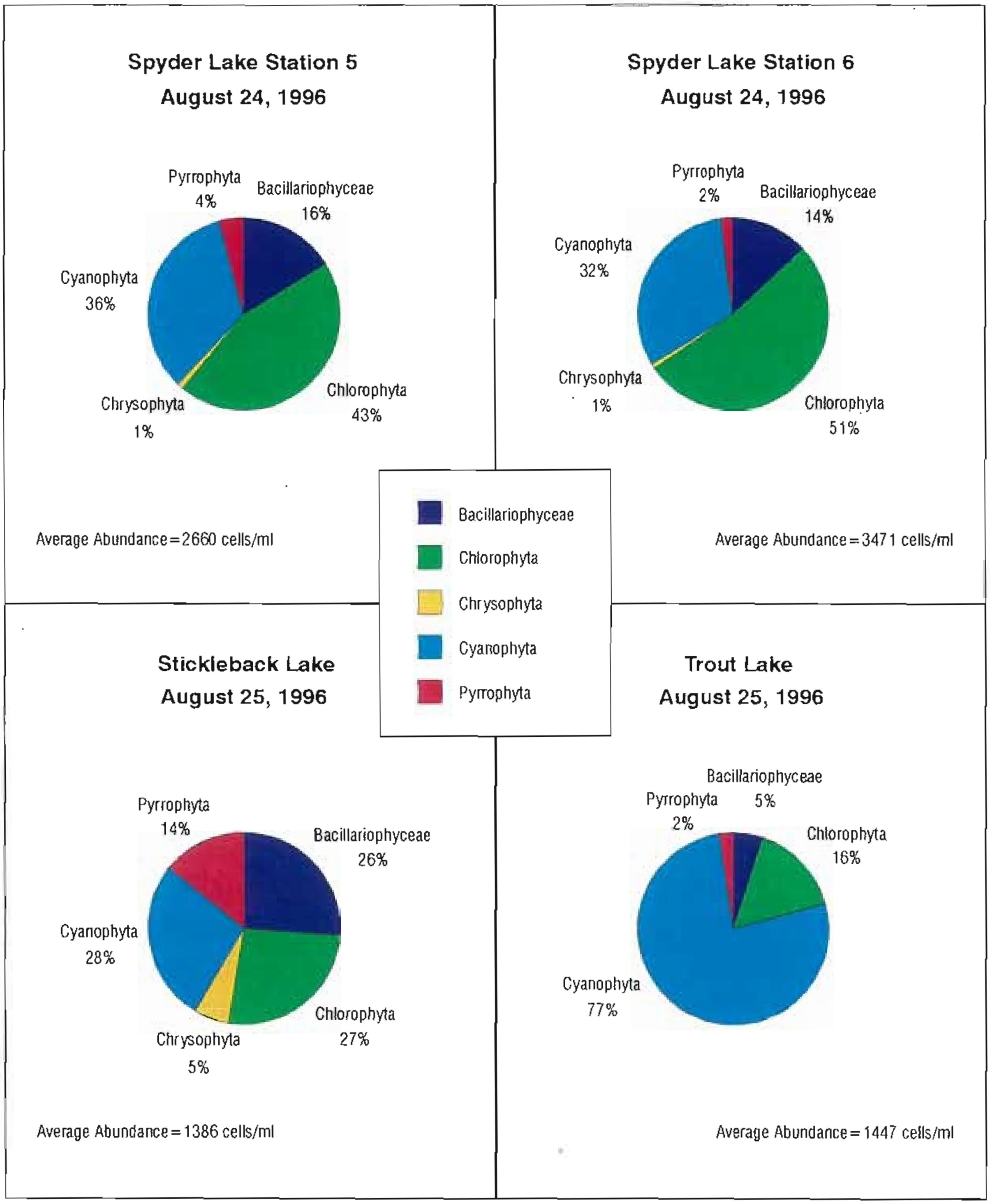

Phytoplankton Taxa Composition for Boston Property Lakes August 24-25, 1996

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	1.69×10^6	28	11	26.3	*Gomphosphaeria*	2.34
Spyder, Stn. 6 August 4, 1996	n = 3	2.06×10^6	22	9	25.5	*Gomphosphaeria*	2.26
Stickleback Lake August 5, 1996	n = 3	7.96×10^6	20	8	70.2	*Anacystis*	1.37
Trout Lake August 5, 1996	n = 3	3.90×10^6	27	6	60.8	*Anabaena*	1.54
Spyder, Stn. 5 August 24, 1996	n = 3	2.66×10^6	29	14	23.5	*Crucigenia*	2.53
Spyder, Stn. 6 August 24, 1996	n = 3	3.47×10^6	25	10	34.6	*Crucigenia*	2.22
Stickleback Lake August 25, 1996	n = 3	1.39×10^6	23	11	20.8	*Anacystis*	2.51
Trout Lake August 25, 1996	n = 3	1.45×10^6	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]

		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**
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

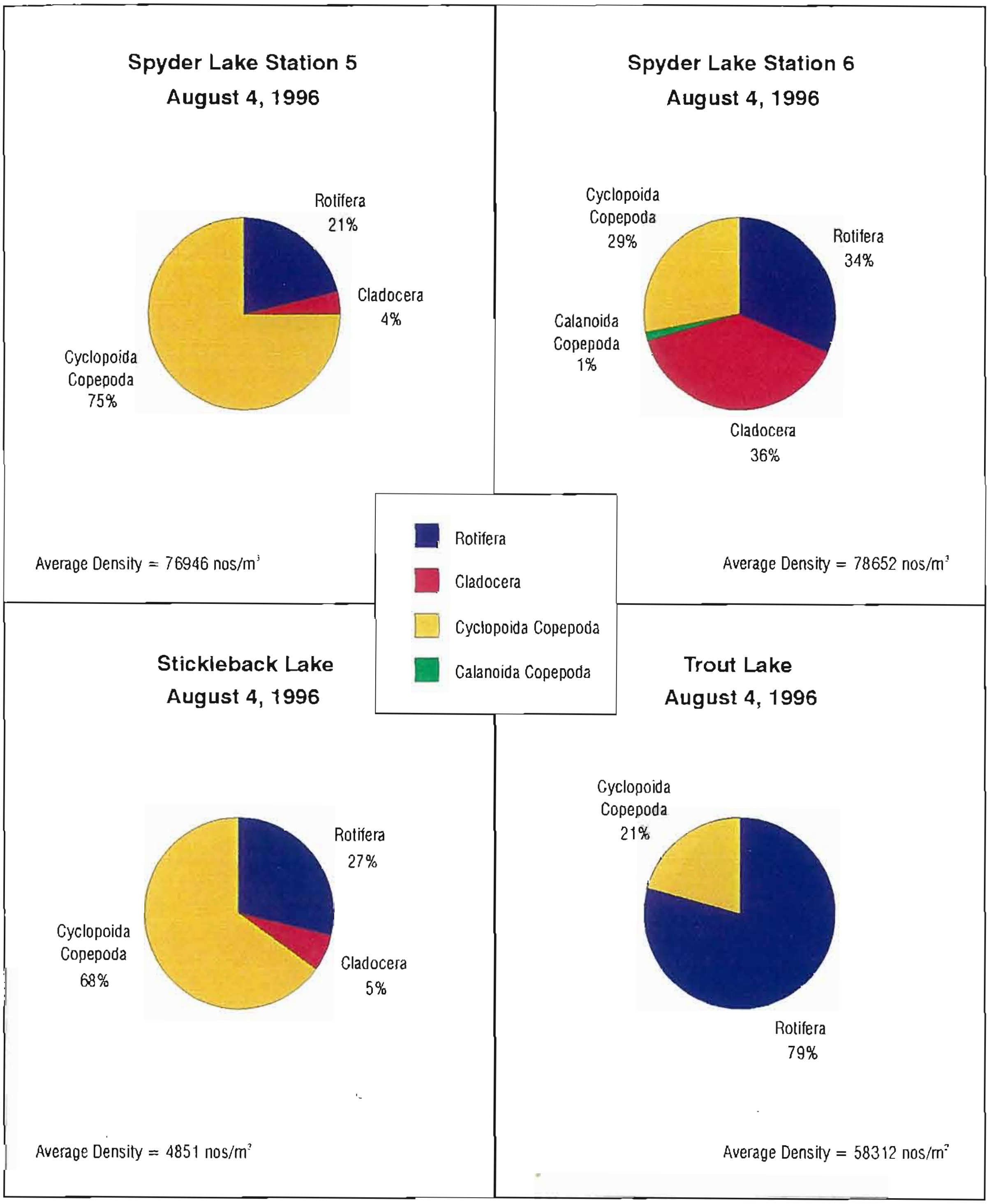
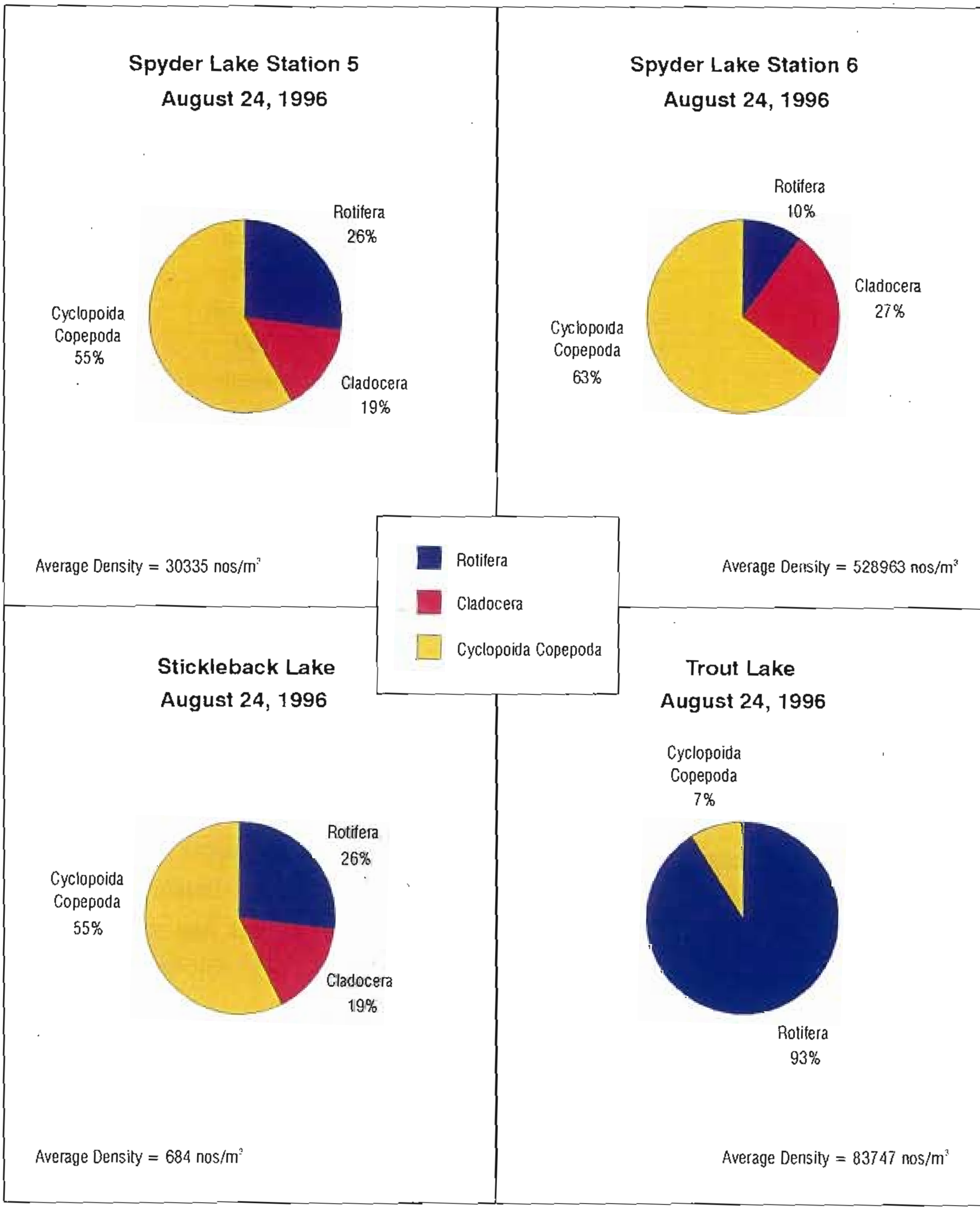


FIGURE 6.1-3

BHP

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

Rescan



BHP

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

FIGURE 6.1-4

Rescan

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.

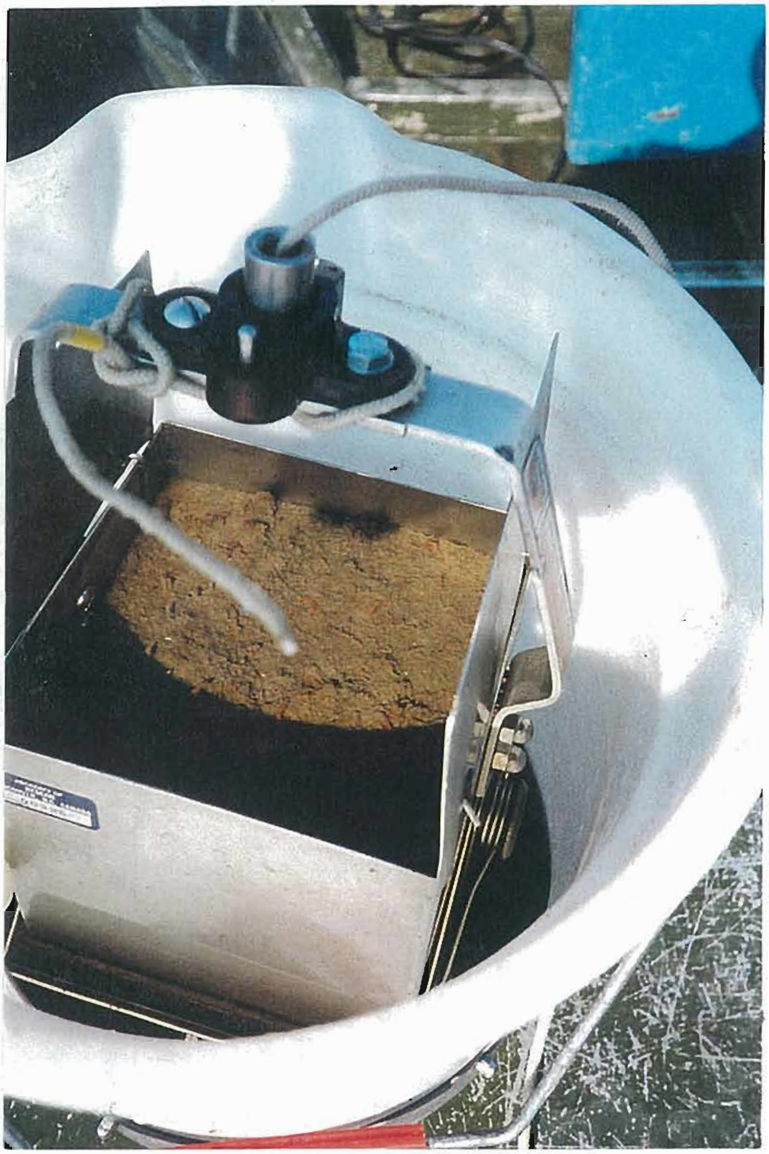


Plate 6-1: Successful sediment grab using an Ekman Sampler. Sampler was immediately placed inside a sieve bucket.

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]

Major Group	Sub-Group	Genus/Species	Spyder Lake Stn. 5 - Shallow Aug. 4	Spyder Lake Stn. 6 - Deep Aug. 4	Stickleback Lake Aug. 5	Spyder Lake Stn. 5 - Shallow Aug. 24	Spyder Lake Stn. 6 - Deep Aug. 24	Stickleback Lake 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						+

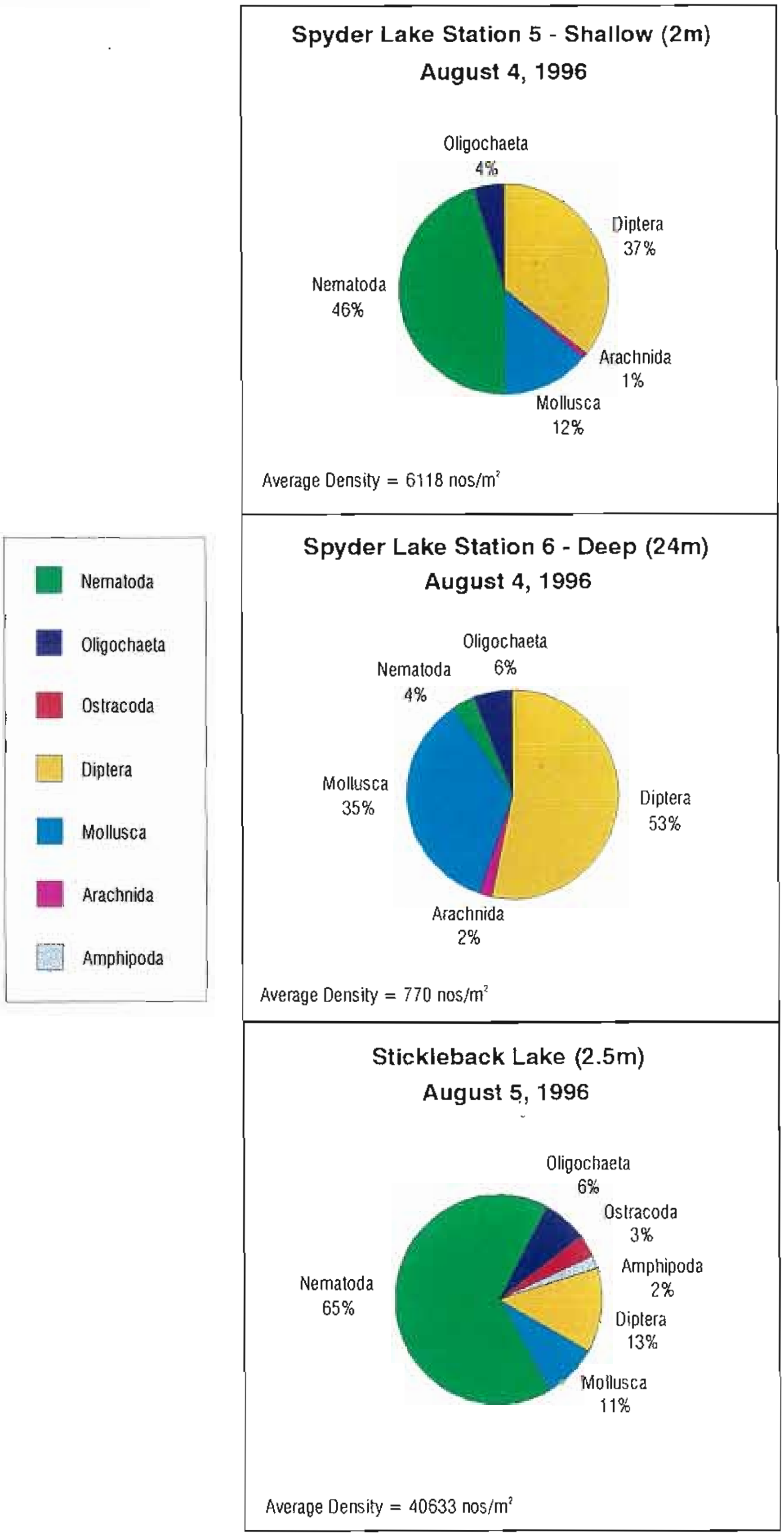
1: + sign indicates taxa as present at sampling site.

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.



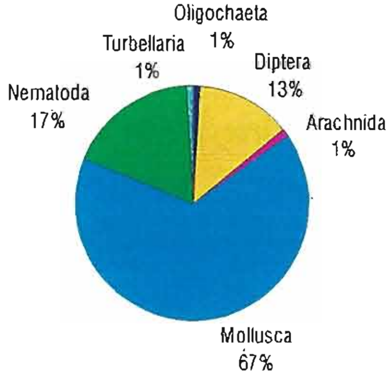
Taxonomic Composition of Lake Benthos Samples, Boston Property, Summer 1996

FIGURE 6.1-5

BHP

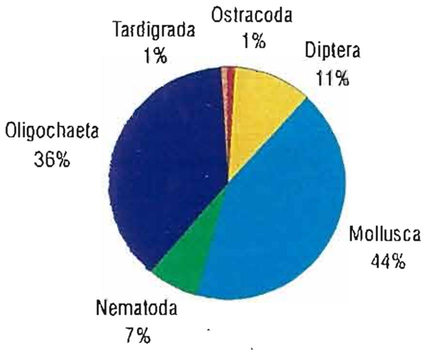
Rescan

Spyder Lake Station 5 - Shallow (2m)
August 24, 1996



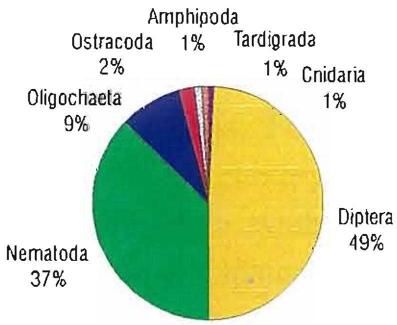
Average Density = 5331 nos/m²

Spyder Lake Station 6 - Deep (24m)
August 24, 1996

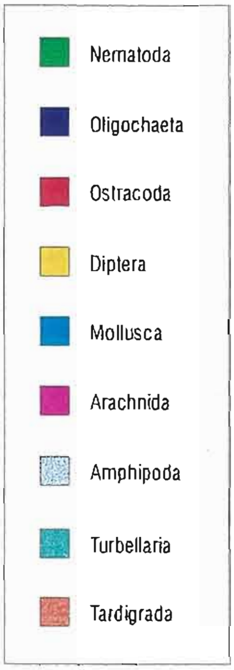


Average Density = 2029 nos/m²

Stickleback Lake
August 25, 1996



Average Density = 16678 nos/m²



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

FIGURE 6.1-6

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Rescan

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		
	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 x 10^5	1.78 x 10^5	3.51 x 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

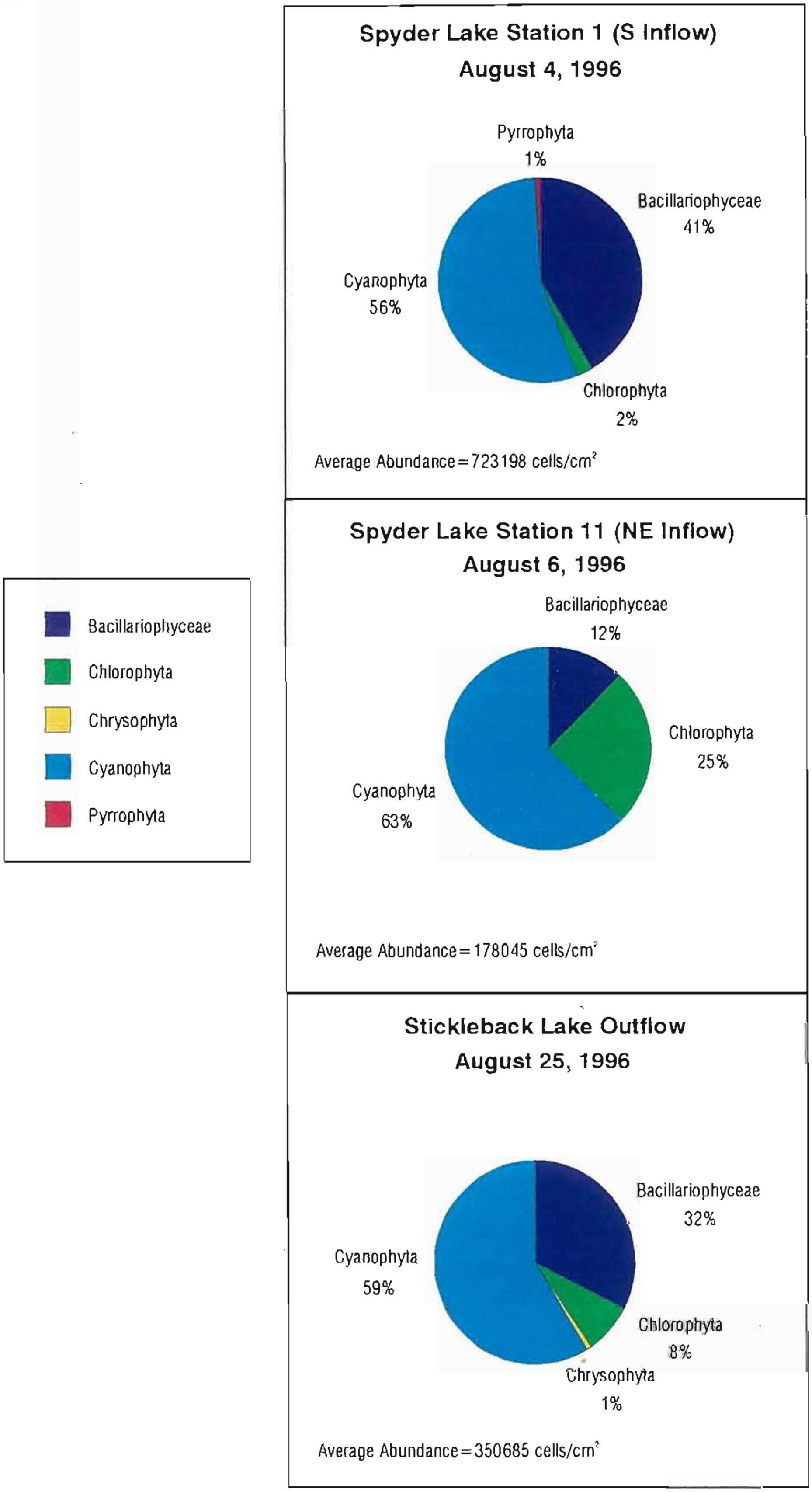

FIGURE 6.1-7

Periphyton Taxa Composition for Boston Property Streams August 1996

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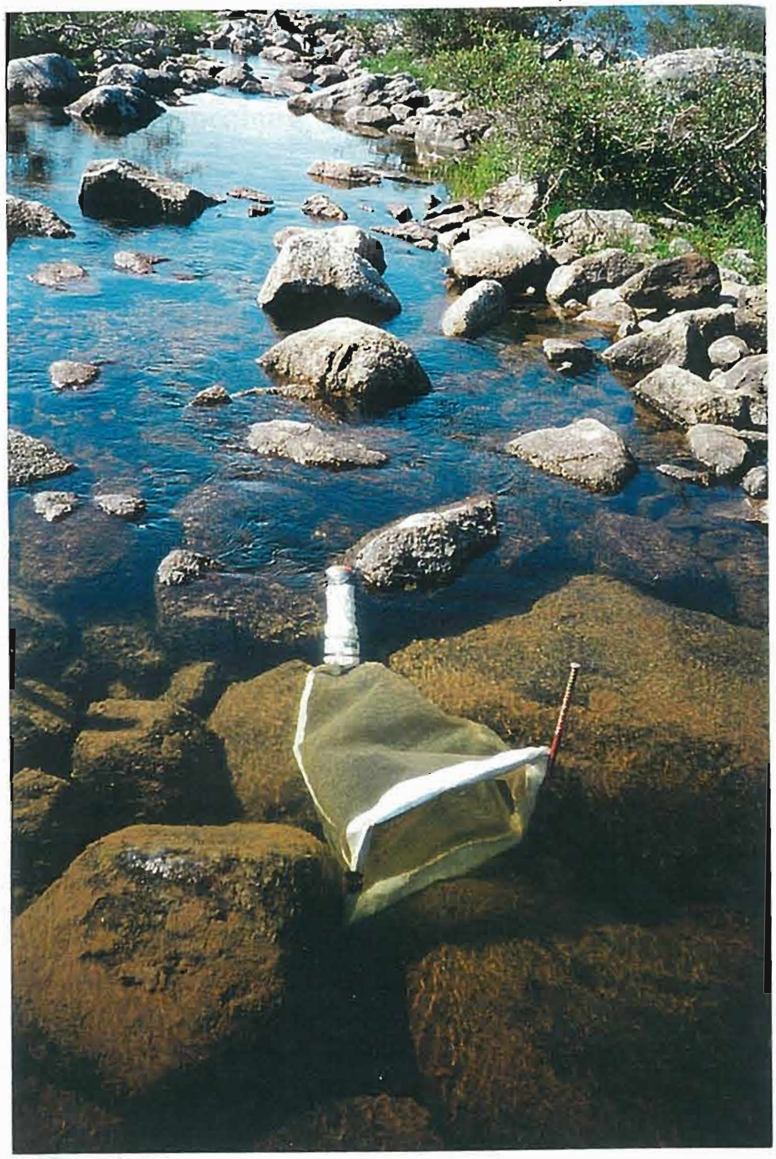


Plate 6-2: Larval drift net placed in flowing steam.

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.

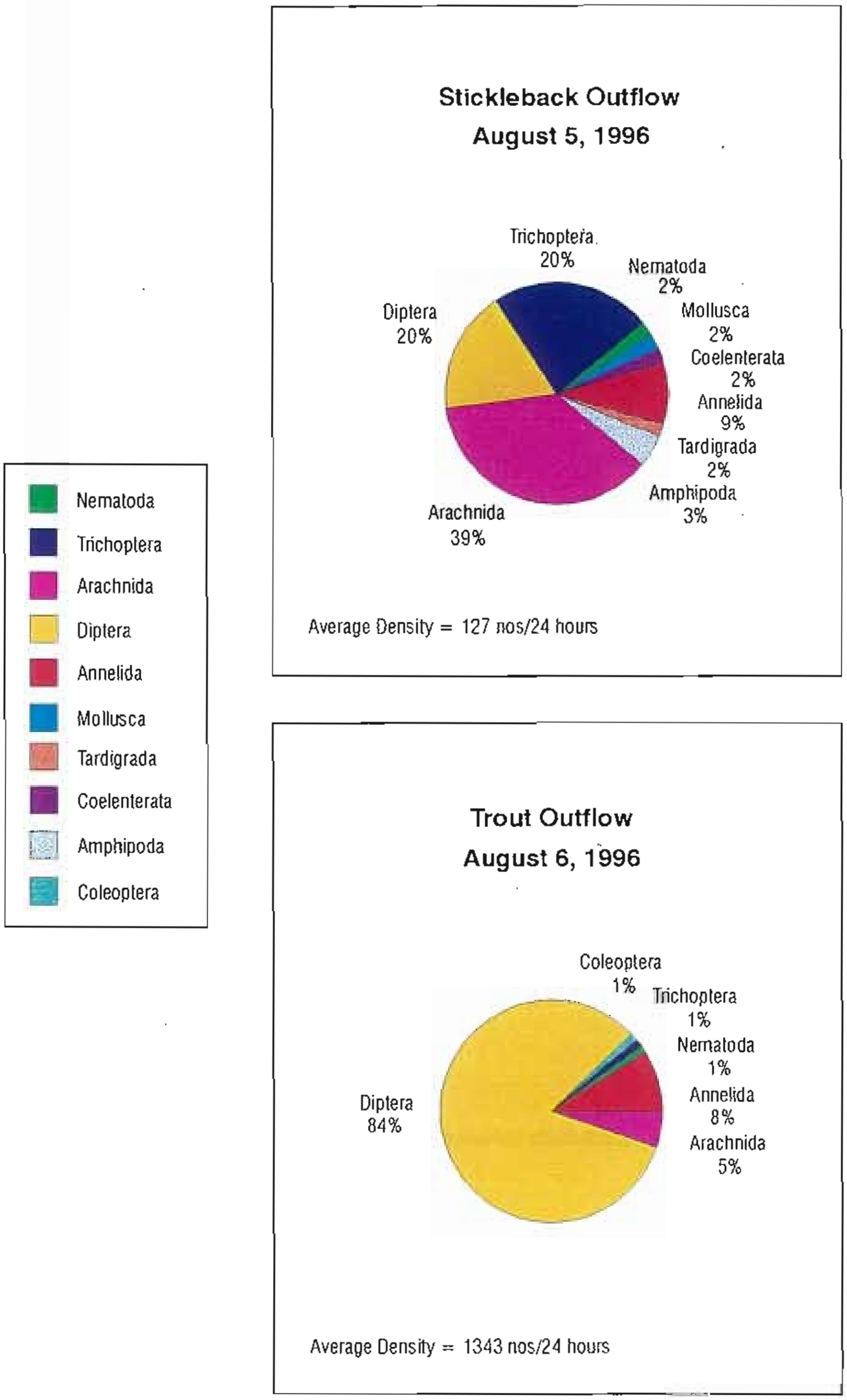


FIGURE 6.1-8

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

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

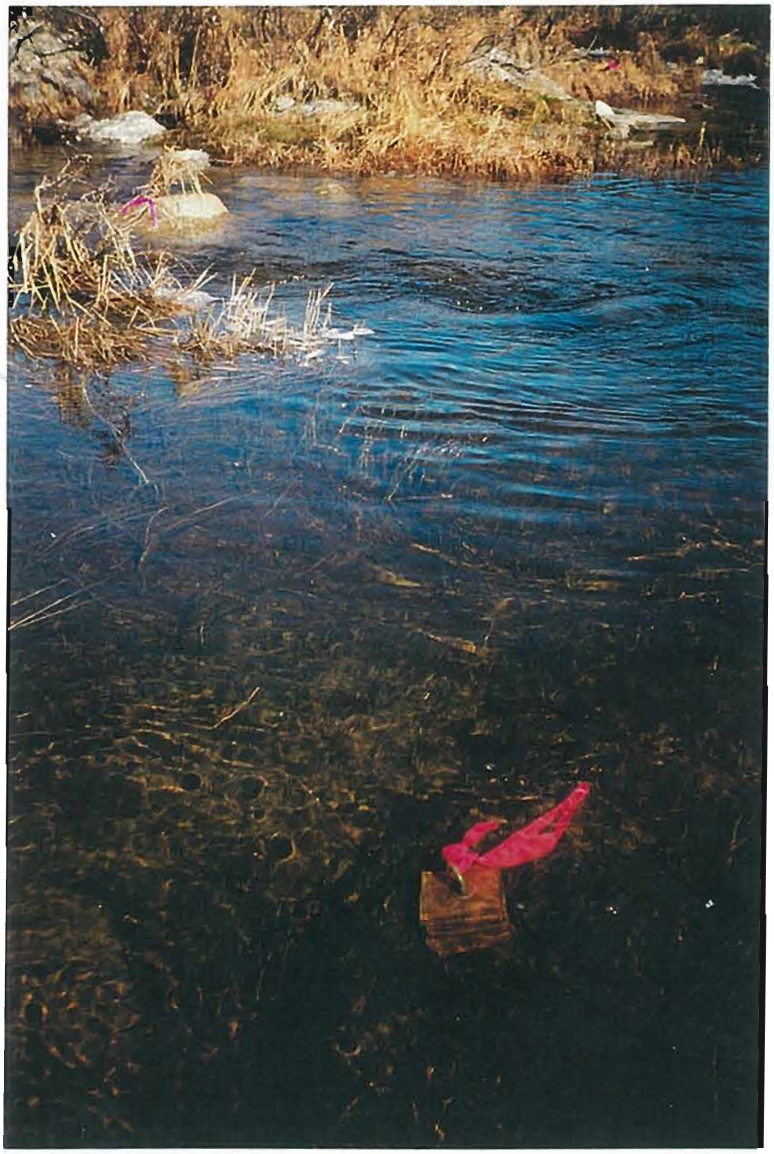
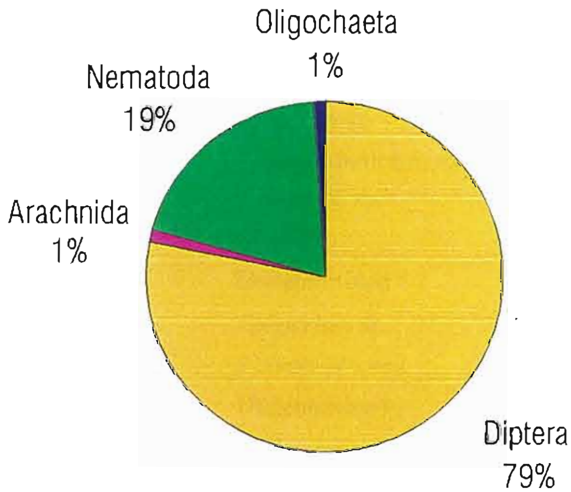


Plate 6-3b: Hester-Dendy artificial substrate sampler placed in flowing water.

Stickleback Lake Outflow

August 25, 1996



Average Density = 963 nos/m^2

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

FIGURE 6.1-9

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 x 10^6 cells/L (Table 6.2-1).

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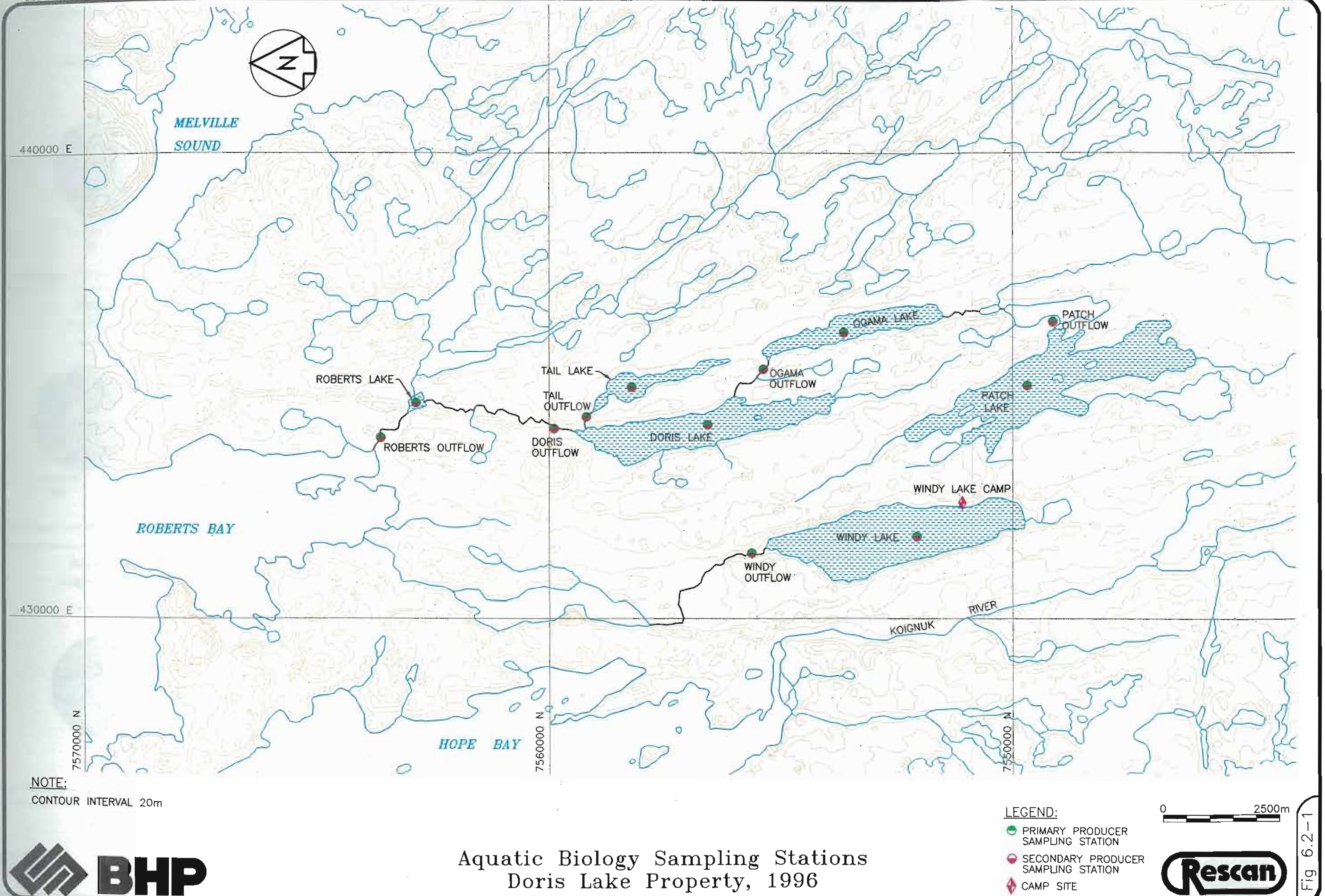
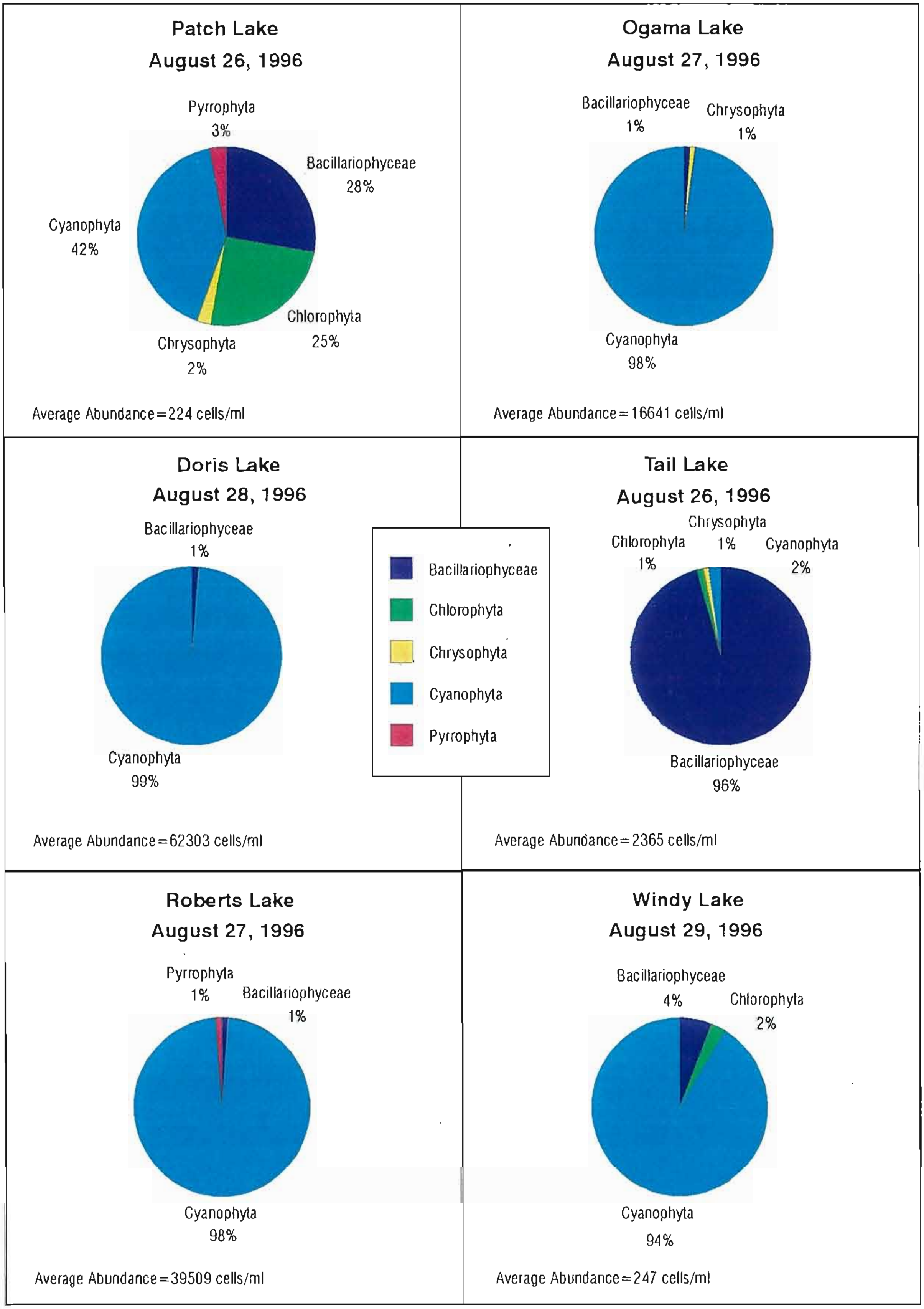


Aquatic Biology Sampling Stations
Doris Lake Property, 1996

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



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

FIGURE 6.2-2

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 August 26, 1996	n = 3	224	24	12	31.0	*Lyngbya*	2.25
Ogama August 27, 1996	n = 3	16,641	13	1	93.3	*Oscillatoria*	0.37
Doris August 28, 1996	n = 3	62,303	12	2	74.4	*Oscillatoria*	0.74
Tail August 27, 1996	n = 3	2,365	14	1	91.9	*Asterionella*	0.44
Roberts August 27, 1996	n = 3	39,509	17	3	60.8	*Oscillatoria*	1.07
Windy 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]

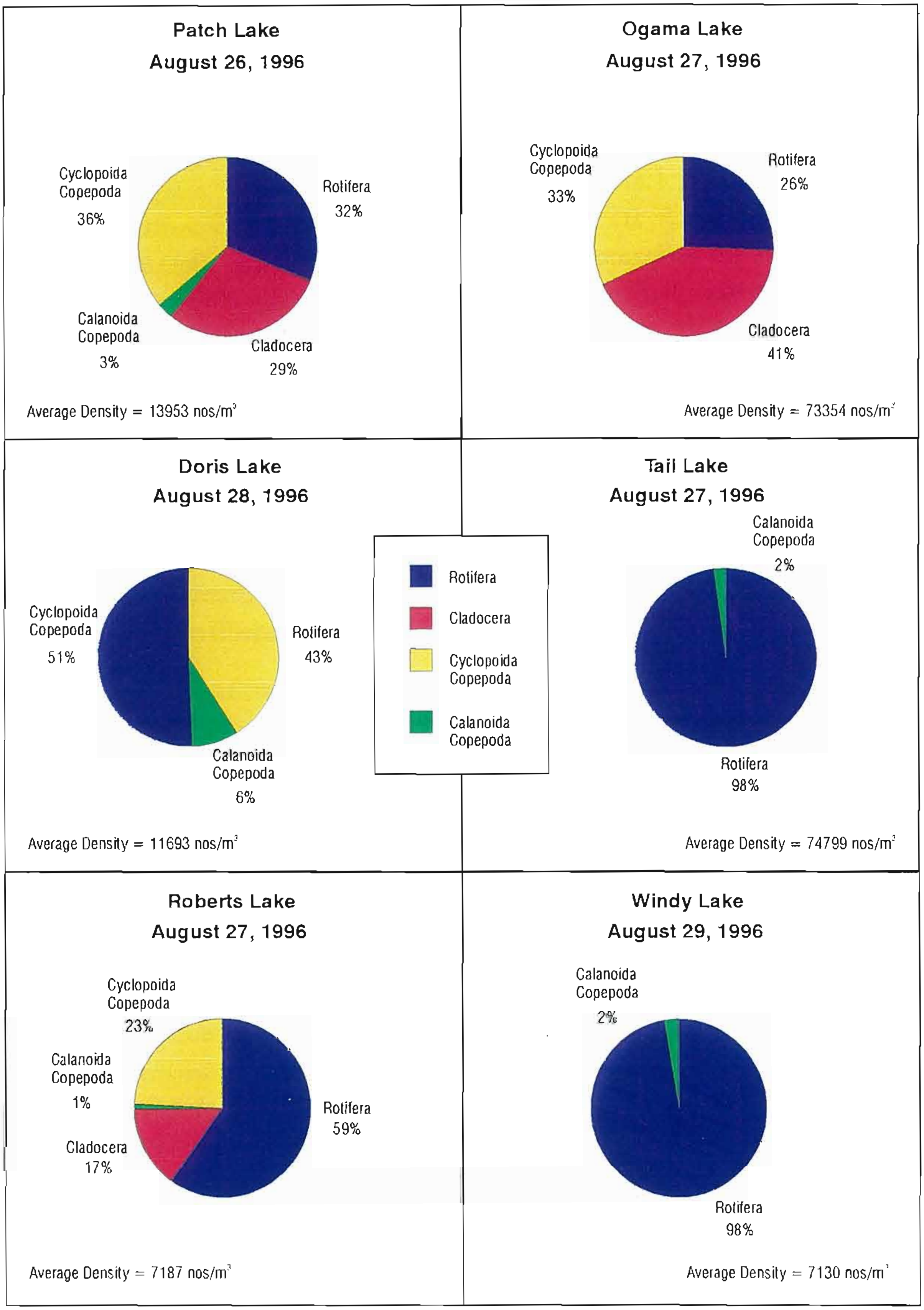
Group/Genus	Stage[2]	Patch Lake Aug. 26	Ogama Lake Aug. 27	Doris Lake Aug. 28	Tail Lake Aug. 27	Roberts Lake Aug. 27	Windy Lake Aug. 29
Cyclops scutifer	M			+	+		
	F			+	+	+	
Cyclopoida	cop.	+	+	+	+	+	+
Lichomolgidae (parasitic)	cop.					+	
	nauplius		+	+	+	+	+

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)

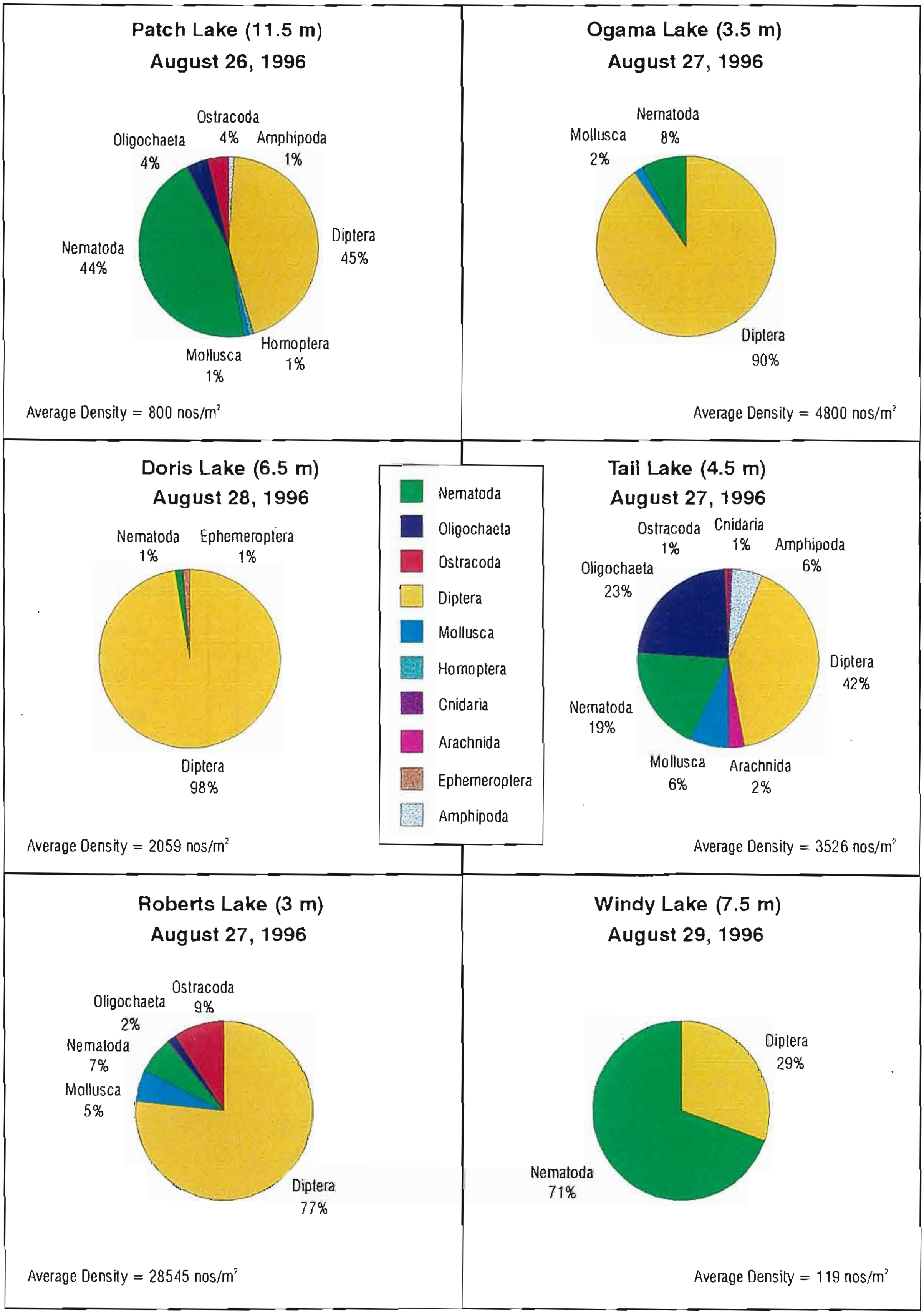
Methods

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

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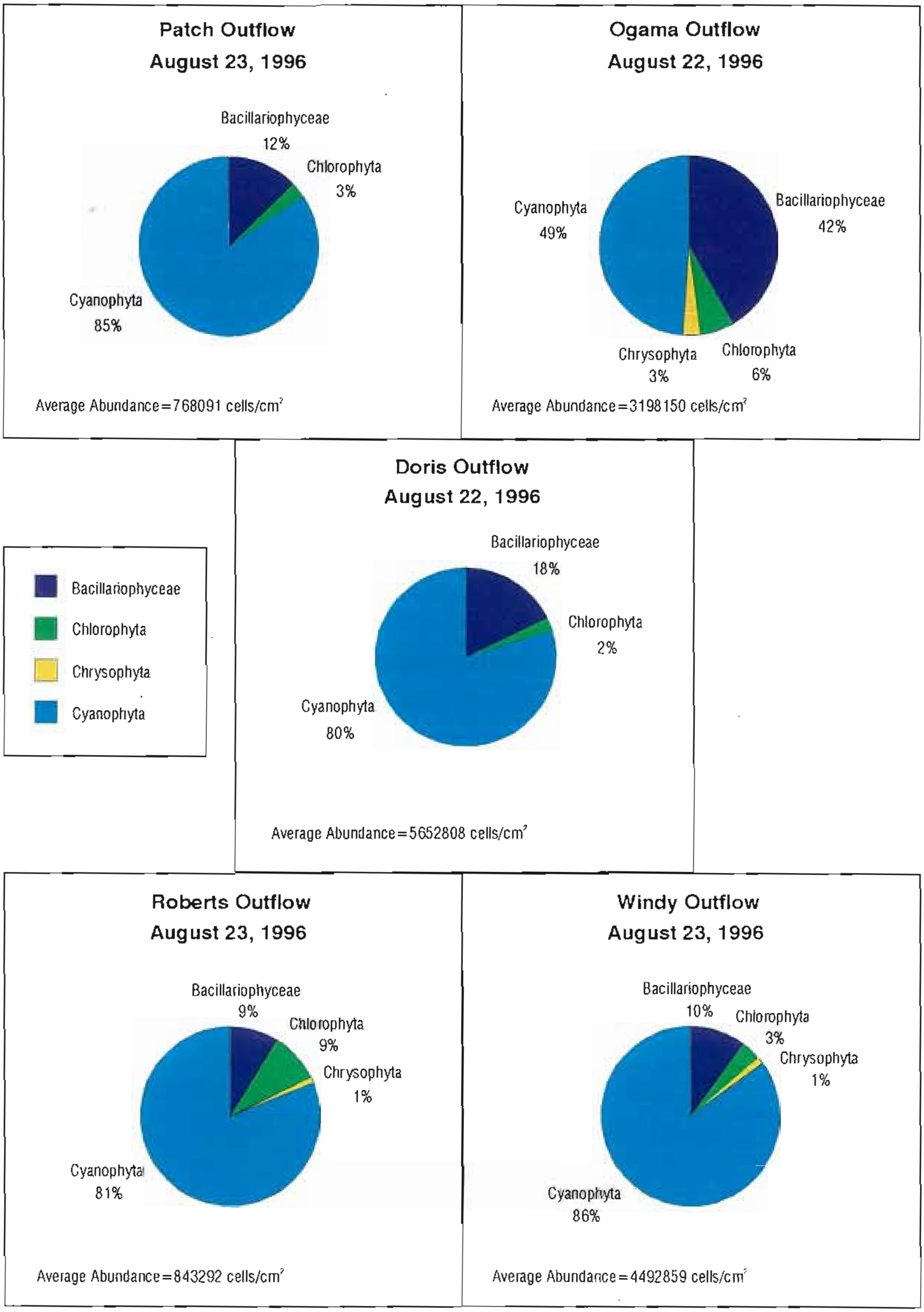


Periphyton Taxa Composition for Doris Lake Property Streams August 22-23, 1996

FIGURE 6.2-5

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)	7.68×10^5	31.98×10^5	56.53×10^5	8.43×10^5	44.92×10^5

Patch Outflow had the lowest periphyton abundance of the five streams, with a cell density of 7.68×10^5 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 56.53×10^5 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.

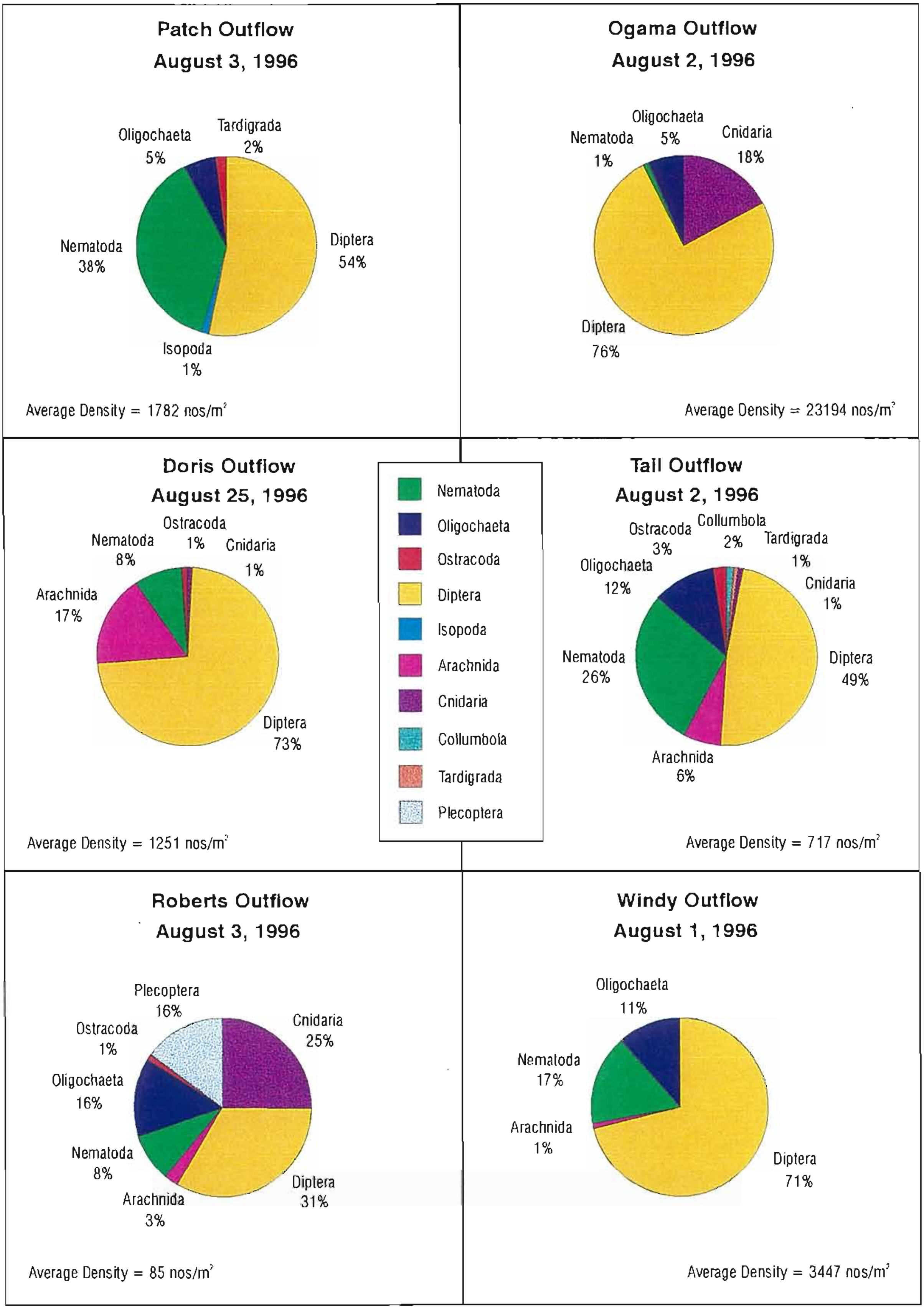
The dipteran community in Roberts Outflow was the most diverse according to the Shannon Diversity Indices (H' = 1.48; Table 6.2-10). The order of the diversity was as follows:

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,

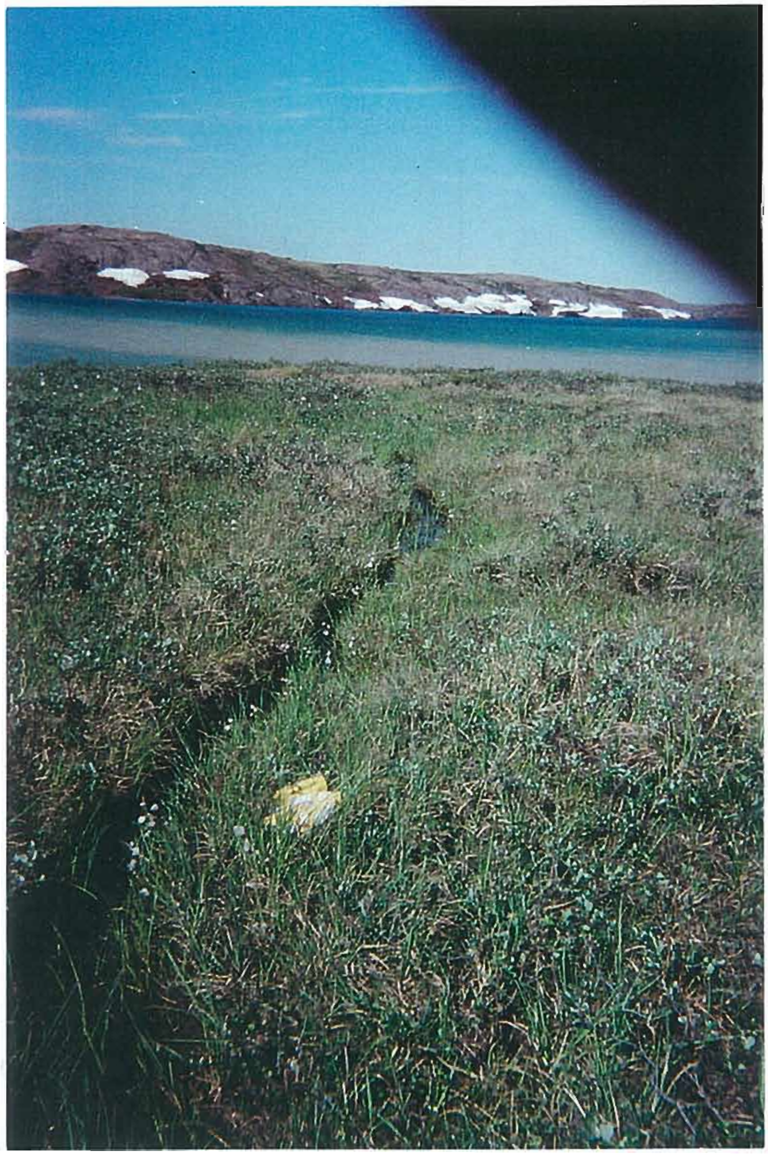


Plate 7-1: This photograph illustrates a typical ephemeral (run-off) stream, here shown flowing into Patch Lake. Numerous such streams are found throughout the Hope Bay Belt Area.

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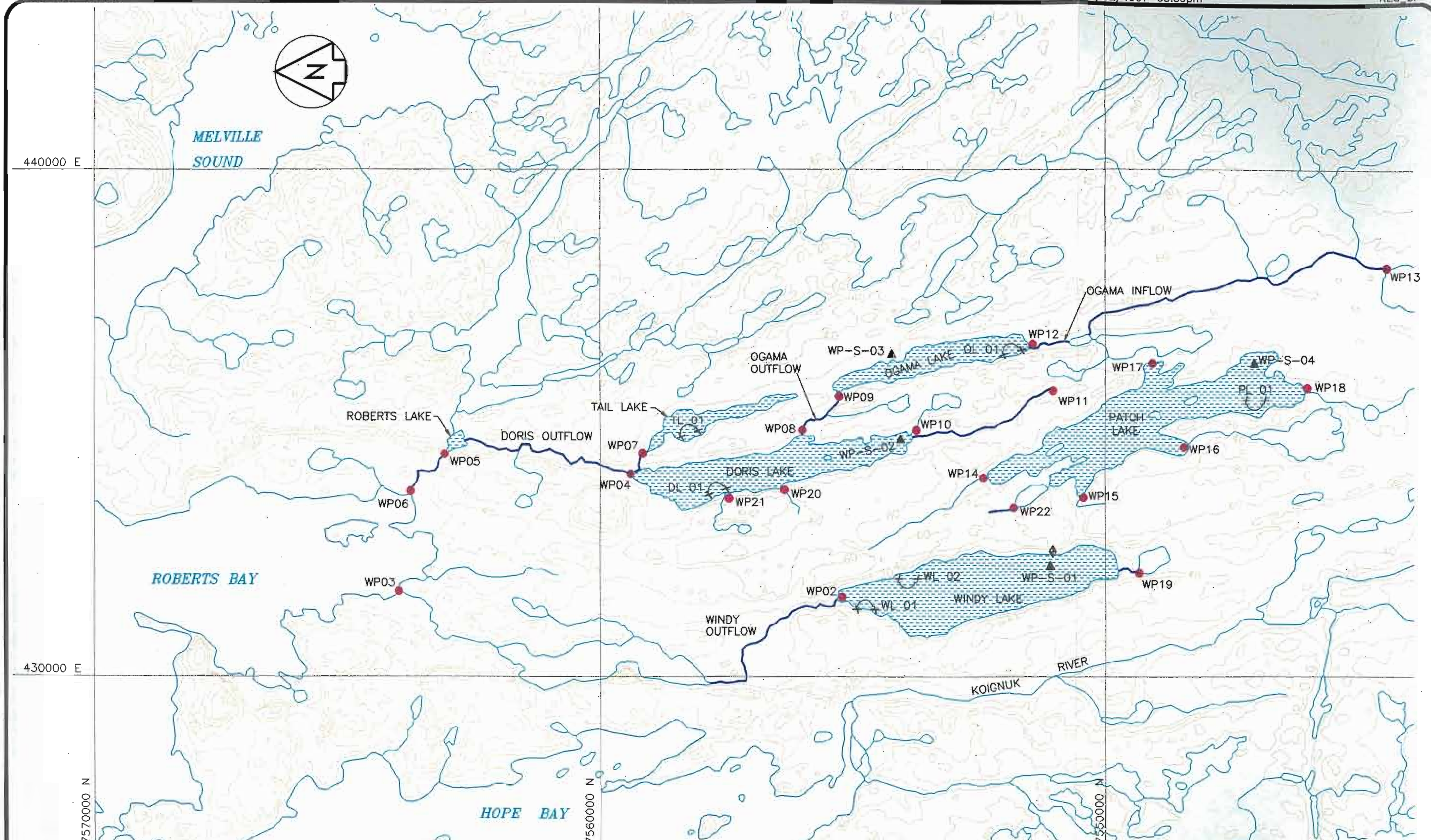


NOTE:
CONTOUR INTERVAL 20m

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

0 — 2500m

BHP

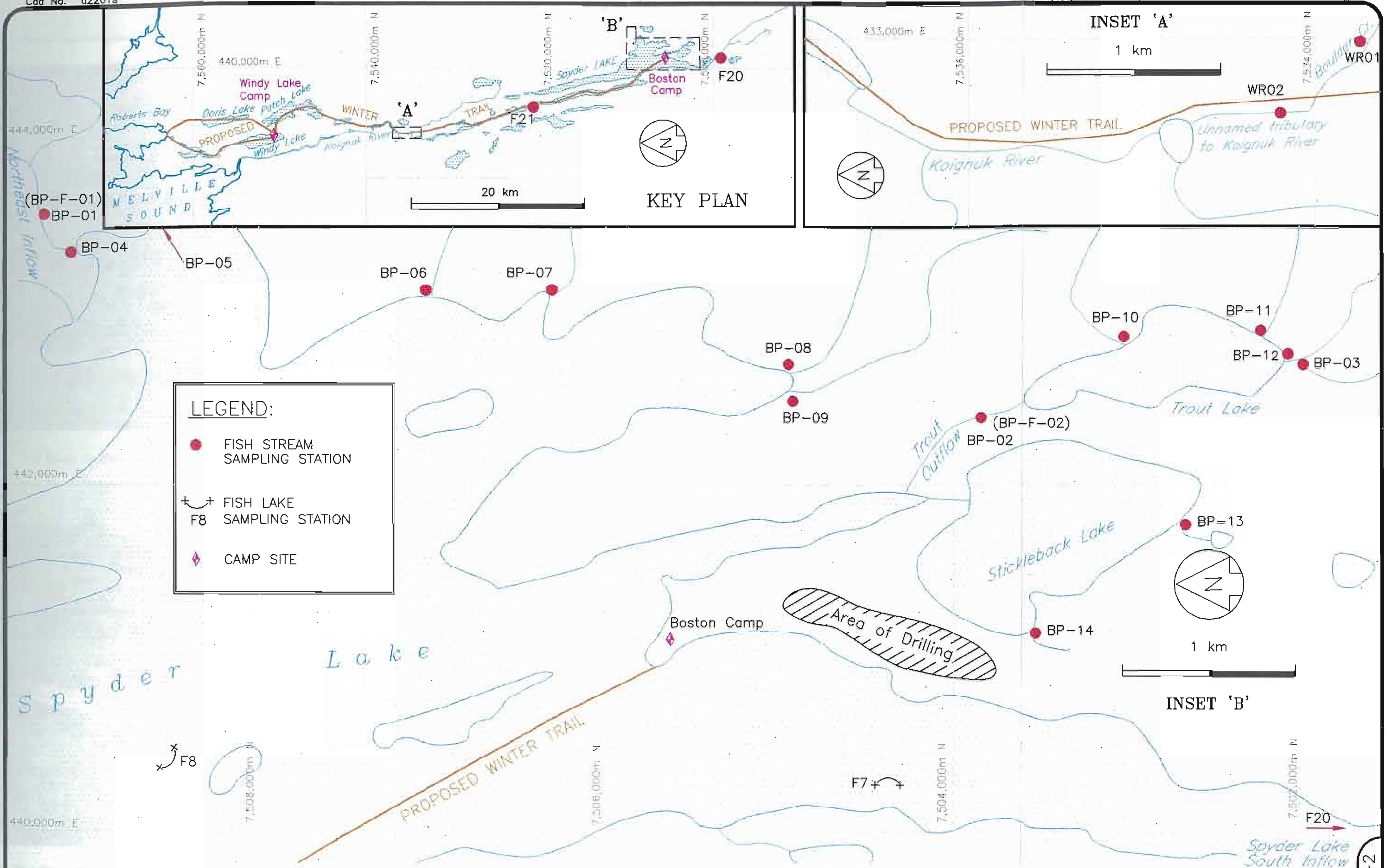
Fisheries Sampling Stations
Doris Lake Property, 1996

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



Fisheries Sampling Stations
Boston Property, 1996

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.

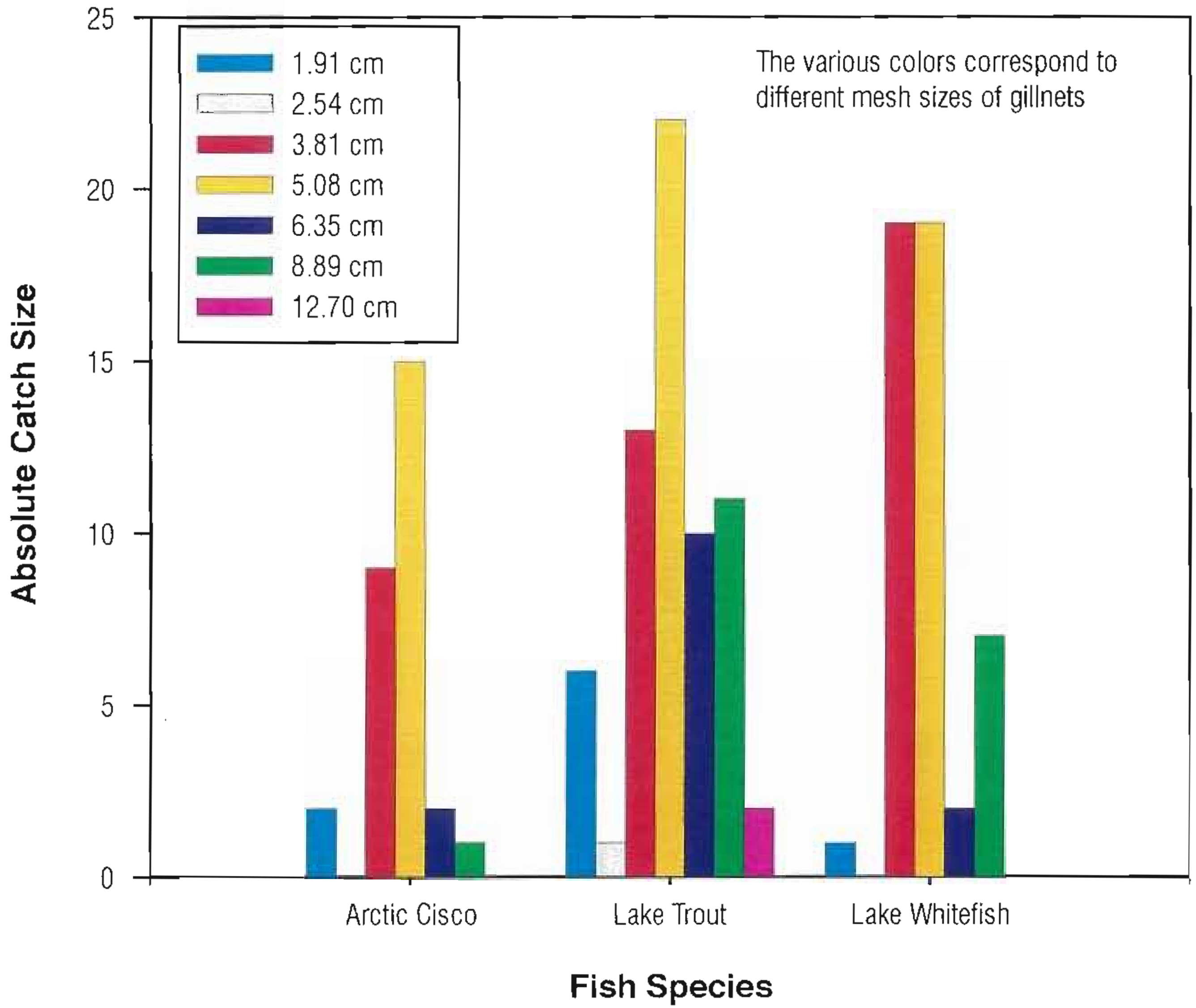


FIGURE 7.3-3

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.

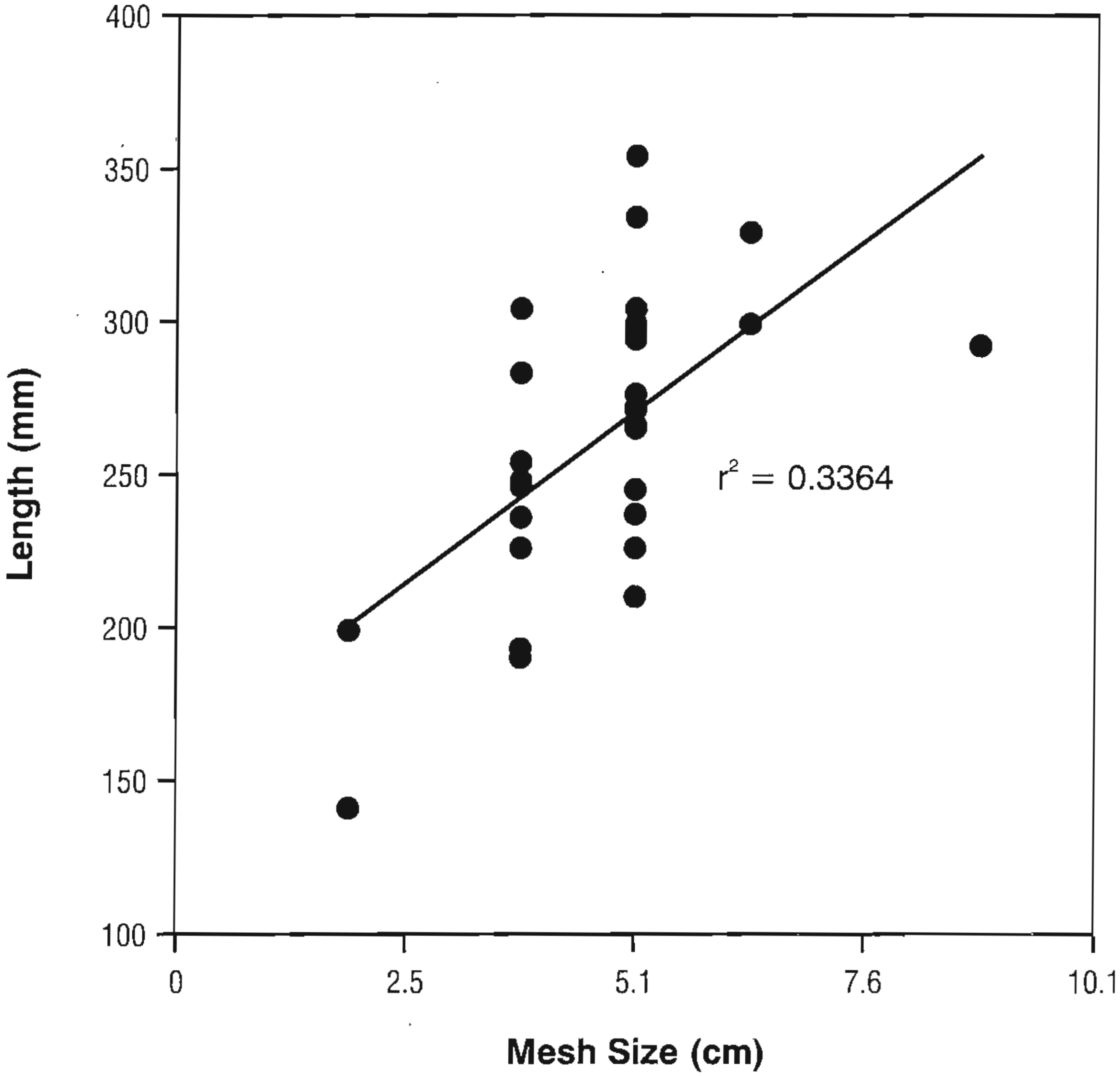
In general, mesh size did appear to have an affect on the size or species of fish captured. Figures 7.3-4 to 7.3-6 illustrate the relationship between gillnet mesh size and fork length of three species captured. Table 7.3-5 presents, by mesh size, lake trout or lake whitefish obtained. Johnson (1976, 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



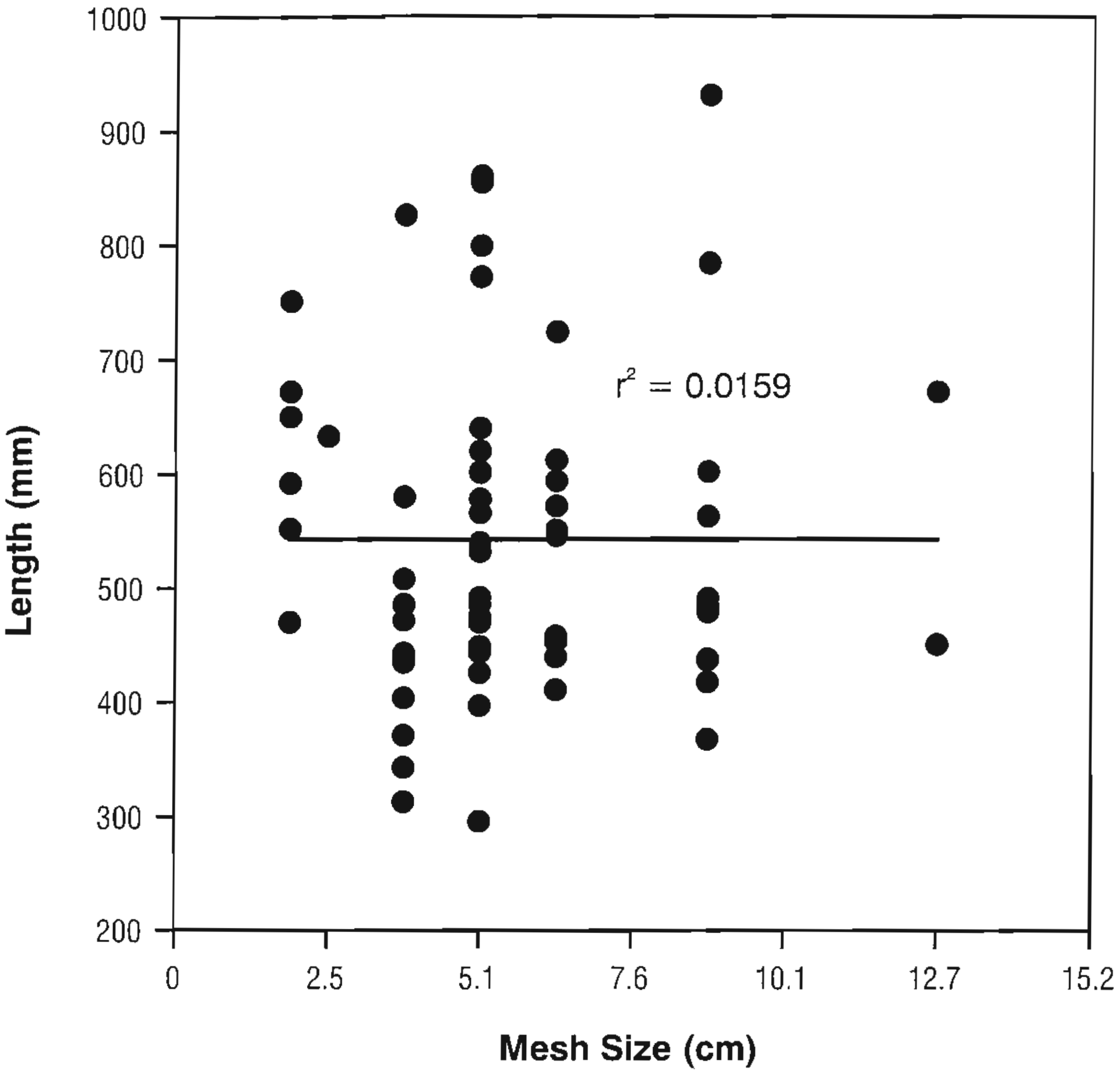
Note: *Data from all study lakes were pooled.*

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

FIGURE 7.3-4

Relationship Between Gillnet Mesh Size and Fork Length of Cisco Captured

BHP Rescan



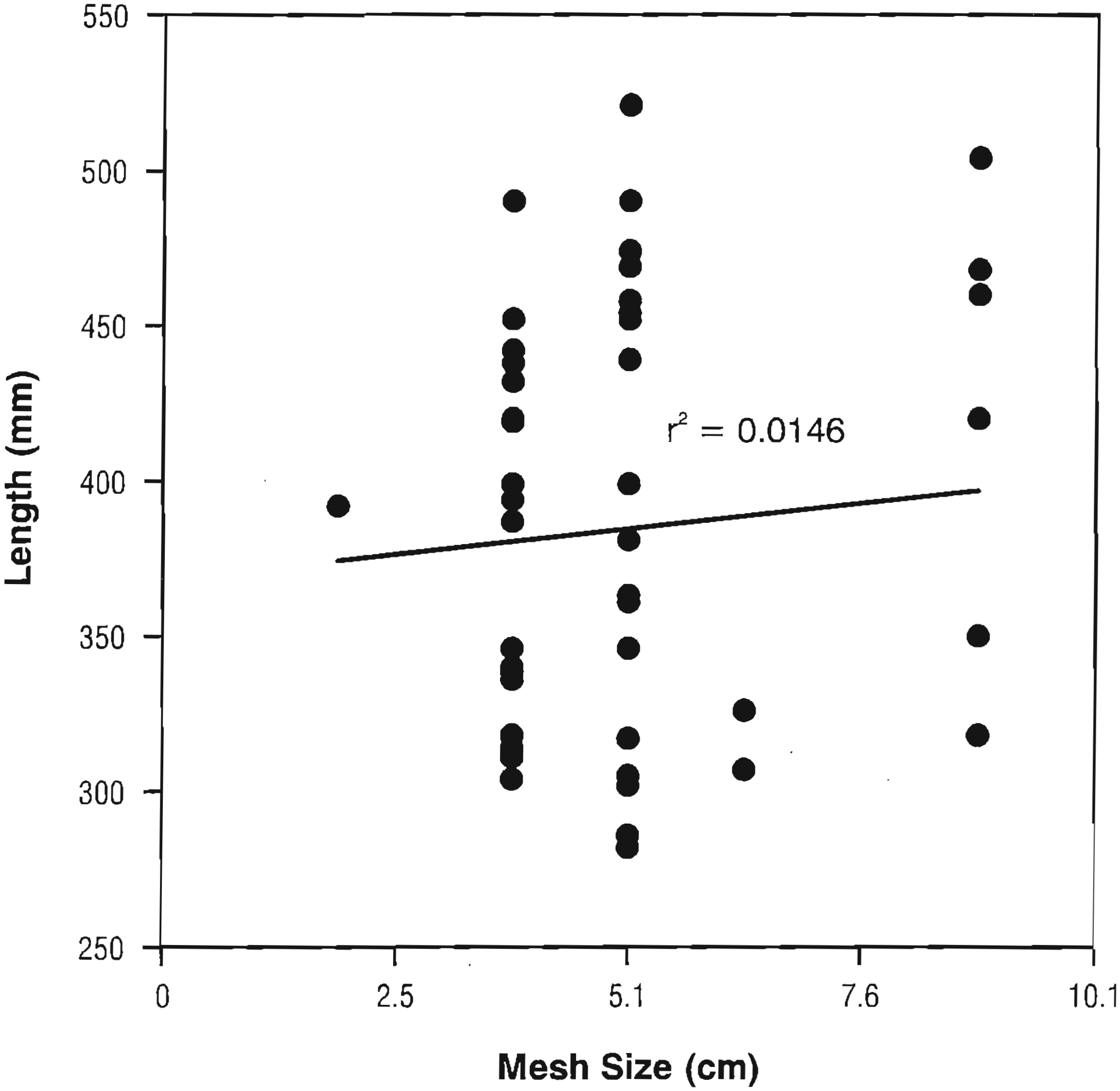
Note: *In contrast to cisco lake trout length did not increase with larger mesh sizes.*

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.

Relationship Between Gillnet Mesh Size and Lake Whitefish Fork Length

FIGURE 7.3-6

BHP

Rescan

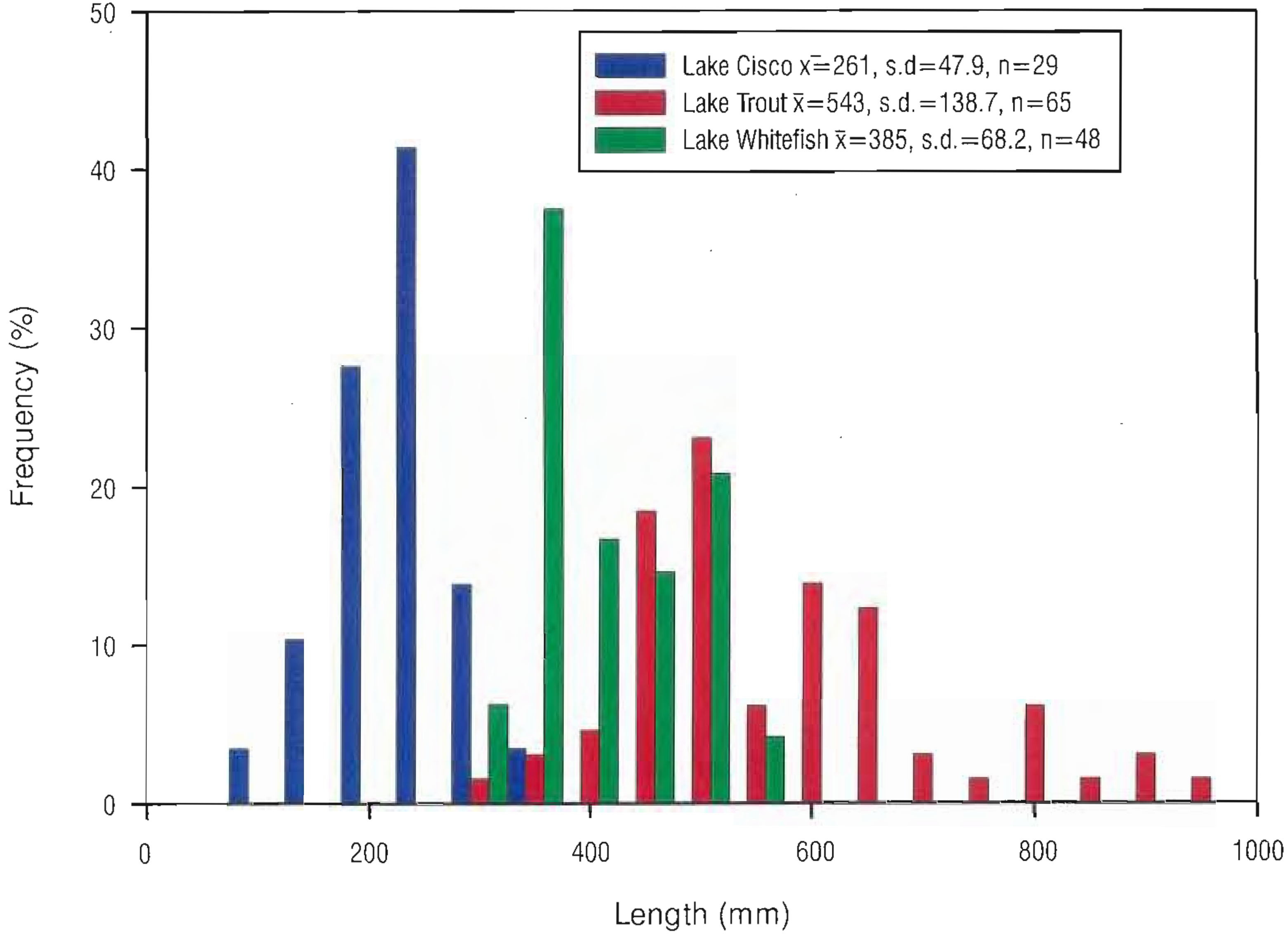


FIGURE 7.3-7

BHP

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

Rescan

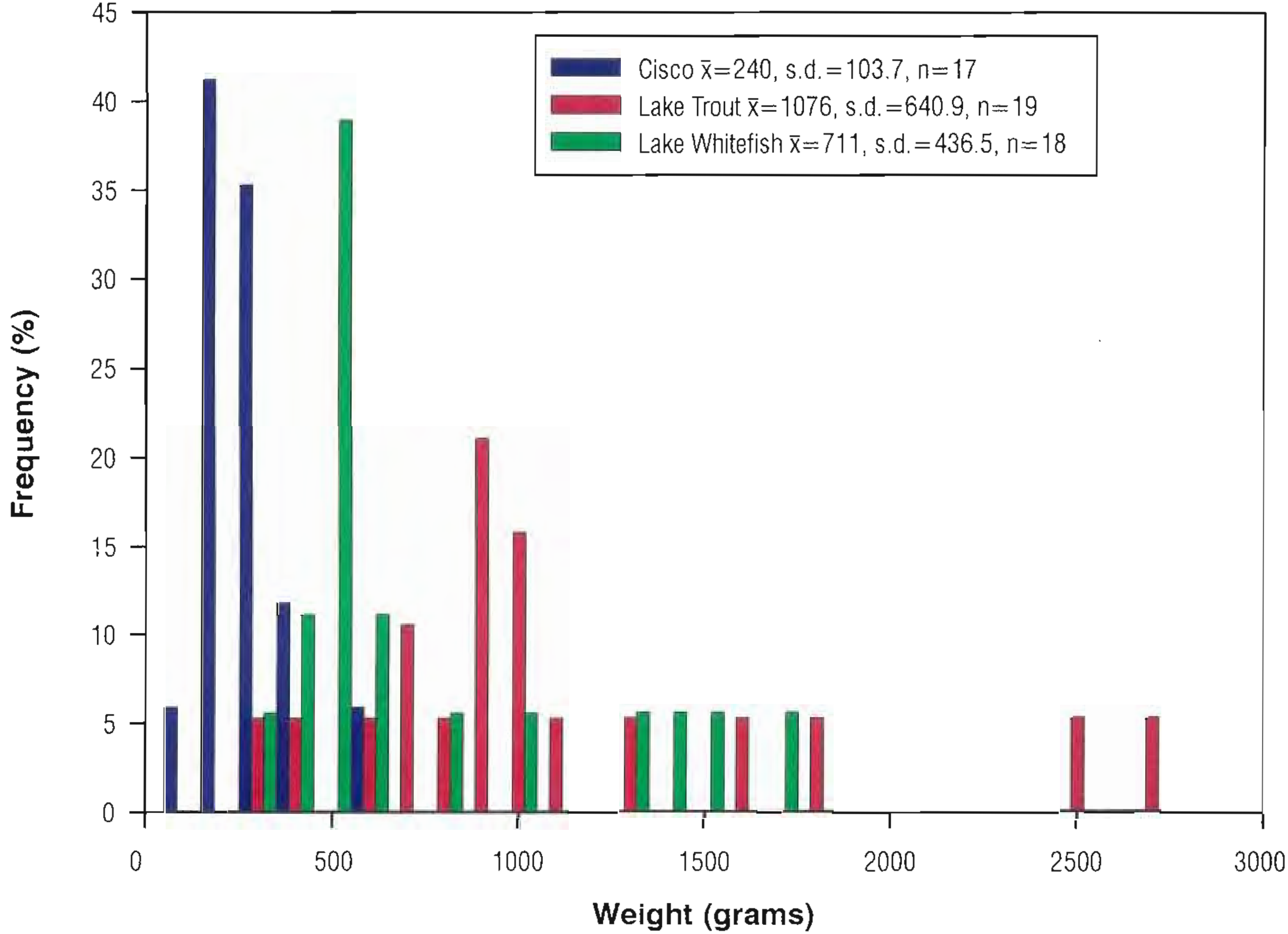


FIGURE 7.3-8

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.

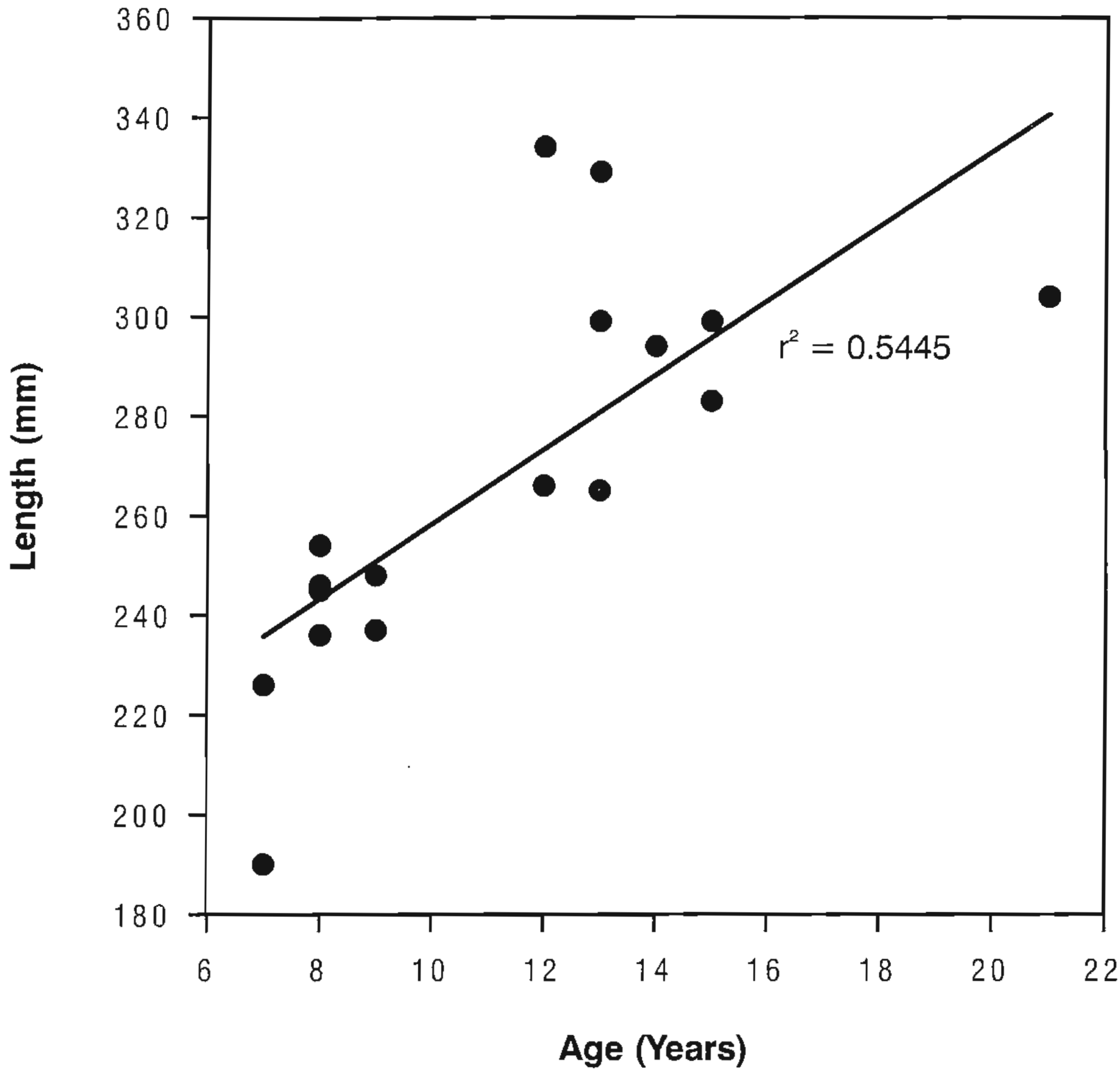
Mercury is the only trace metal for which consumption guidelines, set by Health and Welfare Canada are enforced. The maximum allowable level of mercury in fish tissue is 0.5 mg/kg wet weight (CCREM 1993). To allow a comparison of dry and wet weight values, the Hope Bay Belt data were converted to wet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



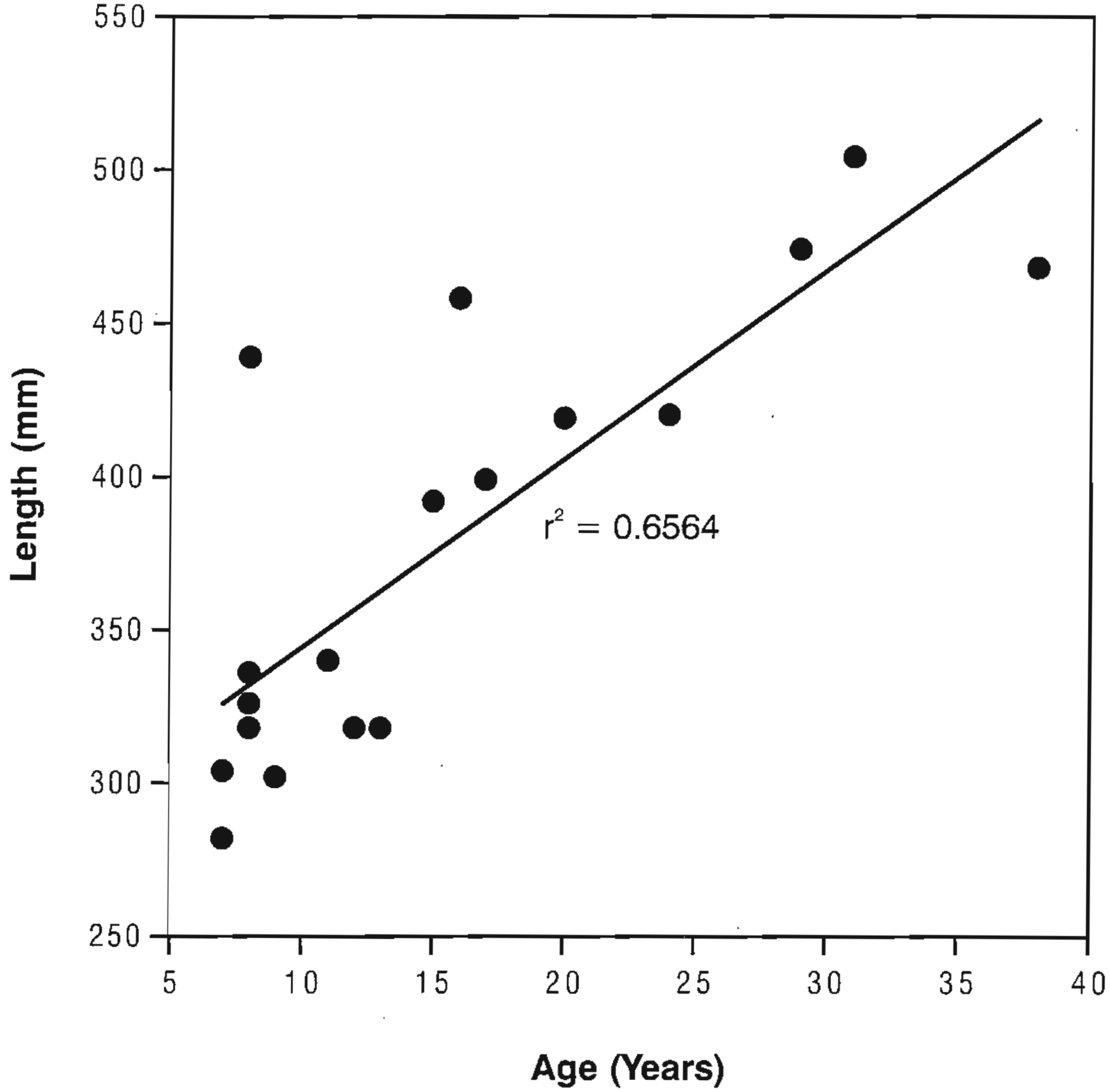
Note: *Data from all study lakes were pooled*

FIGURE 7.3-9

BHP

Size (Length) at Age for Cisco

Rescan



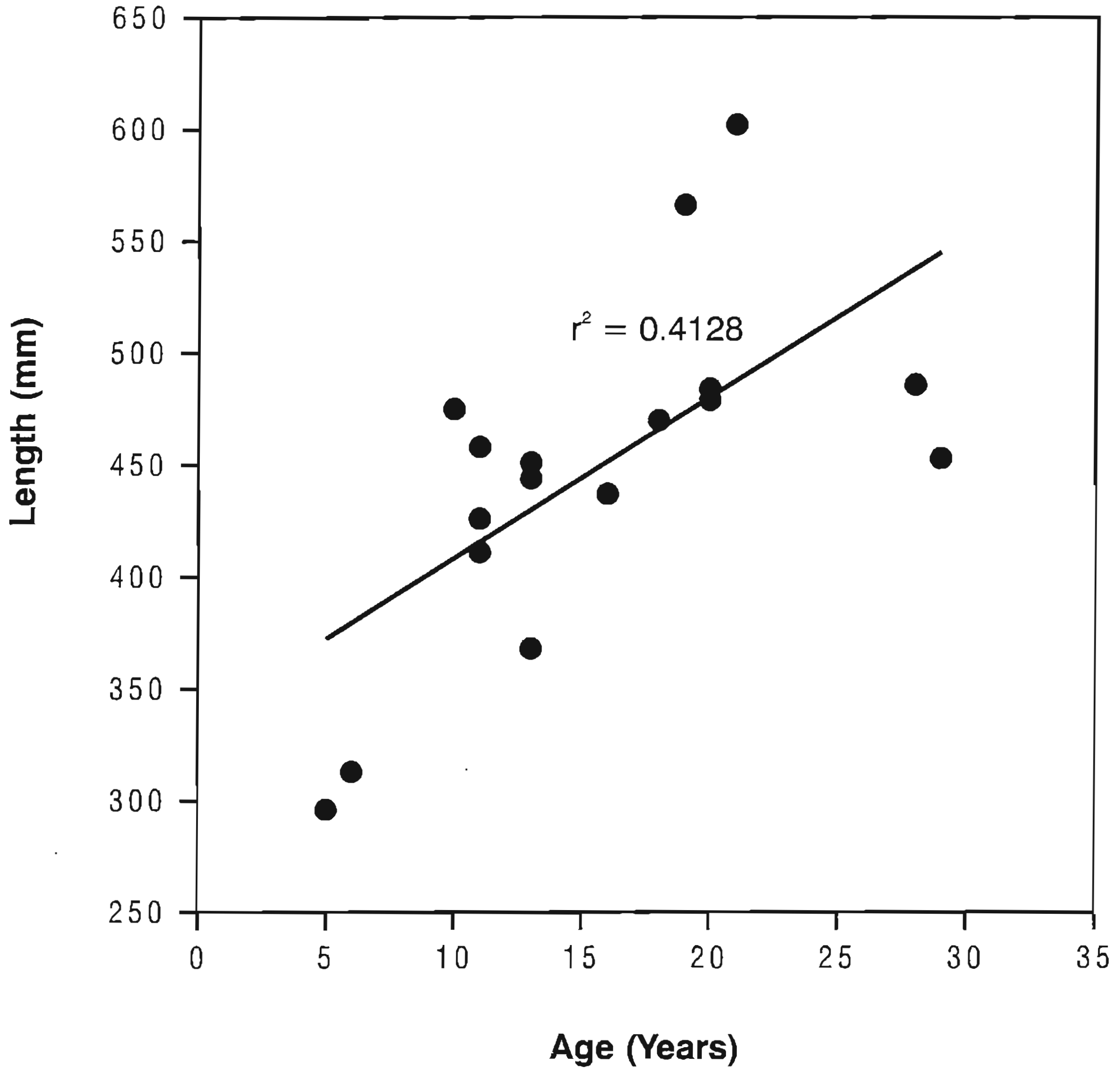
Note: *Data from all study lakes were pooled*

FIGURE 7.3-10

BHP

Size (Length) at Age for Lake Whitefish

Rescan



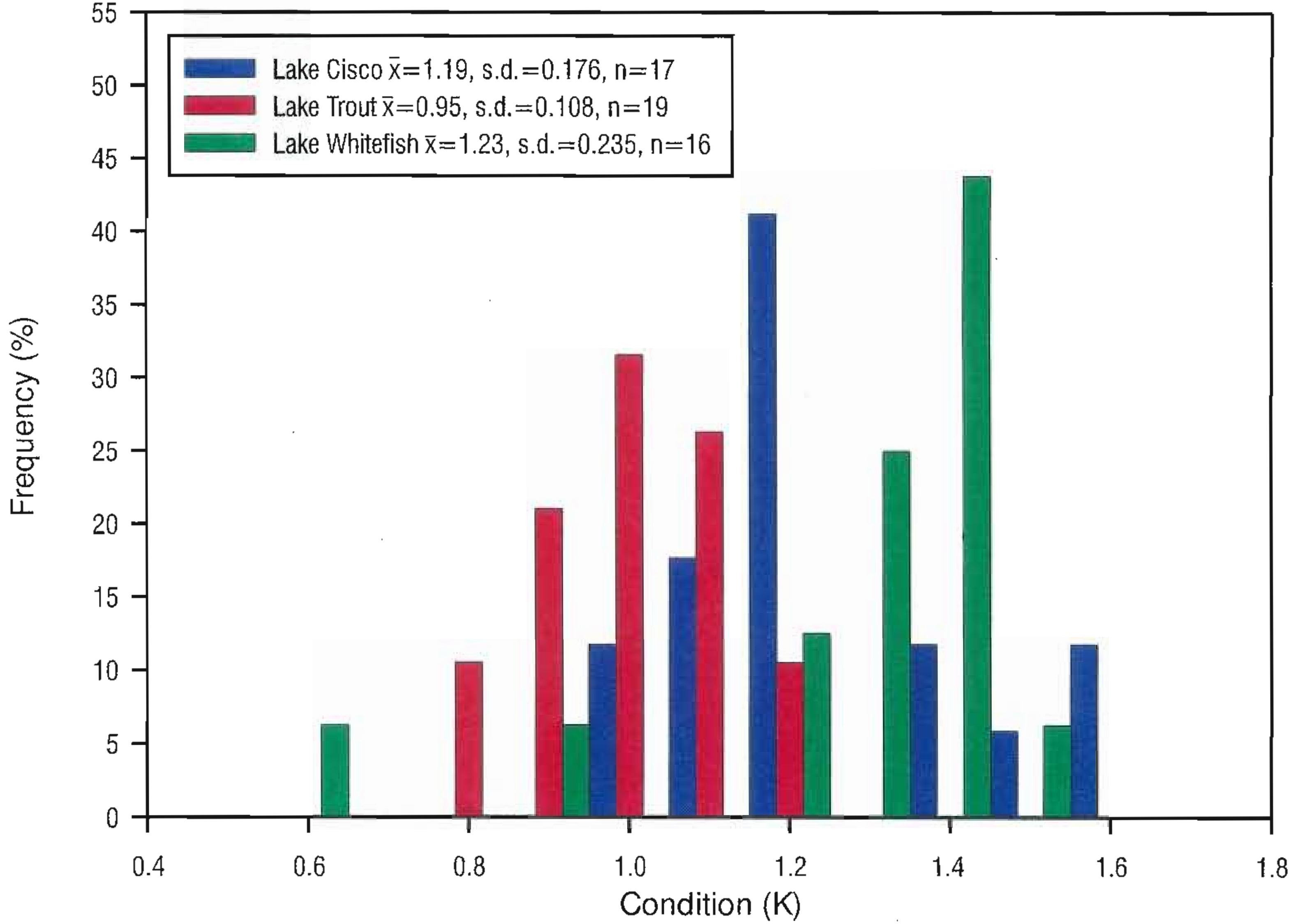
Note: *Data from all study lakes were pooled*

BHP

FIGURE 7.3-11

Size (Length) at Age for Lake Trout

Rescan



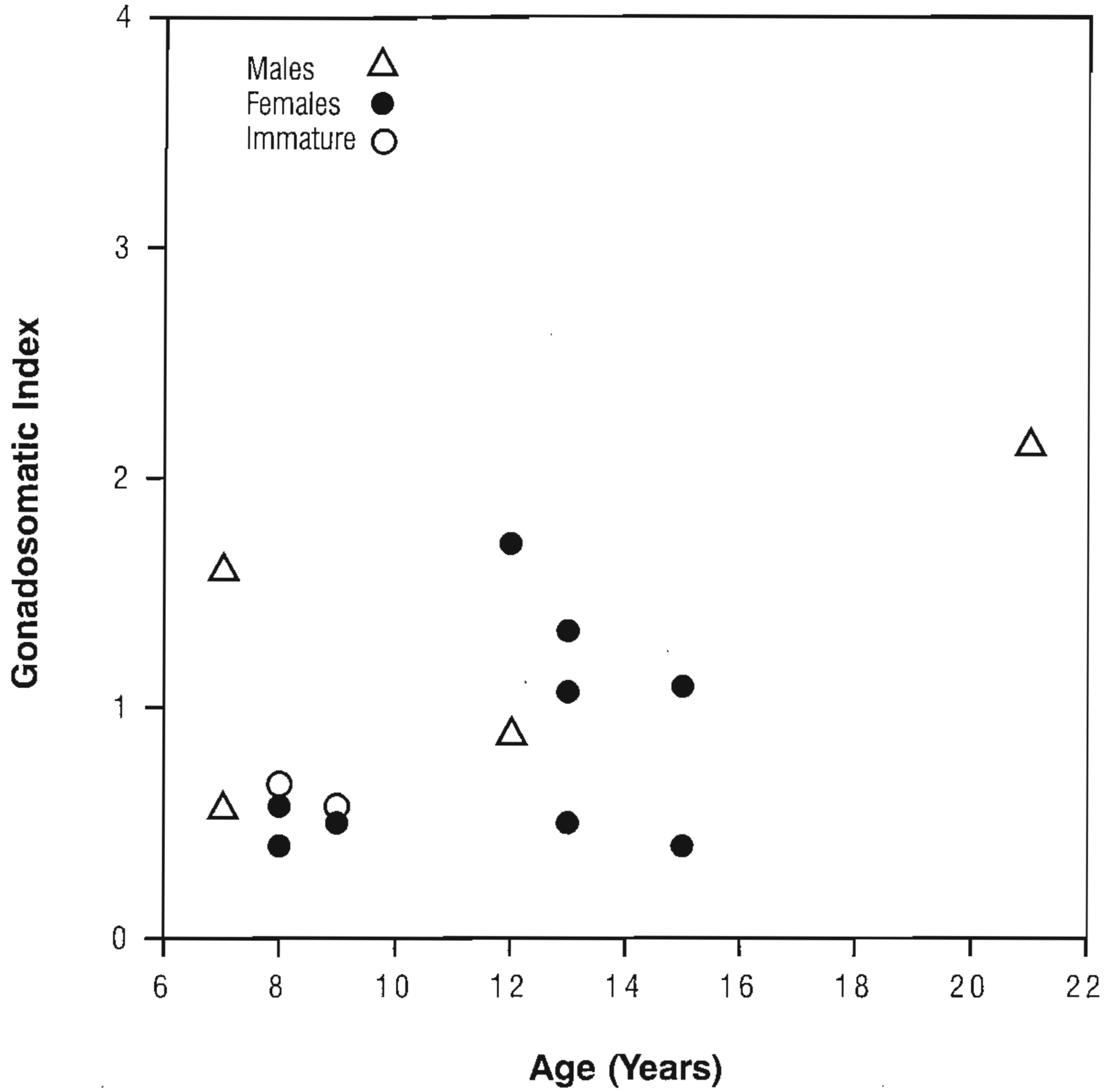
Note: *Data from all study lakes were pooled*

FIGURE 7.3-12

BHP

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

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.*

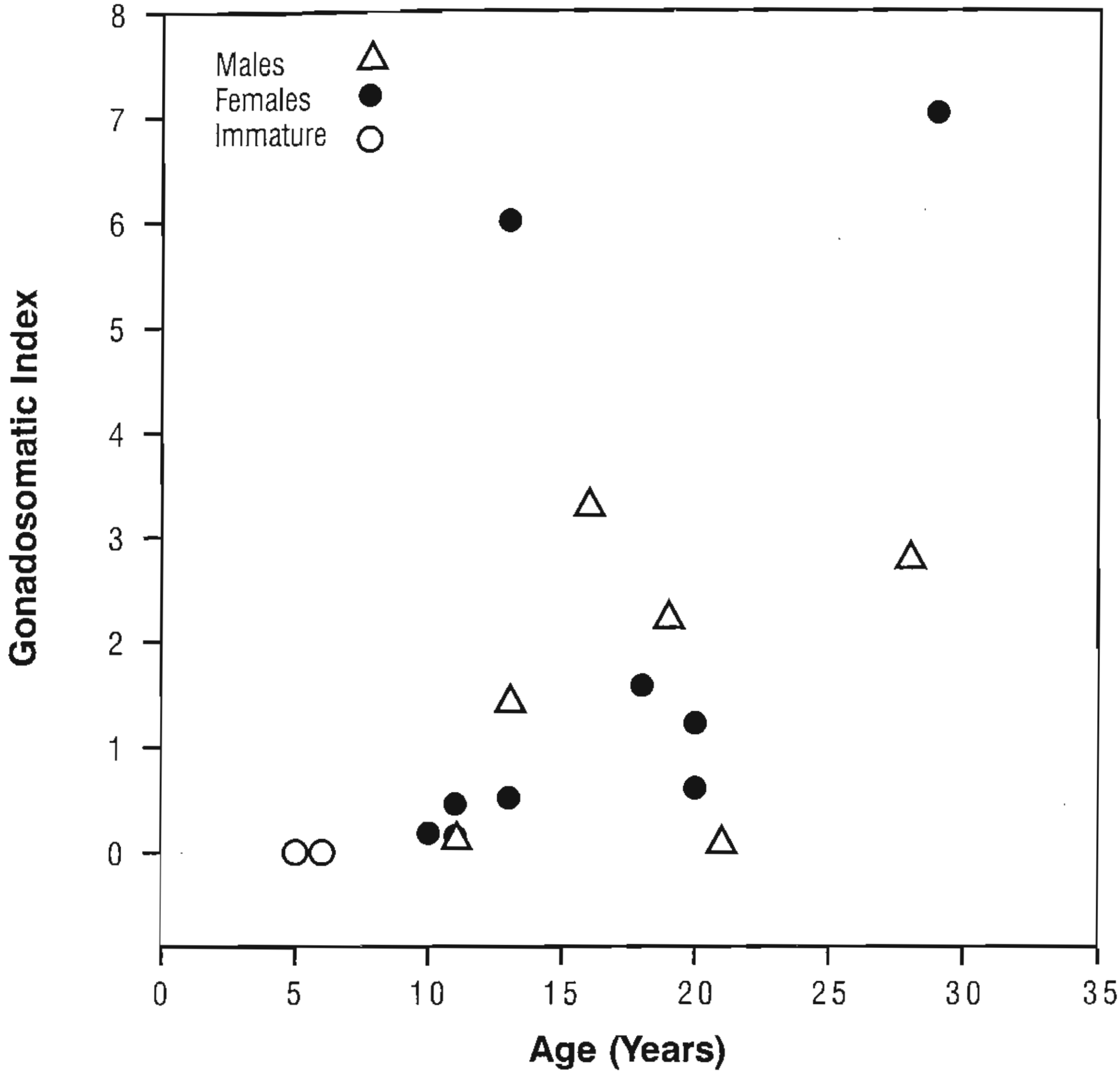
Data from all study lakes were pooled

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)*

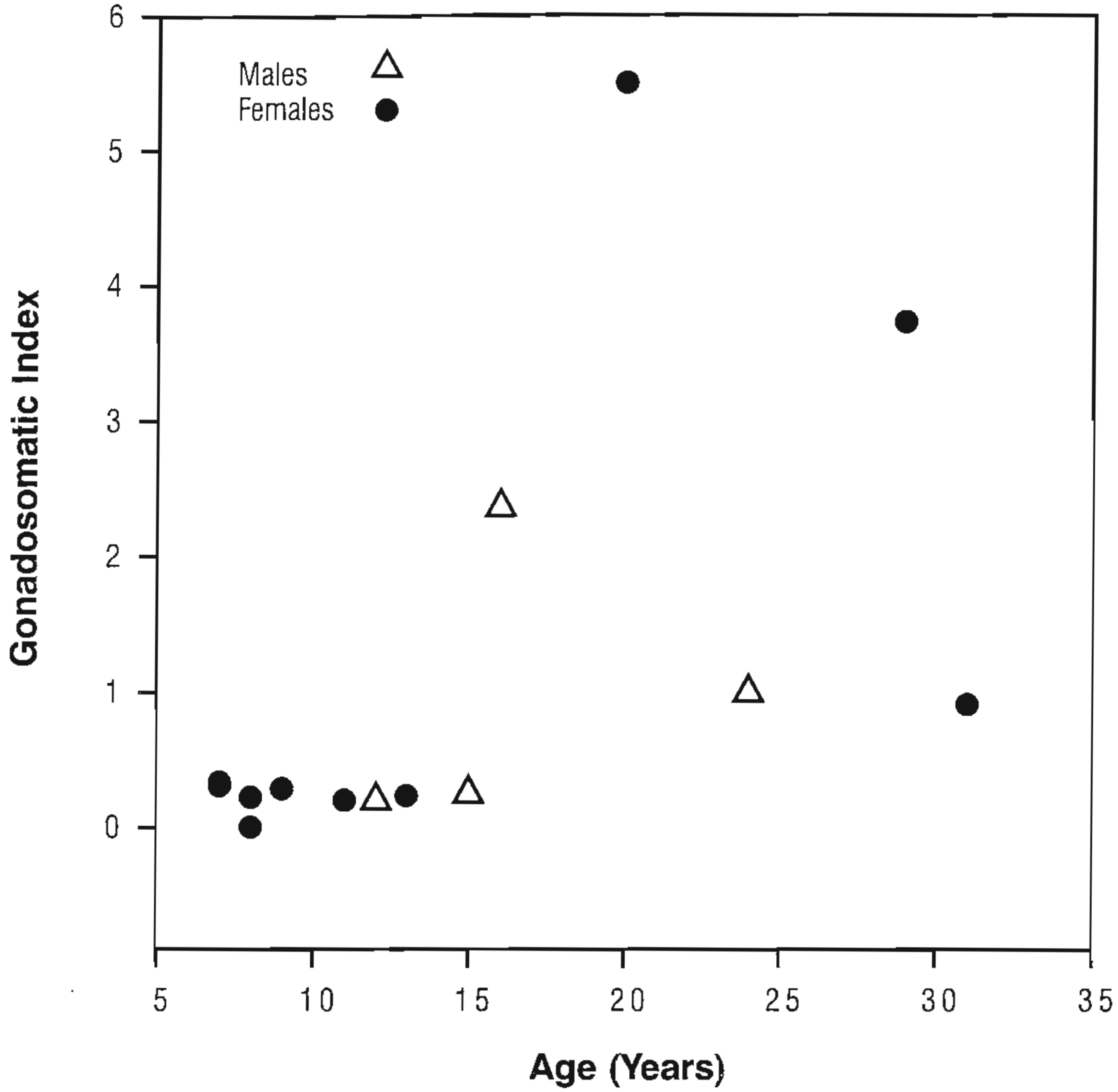
Data from all study lakes were pooled

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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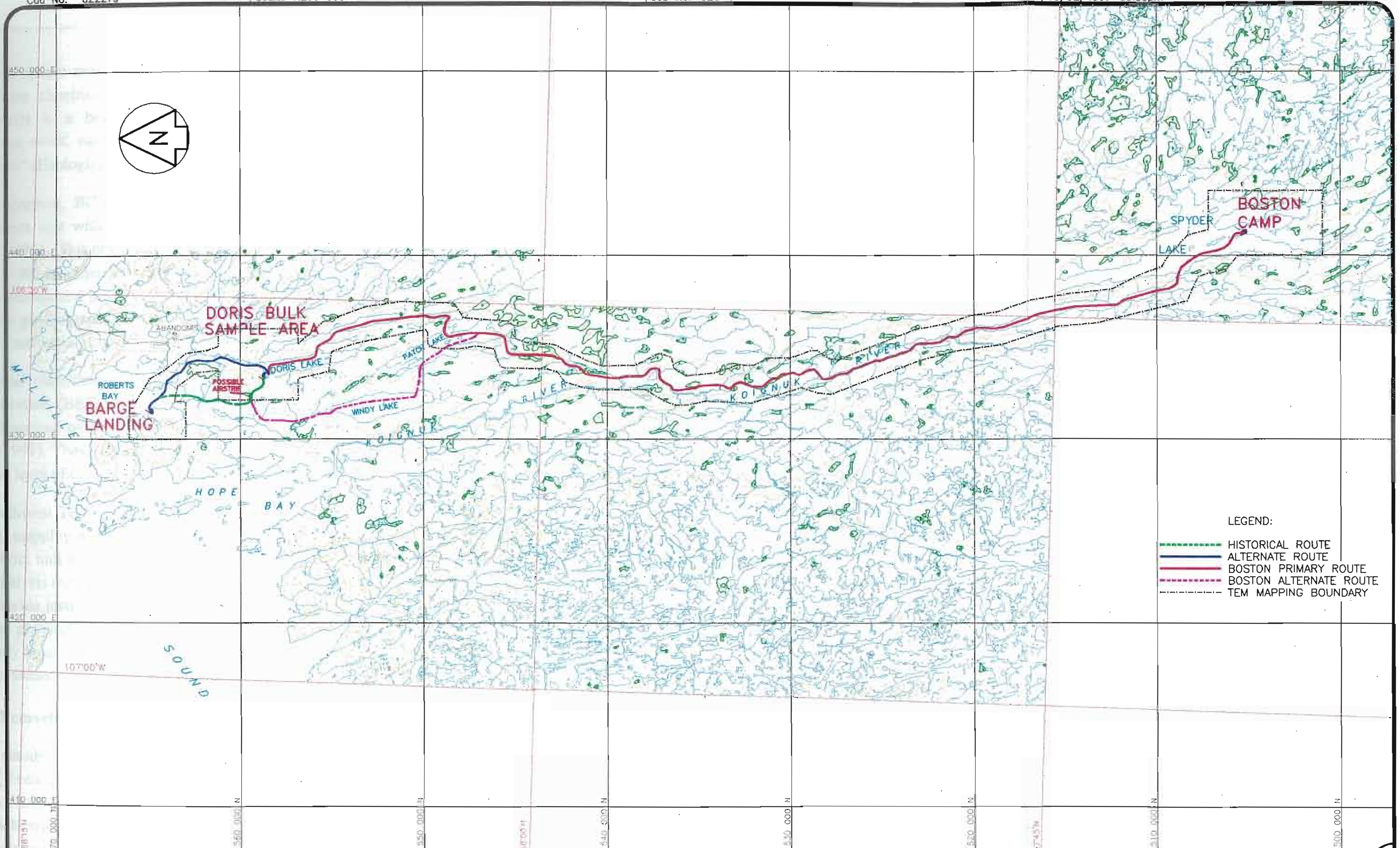


BHP

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.

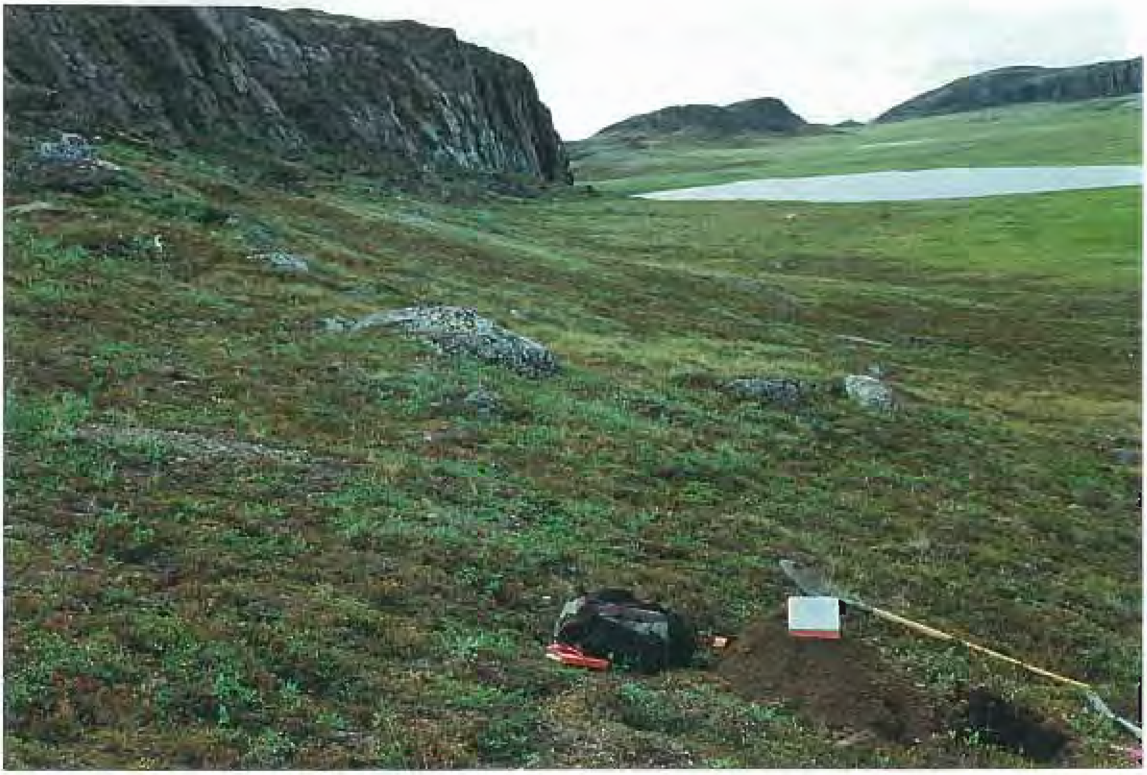


Plate 8.5-7: Dwarf shrub heath.

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).

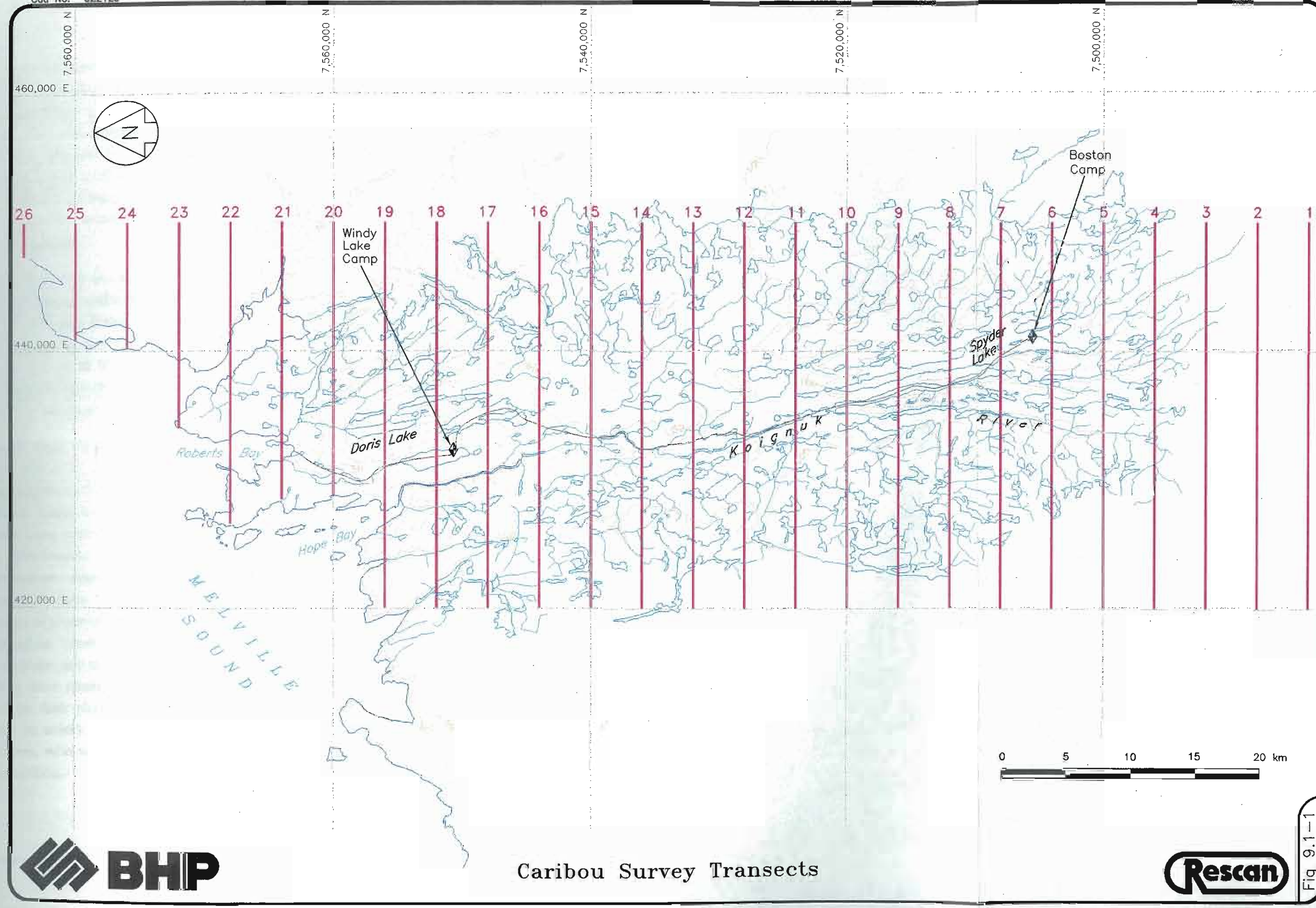
For some analyses (*e.g.*, caribou distribution), the study area was divided into northern and southern sections. The boundary was at the north end of Spyder Lake, between transect lines No. 10 and 11 of the caribou survey route.

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.



Caribou Survey Transects

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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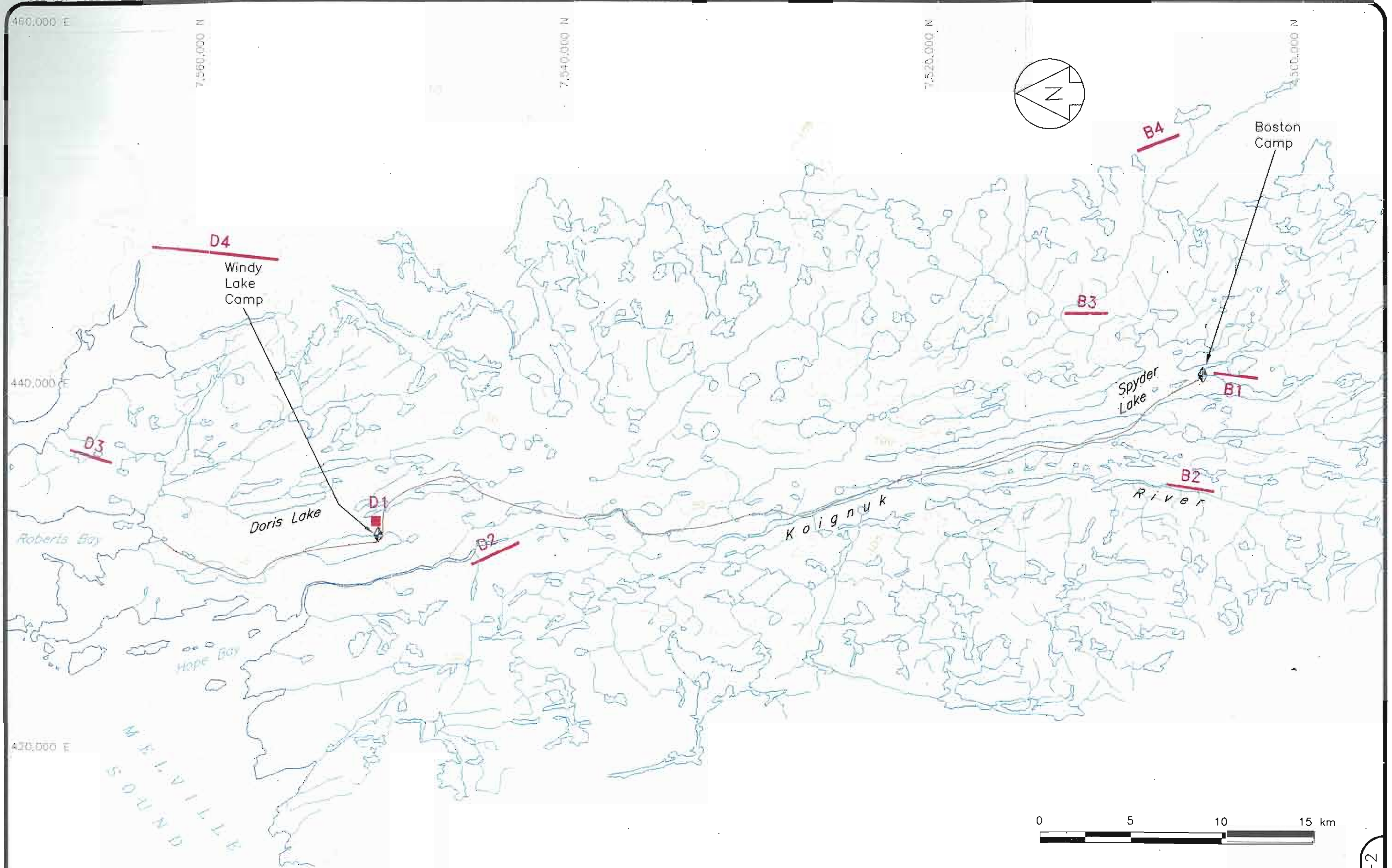

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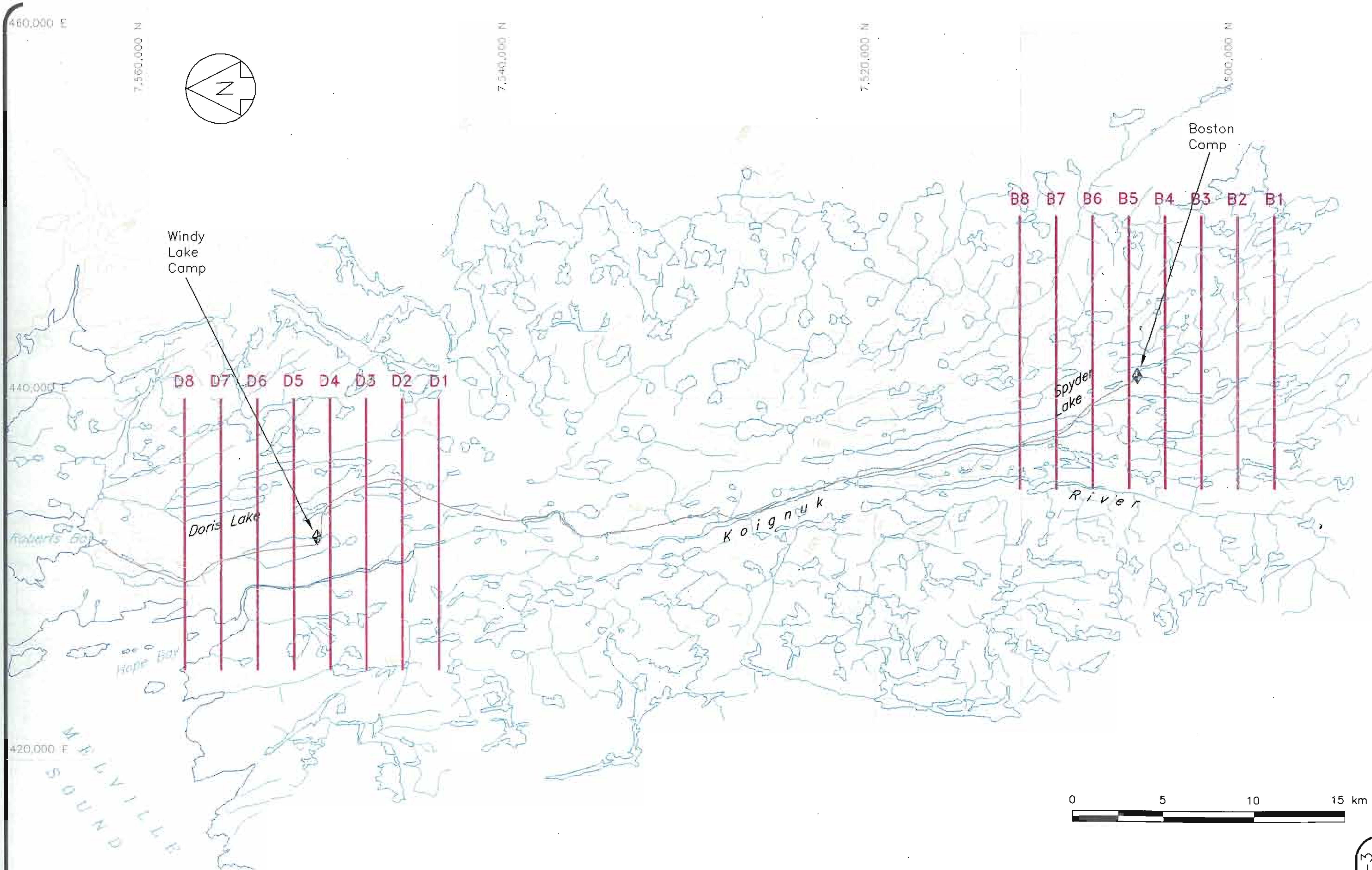
Breeding Bird Census Plots

Rescan

Fig 9.1-2



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Waterfowl Survey Transects

Rescan

Fig 9.1-3

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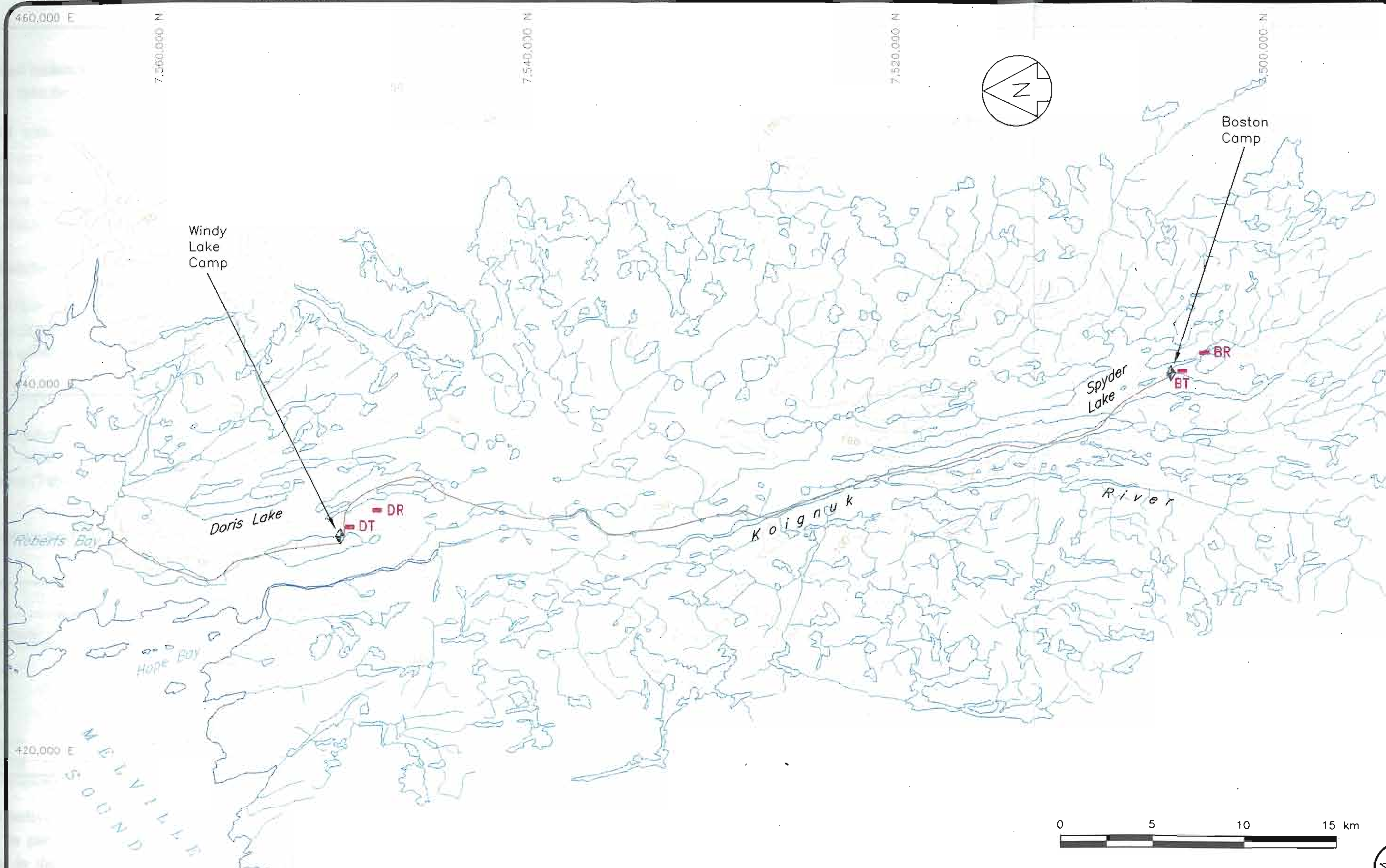

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Small Mammal Trap Lines

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

Survey Date	Area Surveyed (km^2)[1]	On-transect Observations		On-transect Density (per km^2)	
		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.

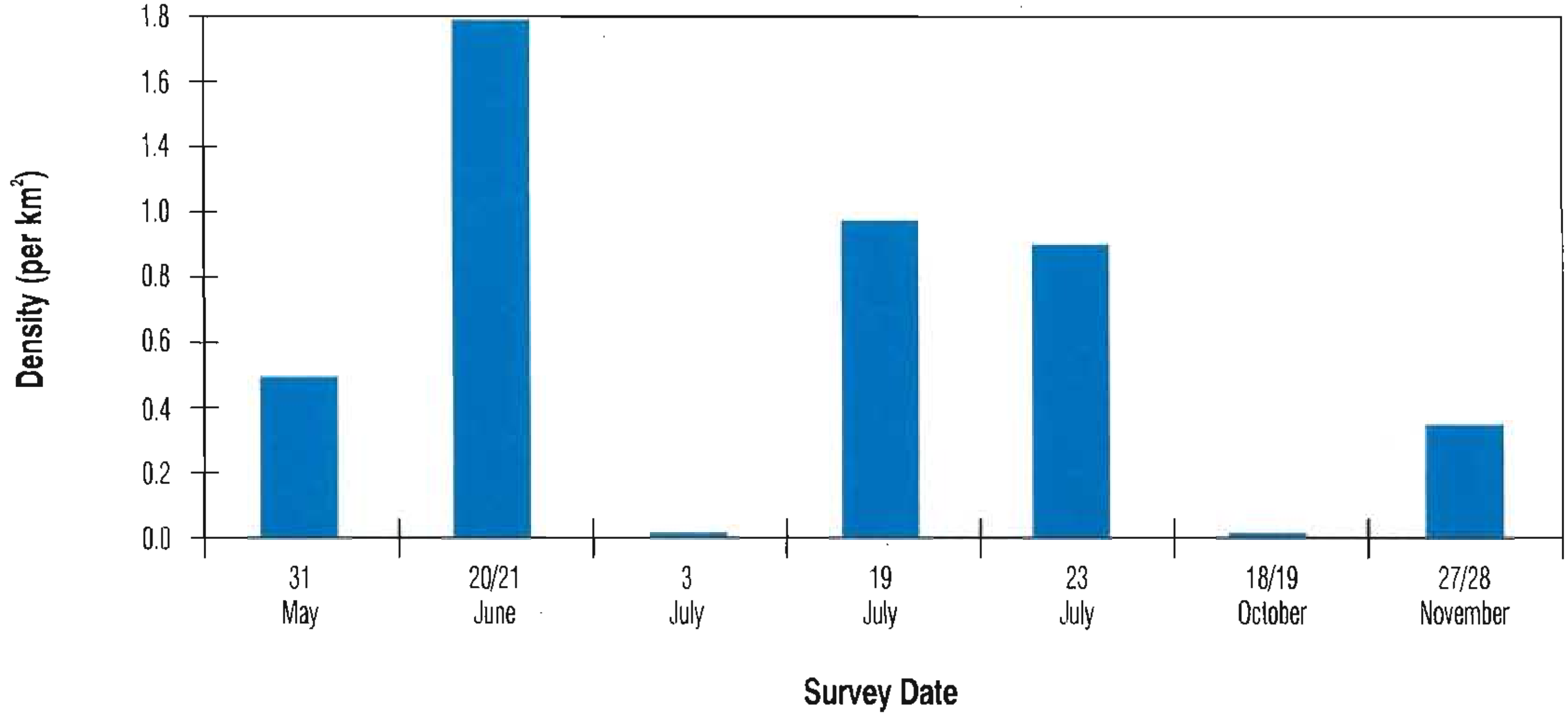

FIGURE 9.1-5

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

Rescan

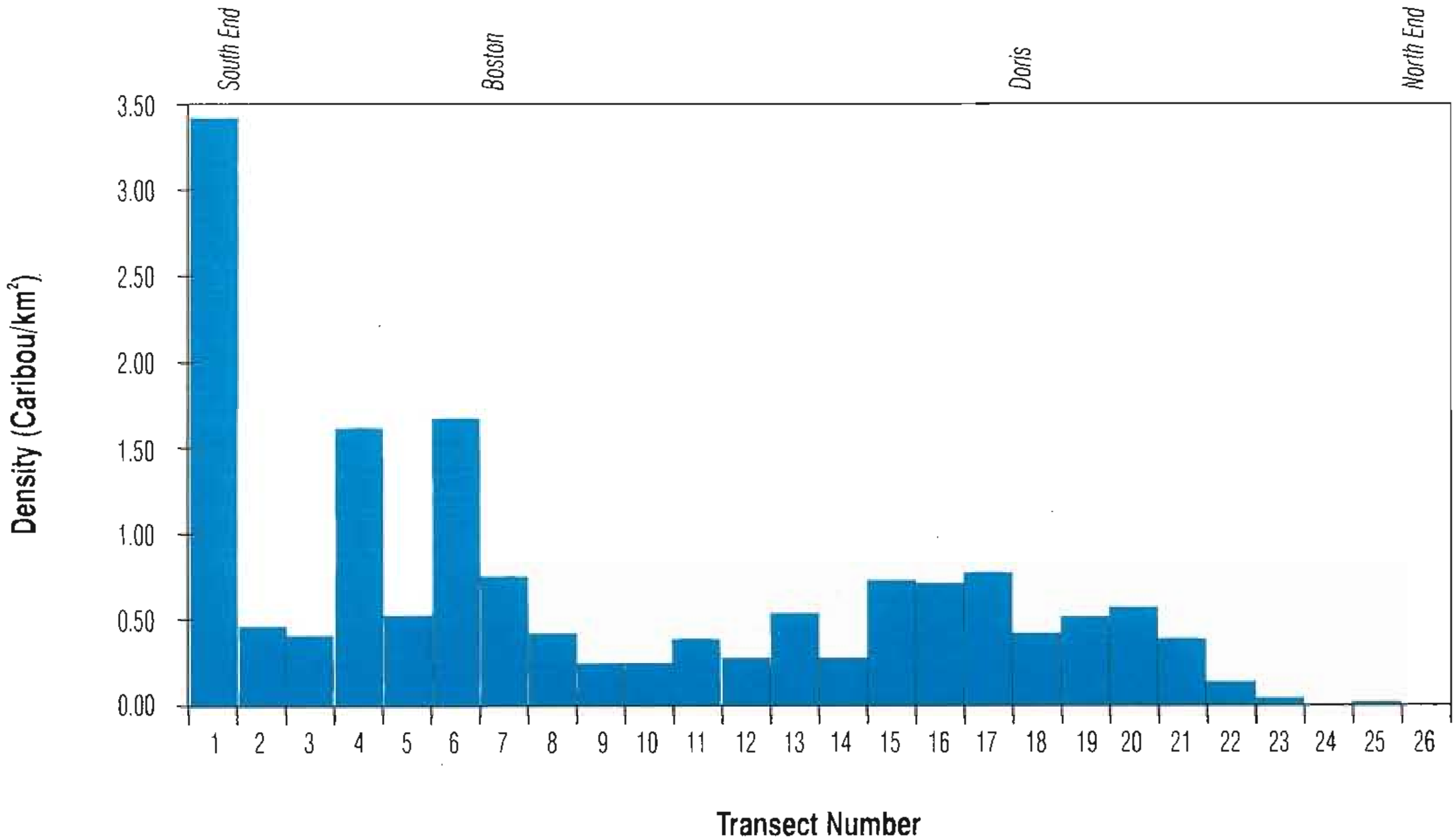

FIGURE 9.1-6

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

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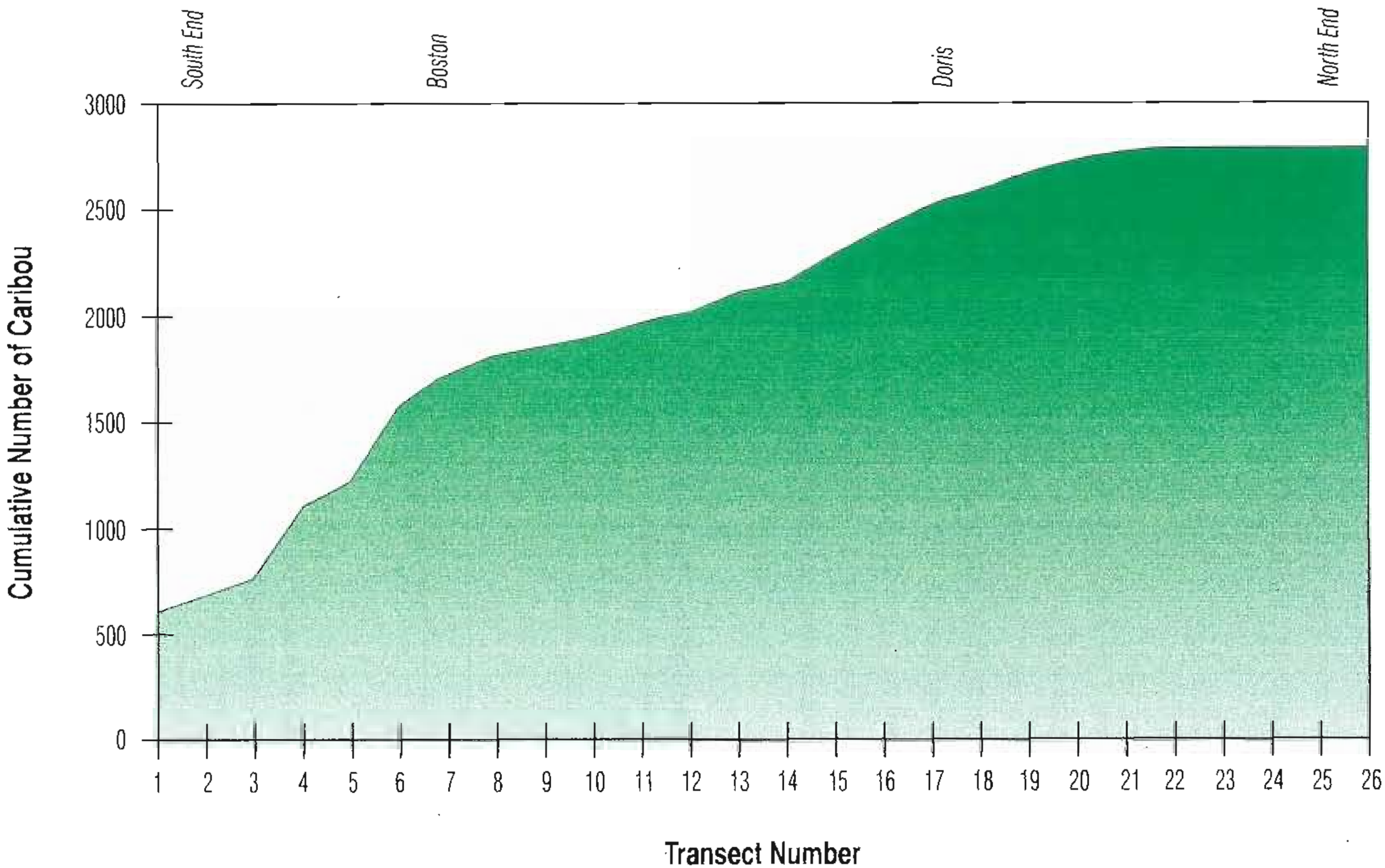


FIGURE 9.1-7

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.

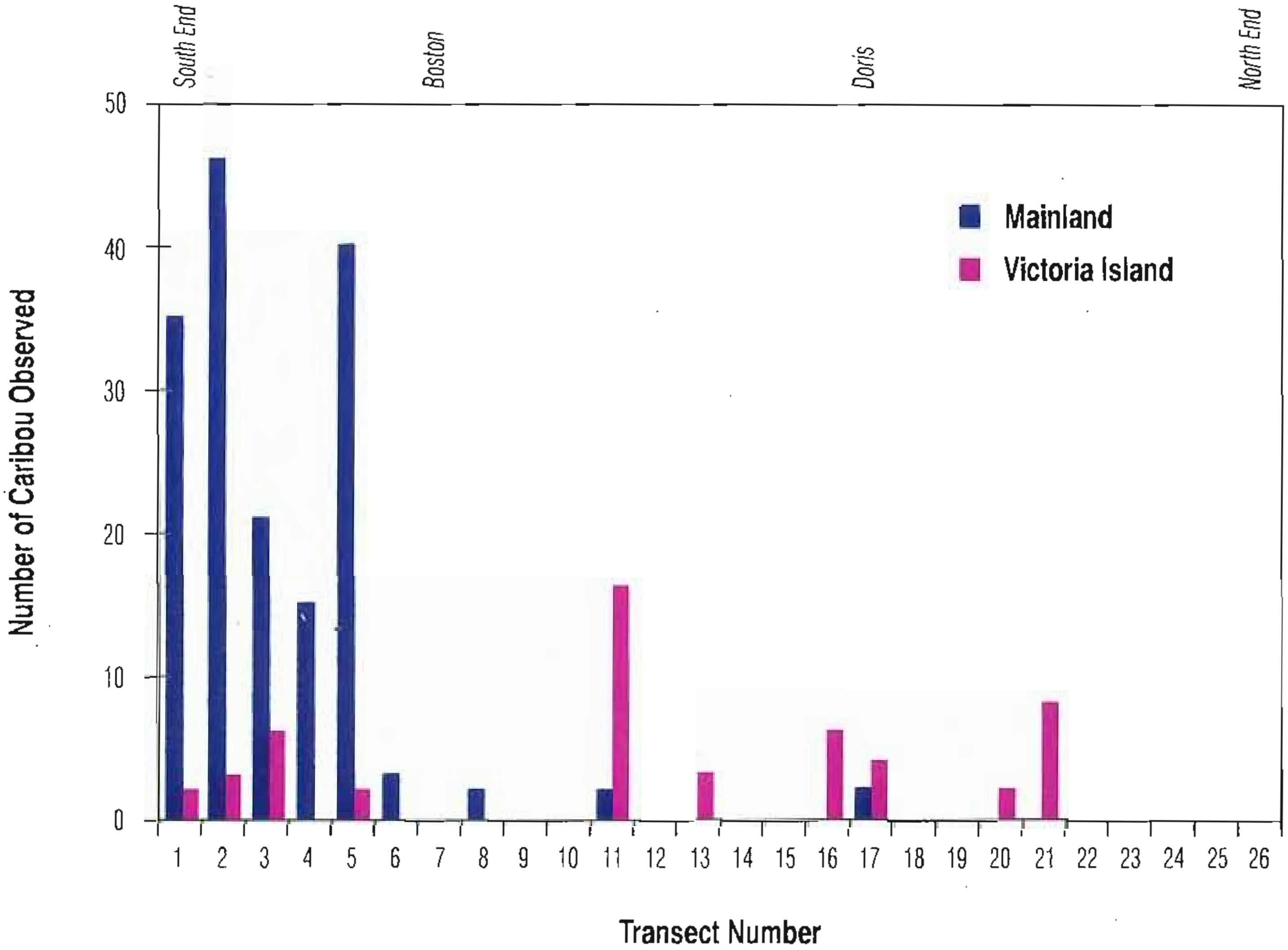
Twelve surveys of the calving grounds of the Bathurst herd were conducted between 1966 and 1995. The Hope Bay Belt area was included within the mapped calving grounds on two of those surveys (1966 and 1995; summary in Hubert and Associates Ltd. 1996). The area used most commonly was east and south of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



BHP

FIGURE 9.1-8

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.

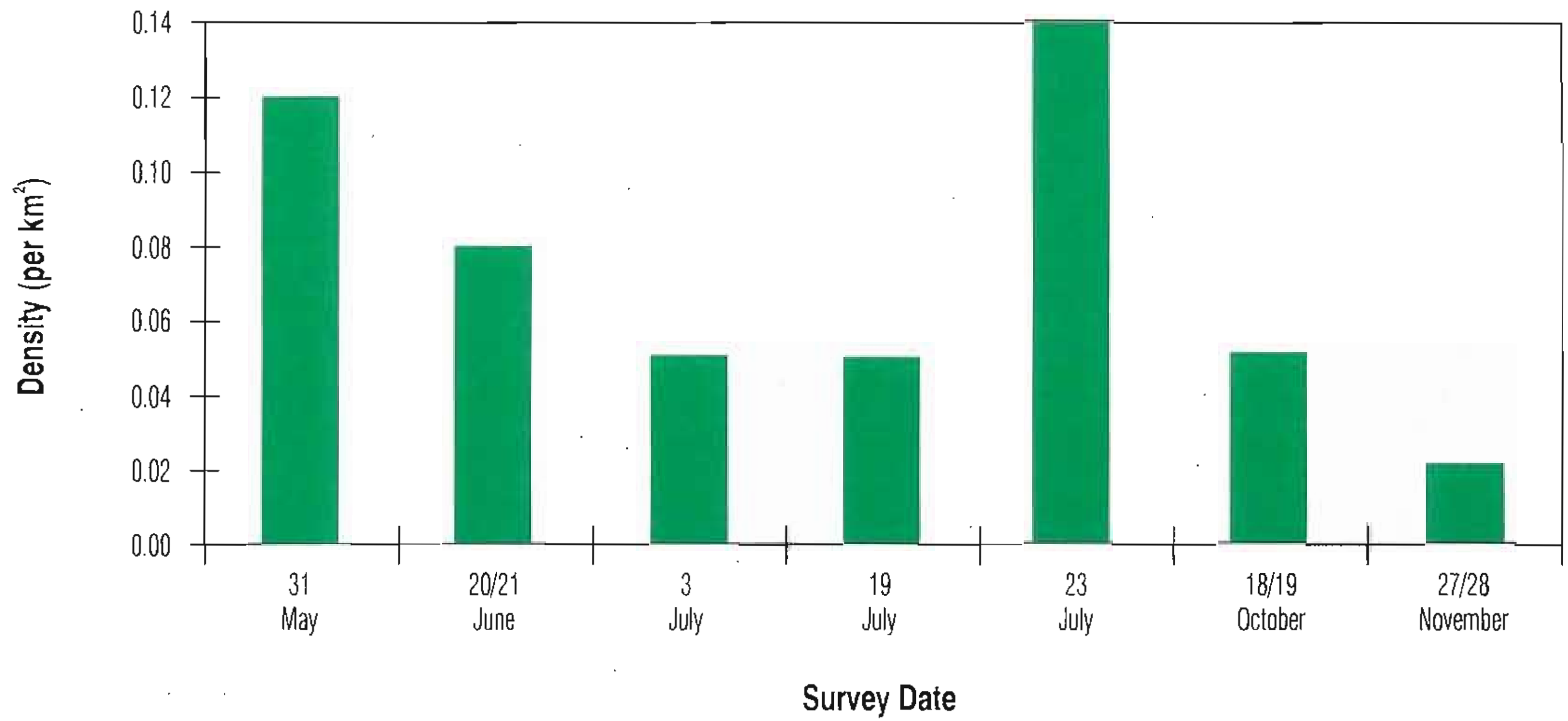


FIGURE 9.1-9

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.

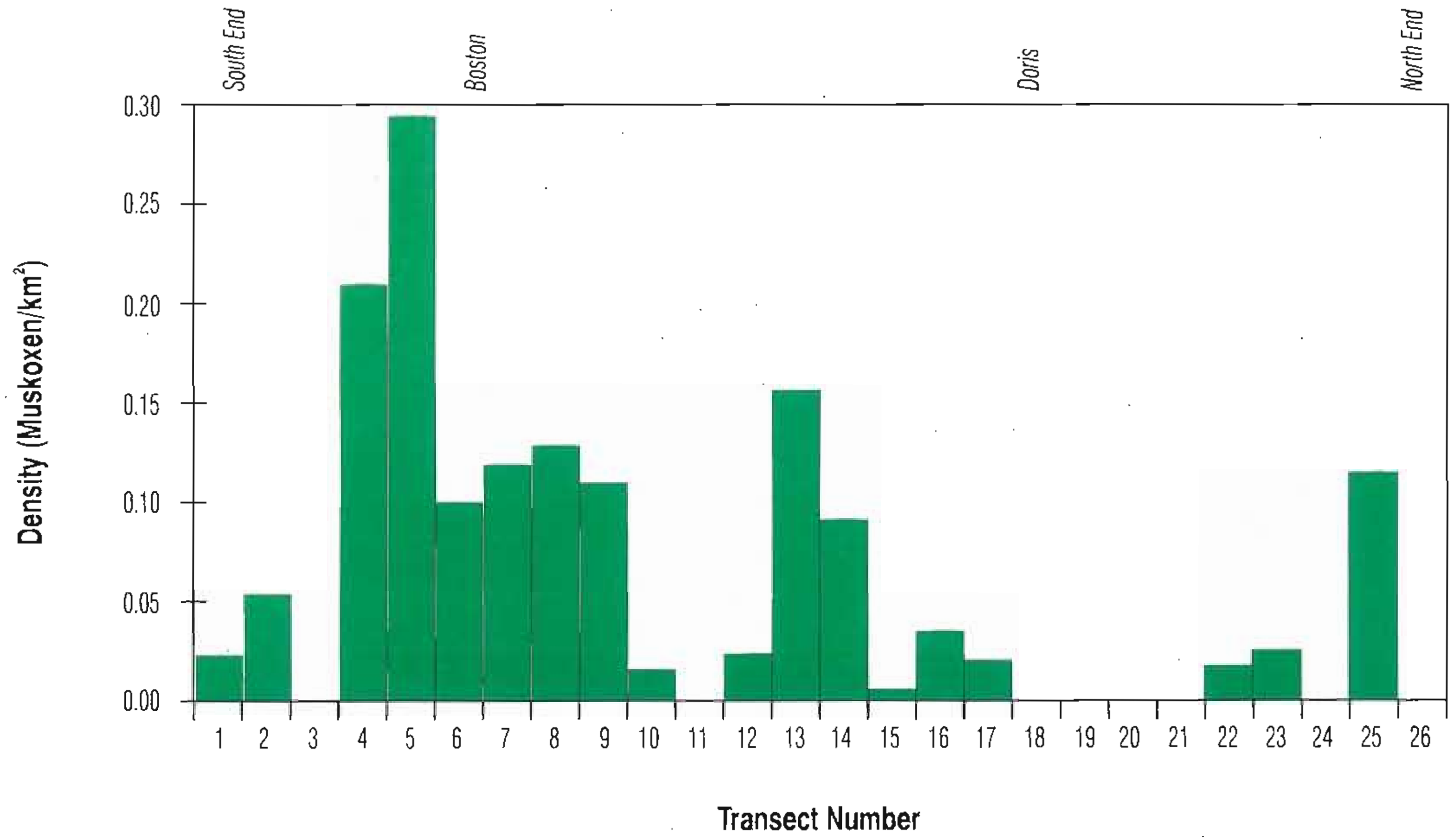
Wolf

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.



BHP

FIGURE 9.1-10

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

Rescan

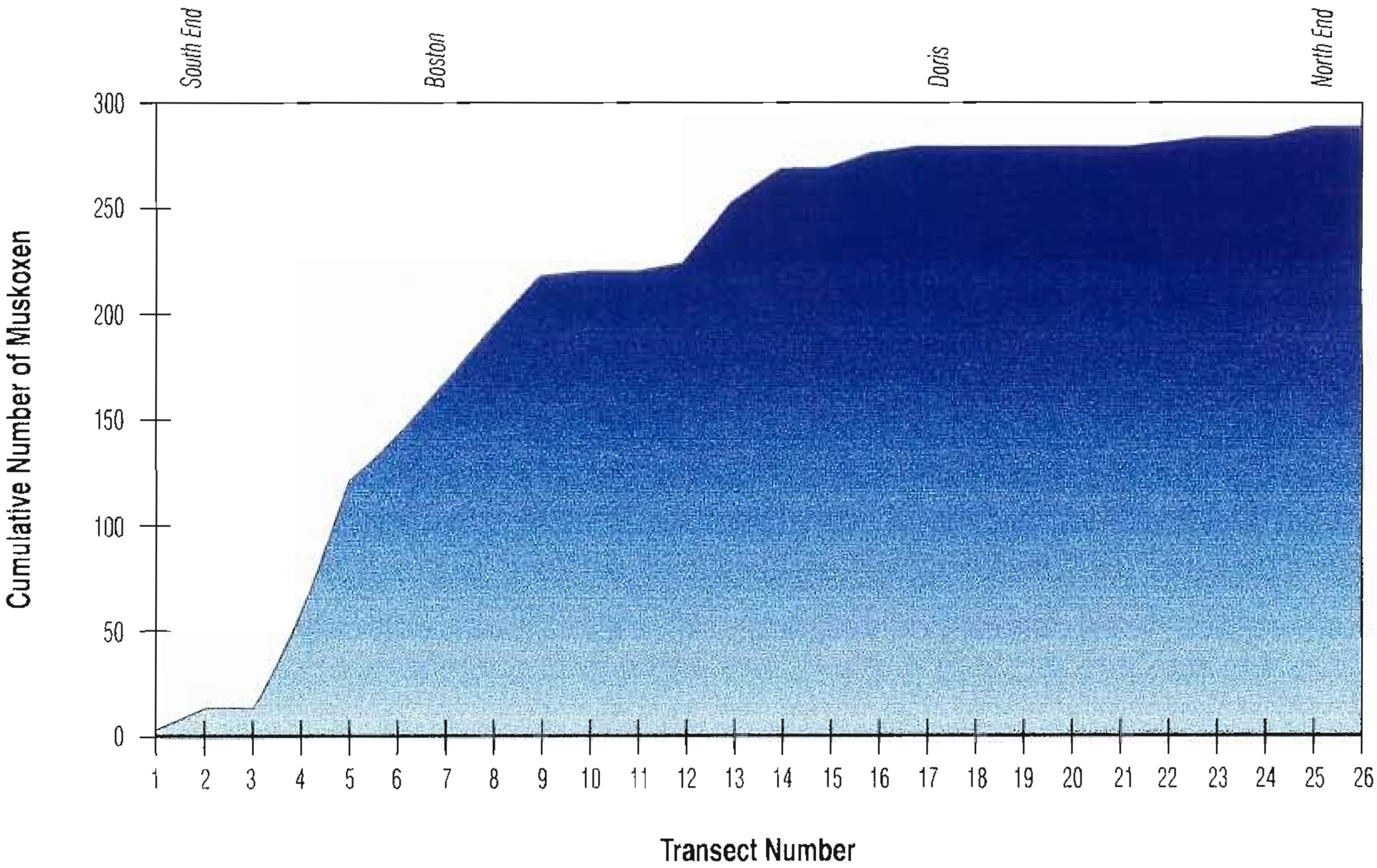


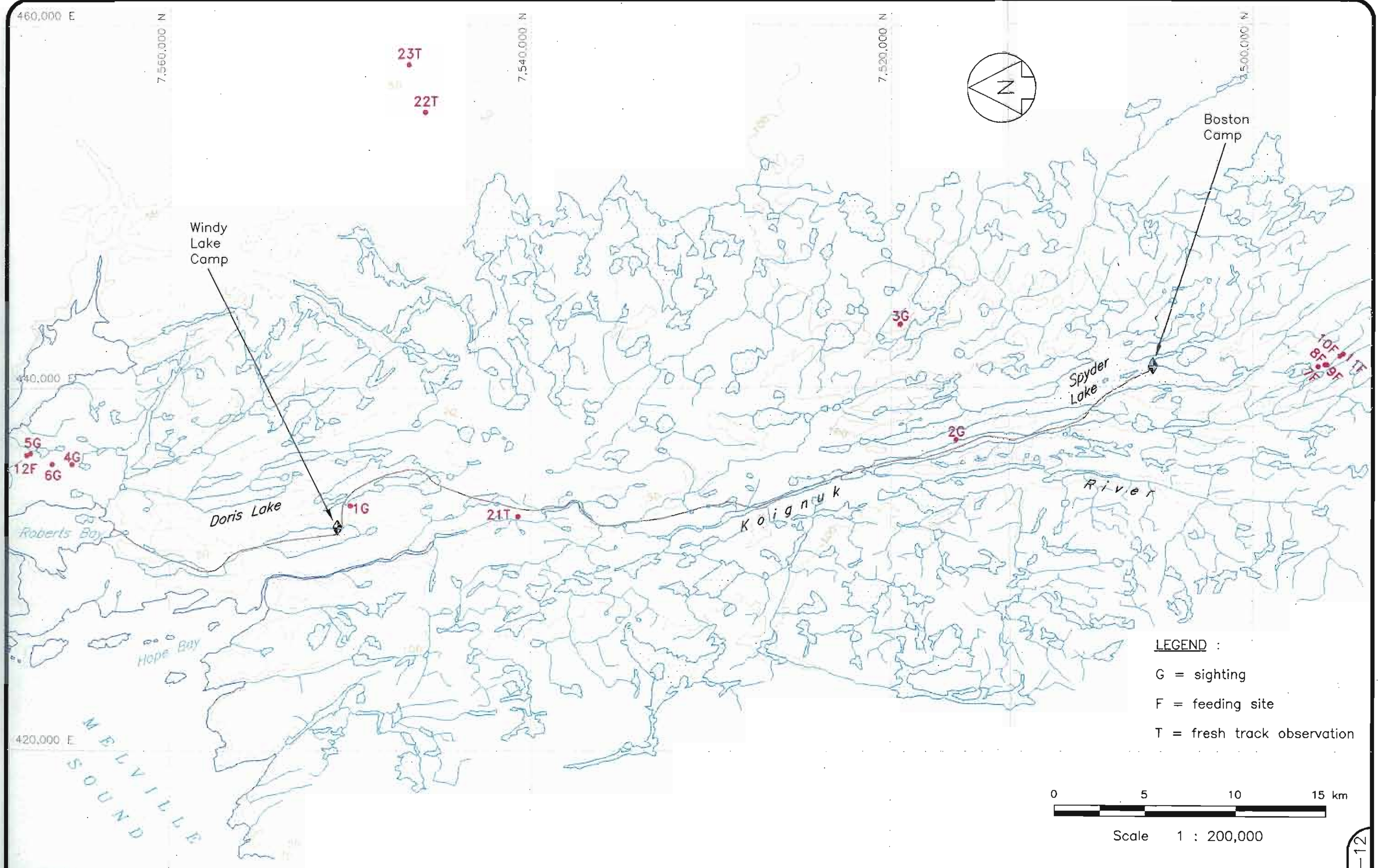
FIGURE 9.1-11

BHP

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

Rescan

Cad No. a2216s | Scale: 1:200 000 | Job No. 526-1 | 14/03/1997-11:44am | RES_BF



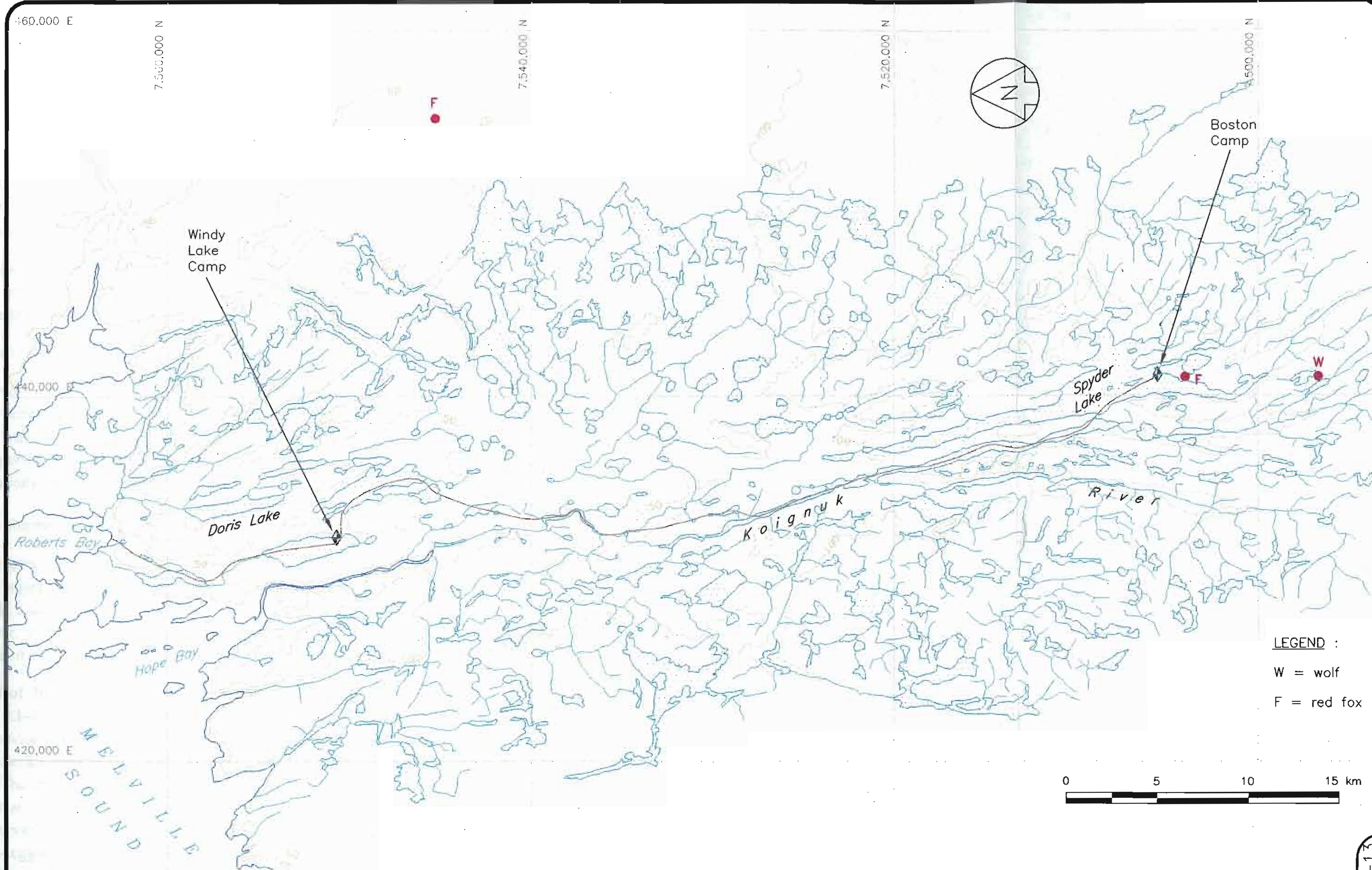
BHP

Grizzly Bear Observations

Rescan

Fig 9.1-12

Cad No. a2217s | Scale: 1:200 000 | Job No. 526-1 | 14/03/1997-11:47am RES_BF



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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.