CANADA-NEWFOUNDLAND
AGREEMENT RESPECTING
WATER RESOURCE MANAGEMENT

WATERSHED MANAGEMENT PLAN FOR GANDER LAKE AND ITS CATCHMENT

GOVERNMENT OF
NEWFOUNDLAND
AND LABRADOR

Department of
Environment

Environment Canada
Environnement Canada

CANADA-NEWFOUNDLAND AGREEMENT RESPECTING WATER RESOURCE MANAGEMENT

Watershed Management Plan for Gander Lake and its Catchment

Prepared by

EDM
ENVIRONMENTAL
DESIGN AND MANAGEMENT LTD.

in association with

R. H. Loucks Oceanology Limited

and

Jacques Whitford Environment Limited

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GOVERNMENT OF NEWFOUNDLAND AND LABRADOR
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Water Resources Division

ENVIRONMENT CANADA
Environmental Conservation Branch
Environmental Conservation Strategies Division

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INTRODUCTION

The Government of Newfoundland and Labrador, Department of Environment, Water Resources Division (under the Canada-Newfoundland Agreement Respecting Water Resources Management) required the assistance of consultants to develop a watershed management plan for Gander Lake and its catchment. A secondary purpose of the study was to develop a scientifically defensible method for assessing and conserving protected water supply areas in Newfoundland.

EDM Environmental Design and Management Limited, in association with Loucks Oceanology Limited and Jacques Whitford Environment Limited, was awarded the contract in April 1995. Project research began in May 1995 and field work was conducted in June and September of that same year.

BACKGROUND

Gander Lake, in the northeast part of Newfoundland, is one of the largest lakes on the island. It provides a potable water supply for the Towns of Glenwood, Appleton, and Gander. The Lake and the watershed are also in demand for recreation, natural resource extraction, and urban development.

Such activities result in use of land and water environments and present challenges in terms of jurisdictional conflicts. Federal, Provincial and Municipal government departments; groups with legal access rights, and private land owners all hold interests in the natural resources found within the protected watershed of Gander Lake. This requires decisions to be made about how the water supply watershed should be used. These decisions must be based on knowledge of how Gander Lake and its catchment function as natural systems. This study was undertaken to address these concerns and to ensure long-term sustainable multiple use of Gander Lake.

GOAL AND OBJECTIVES

The goal of this study was to develop a watershed management plan for Gander Lake and its catchment that protects the potable water supply of the Towns of Gander, Glenwood, and Appleton, while providing long-term sustainable multiple use by a number of private and public concerns.

The specific objectives of the study, as set out in the terms of reference, were as follows:

[1] Development of a database on:

- (a) the past, present and potential future land uses within the catchment area of Gander Lake;
- (b) the past, present and potential future uses of the Lake;
- (c) the existing and potential pollution sources, the associated pollutants and pollutant loads, and the areas of the catchment affected; and
- (d) the hydrologic, morphologic, thermodynamic, hydrodynamic, and water quality characteristics of the Lake.

[2] Set-up and validation of an existing one-dimensional hydrodynamic/thermodynamic model to simulate the Lake's water temperature and quality.

[3] Development of watershed management plan for Gander Lake and its catchment which would include:

(a) identification of areas of the Lake which are presently, or which could potentially be, adversely affected by conflicting uses of the Lake;

(b) identification of high risk, moderate risk and low risk areas within the catchment, based on land uses and associated pollutants;

(c) identification of measures to correct or mitigate the problems relating to the pollution of the Lake;

(d) classification of the Lake and its catchment into a number of zones for different types of compatible uses; and

(e) identification of appropriate management and protection strategies to facilitate the long-term and sustainable use of Gander Lake and its catchment area for multiple purposes such as municipal water supply, recreation, etc.

REPORT ORGANIZATION

The report is organized in four parts: 1: Data Collection; 2: Modelling; 3: Integrated Watershed Management Plan; and Part 4: Conclusions and Recommendations.

Part 1 presents and describes the data collected and information gathered. It includes research methods, background information, lake water quality information, land use and lake use descriptions. Part 2 summarizes the hydrologic and bathymetric modelling. It includes methodology, results and discussion of lake modelling exercises and comments on the present state of the Lake. These two Parts provided the basis for the analysis and the watershed management plan contained in Part 3. Part 3A describes the development of the watershed management decision model (created in a GIS), explains how the model was used to assess the present and estimated future pollutant situation in Gander Lake, and classifies the Lake and catchment in terms of sensitivity. Part 3B presents an evaluation of legal jurisdiction in the protected watershed, the goals and objectives of the watershed plan, implementation options, long term water quality monitoring and modelling recommendations, and additional data that might be collected to provide further insight into the conditions of Gander Lake and its catchment.

PART I: DATA COLLECTION

1.1 INTRODUCTION

The Data Collection component of this project included the collection of both existing and new information. Topics included background information on the Lake and its catchment, information on Lake water quality, and information on both Lake use and catchment land use. The purpose of the data collection was to support the water modelling (Part 2) and ultimately to develop an integrated watershed management plan (Part 3).

What follows is a description of the data collection methodology, followed by a summary of the key data collection results or conclusions in each topic area (Background, Lake Water Quality, Land Use and Lake Use). All collected information was provided to the Department of Environment, Water Resources Division, at the end of the project. Information reviewed is named in the first section where it was useful; it may be referred to in subsequent sections of Part 1.

1.2 METHODOLOGY

1.2.1 Information Collection Method

Existing information on water quality, land use and lake use, was compiled through interviews conducted by EDM Environmental Design and Management Limited (EDM) staff with relevant agencies and groups, as well as from readily available published and unpublished information.

Staff conducted interviews with employees of relevant federal departments. Interviews were also conducted with staff from departments of the Government of Newfoundland and Labrador which manage land and water resources and their use in the area. Engineering staff from the Town of Gander provided documented information sources and local knowledge, as did staff at Memorial University of Newfoundland. The project team also interviewed members from the Western Newfoundland Model Forest Committee and long time residents of the area.

Where existing information (in published and unpublished format) was available, it was collected at the time of interview or later as the study unfolded. Library resources were also used.

EDM staff made a preliminary field trip on May 23, 1995. New information on Lake and land use was also collected during a two day field visit conducted by EDM staff on September 23 and 24. During this time, most areas of the catchment were observed, and additional measurements and observations in support of water modelling and land use mapping results were noted.

1.2.2 Field Survey Method

Data on water quality and bathymetry was collected during a field sampling program in the late spring and late summer. Prior to undertaking the field program, sensitivity analysis of the MinLake model parameters was conducted in order to inform the sampling program. The field program was undertaken by staff of Jacques Whitford Environment Limited (JWE). The field program was conducted on June 8 and 9 (chemical water sample analysis), June 23 and 24 (bathymetry data and dissolved oxygen/ temperature/conductivity probes), and September 7 and 8, 1995 (chemical water sample analysis and oxygen/temperature/conductivity probes).

Instrument specifications for the Si-Tex Video Sounder, the TransPak II GPS (Geographical Positioning System), and the Seabird CTD with DO_2 Sensor are attached as Appendix A and some description of the equipment and its use is included in Table 1.2. The GPS was used to position the depth sounder. Additional information about how these pieces of equipment were used is provided in the next three sections. Due to rough conditions on Gander Lake during the June sampling program, a larger boat (8 m) was used for stability during the water quality testing in September, 1995.

1.2.2.1 Bathymetry Survey

The original field survey plan called for collection of bathymetry data in conjunction with the first sampling program. This was not possible because the survey subcontractor was unable to locate and obtain the necessary survey equipment in time to coordinate with the June sampling program. In addition, shoreline conditions along a number of the transects made the use of traditional survey methods inefficient in positioning the vessel. Conditions included heavy tree cover at the shoreline; long distances (>5 km) along some transects and access problems such as shallow water. Fixing the vessel position from shore was difficult given the rough conditions encountered during the survey.

As a more efficient approach to collection of the bathymetry data, it was decided, subsequent to the June 8, 9 field survey, that a differential Global Positioning System (GPS) would be obtained and used in conjunction with the JWE sounder.

1.2.2.2 Water Quality Sampling

Sample stations were initially located using the vessel GPS. Sampling points were subsequently relocated using a combination of the vessel sounder and non-differential GPS.

Water samples for chemical analyses were collected at all sampling locations using two 5L PVC Niskin bottles attached to a winch deployed stainless steel cable. Depths for water sample collection were recorded using a metre block.

Water samples were transferred to sample containers provided by the analytical laboratory (MDS Environmental Services, Toronto). Immediately upon collection, samples were placed in coolers, with sufficient freezer packs to maintain a temperature of 4°C.

Secchi disc readings were also recorded at each of the sampling locations. The depth at which the Secchi disc disappears was recorded and the disc was then raised until it reappeared. The average of the two depths was recorded as the Secchi disc depth.

1.2.2.3 Conductivity/Temperature/Depth Probe with Optional Dissolved Oxygen Probe

The conductivity/temperature/depth (CTD) with optional dissolved oxygen (DO) probe was deployed at all sampling locations where appropriate depths (>30 m) were encountered during the June 23/24 and September 7/8, 1995 surveys.

Data was collected using a winch deployed data logging instrument (Seacat SBE19 CTD with DO probe). This instrument is designed to provide a continuous recording of depth, temperature, dissolved oxygen, and conductivity information with the additional capabilities of information storage and down loading. The data files are also provided as digital files.

The CTD was calibrated by ASL Environmental Sciences (supplier) prior to shipment. In conjunction with the CTD, deployment water samples were collected and field preserved for subsequent dissolved oxygen measurement using Winkler Titration. Dissolved oxygen measurements were completed by LeDrew Environmental Management Ltd. (LEM), in St. John's.

During the June 23/24 surveys six DO samples were collected at five locations with depths ranging from surface to 120 m. During the September sampling, this was increased to 12 samples at six locations; depths were restricted to surface and 60 metres.

1.3 BACKGROUND INFORMATION, BASE MAP, AND BATHYMETRY

1.3.1 Background Information Reviewed

Existing information, presented in the following list, was supplemented by interviews and collection of new data in Gander Lake and its catchment area. See the end of Part I for a full list of sources.

- Agriculture Canada. 1972. Soil Survey of the Gander-Gambo Area, Newfoundland.
- Batterson, Martin J. and Spencer Vatcher. 1991. Quaternary Geology of the Gander (NTS 2D/15) Map Area. Current Research (1991) Newfoundland Department of Mines and Energy, Geological Survey Branch, Report 91-1, pages 1-12.
- Catto, Norm. 1995. Personal Communication. Memorial University of Newfoundland.
- Dziwowski, P.A., G. Kirby, G. Read and W. G. Richards. 1984. The Climate for Agriculture in Atlantic Canada. Atlantic Advisory Committee on Agrometeorology. Publication No. ACA 84-2-500.
- Environment Canada, Atmospheric Environment Service. Climate Normals, Gander, 1937-1990.
- Environment Canada, Atmospheric Environment Service. Daily maximum temperature, Gander, 1979.
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- Environment Canada, Atmospheric Environment Service. Daily meteorological data, Gander, June 1979 - December 1979.
- Environment Canada, Atmospheric Environment Service. Daily minimum temperature, Gander, 1979.
- Environment Canada, Atmospheric Environment Service. Daily precipitation, Gander, 1979.
- Environment Canada, Atmospheric Environment Service. Evaporation data, Gander, 1979.
- Environment Canada, Lands Directorate. Soil Capability for Agriculture. 1:1,000,000 Map Series. Atlantic Provinces.
- Kerekes, J. 1990. Western Brook Pond (T. Kira ed.) Data Book of World Lake Environments. Vol. 3, A survey of the state of world lakes, Internat. Lake Environment Comm. (ILEC) and UNEP. Otsu, Japan. pp. 1-10 NAM-31.
- Macpherson, Alan G. and Joyce Brown Macpherson, eds. 1981. The Natural Environment of Newfoundland, Past and Present. Department of Geography, Memorial University of Newfoundland.
- Memorial University of Newfoundland, Physics Department. 1962. 1:50,000 scale bathymetry map of Gander Lake.
- Memorial University of Newfoundland, Physics Department. 1978. Cross-sectional and longitudinal depth profiles of Gander Lake.
- Memorial University of Newfoundland, Physics Department. 1983. Report on cross-sectional and depth-temperature profiles of Gander Lake.

- Murray, Alexander. 1874. Survey of the Gander River and Lake. Geological Survey Office.
- National Topographic System, North American Datum 1927, 1: 50, 000, map sheets 2D14, 2D15, and 2D16, published in 1987.
- O'Connell, Dr. Mike. Personal Communication. 1995. Fisheries and Oceans Canada.
- Sullivan, John. 1995. Personal Communication. Manager Quarry Rights. Newfoundland and Labrador, Department of Natural Resources, Mines Branch, Mineral Lands Division.

1.3.2 Summary of Background Information

The following is a brief summary of the pertinent background information about Gander Lake, its inflowing and outflowing rivers, geological history, geology, soils, topography, climate, and history of scientific study. Figure 1.1: Base Map of Gander Lake and its catchment, may be referred to for the general location of the elements described below.

1.3.2.1 Location and Size

Gander Lake, one of the largest lakes in Newfoundland, is located at latitude 49°N, longitude 54°W in northeast Newfoundland. Gander Lake is part of the Gander River Basin. The entire Gander River basin has a natural drainage area of 5,310 km^2, making it the third largest drainage basin on the island. The physical dimensions of Gander Lake are approximately 50 km at its maximum length with an average width of 2 km and a surface area of 112 km^2. More specific measurements are given in Section 1.4.5, for the purposes of limnologic modelling.

1.3.2.2 Inflowing and Outflowing Rivers

There are two large rivers and several smaller streams entering Gander Lake, together with a single outlet. The Northwest Gander River and the Southwest Gander River, both entering at the west end of the Lake, are the two large inflowing rivers. They drain approximately 79% of the total watershed. Smaller inflowing streams drain the local catchment of the central and eastern portions of the watershed. The largest of these is Soulis Brook, which enters at the far eastern end of the Lake. The single outlet, at the west end of the Lake, is the Gander River.

1.3.2.3 Geological History

While Gander Lake has not been studied extensively, scientists have developed theories of the Lake's origin (Catto, 1995). It is believed that Gander Lake is a former fjord that became separated from the sea in a similar manner to Western Brook Pond in Gros Morne National Park in western Newfoundland (Kerekes, 1990).

The Gander area has been affected by at least two separate ice flow events (Batterson, 1991), the most recent being about 7,000 to 8,000 years ago (Agriculture Canada, 1972). Geological evidence indicates that Gander Lake was either formed or modified (it may have been an existing fault valley) by this first ice flow that headed eastward, parallel to the present Lake.

Geologists believe that Gander Lake was an open fjord at the beginning of the second ice flow event. Evidence shows that the ice moved in a north-northeast direction towards what is now Freshwater Bay. At this end of the Lake, a deep valley is filled with material that was deposited when the glacier retreated. Northwest Gander, Southwest Gander, Fifteen Mile Brook and the Gander River formed at this time as a result of glacial melt water (Batterson, 1991).

One result of the geological history is a tremendous deposit of sand and gravel at the eastern end of Gander Lake. The deposit is used as one of the main sources of gravel in the area. It is mainly used for backfill for local construction and, because it is inferior for making cement, is much less desirable for export outside of the area (Sullivan, 1995).

1.3.2.4 Geology

Agriculture Canada (1972) and Batterson (1991) describe the surficial geology of the Gander Area. The Gander Lake area landscape is characterized mainly by the results of glacial action, movement, melt down, and deposition. Many areas are covered in glacial till of granite origin, ranging from between five centimetres and three metres thick. Some areas are scraped clean of material by glaciers. Other areas are covered in glaciofluvial deposits where melt water formed channels.

Glacial till, which covers most of the Gander Lake catchment on the north side of the Lake, is generally thin with bedrock exposed in several areas. On the south side of Gander Lake, the landscape becomes more hilly with thicker till, less bedrock outcrops, and till hummocks around Hunts Pond and at the catchment boundary around Fifteen Mile Brook.

The valleys of Southwest Gander River and Northwest Gander River exhibit glaciofluvial material in deposits that are higher than the present rivers. Outwash sediments exist around Careless Brook Valley, and Hunts Brook Valley. Most of the remaining materials are modern organic deposits which exist in poorly drained depressions to the east and west of the Town of Gander, or colluvial deposits at the bottom of steep slopes on the north side of Gander Lake, below the Town.

The existence of glacial tills indicate potential for sand and gravel extraction. Most of the known deposits are not of high enough quality to be suitable for large scale extraction and export outside of the area (Sullivan, 1995). There is potential for aggregate resources around Fifteen Mile Brook (Batterson, 1991).

The presence of colluvial deposits on the north side of Gander Lake indicates unstable slopes and, therefore, should not be used as construction sites. The well drained tills and glaciofluvial deposits indicate that underground storage or land filling activities might jeopardize the Lake water quality because of the potential for leachate percolation (Batterson, 1991). The local soils are permeable, and shallow over a bedrock that is fractured only near its surface.

1.3.2.5 Soils

The soils of the catchment area are mainly podzols with a small amount of gleysols and brunisols. Most glacial till, in the Gander area, was carried only 2 to 25 km, making the parent material relatively local in nature. Areas covered in material not derived from glacial till are characterized as muck, peat, or rocky land (Agriculture Canada, 1972).

Soils that developed from granite parent materials have sandy textures and are grayish brown in colour, with numerous boulders. Drainage is rapid and the soil may suffer from drought. Soils developed from tills derived from sedimentary rocks range from loam to silt loam to clay loam. These soils are mainly olive colour, shallow in profile, and hold water better than those soils that developed from granite till.

Gander area soils are characterized as unsuitable for agriculture by Canada Land Inventory Soil Capability for Agriculture standards. While this may be the case, several alluvial deposits around the Gander Lake area are some of the most agriculturally suitable soils in Newfoundland.

1.3.2.6 Topography

The catchment area of Gander Lake consists of flat areas to gently rolling plains that slope slightly to the northeast. In the area surrounding the airport, where most of the bogs lie, slopes are less than 5%.

Gander Lake itself has a surface elevation of approximately 25 m a.s.l. The hills that surround Gander Lake valley, rise steeply, especially at the middle part of the Lake. This is true on both the north and south sides of the Lake: slopes average about 50% in these areas. This is most pronounced on the south side between Fifteen Mile Brook and Hunts Brook, and on the north side between Soulis Brook and the golf course at Gander.

Above the steep Lake valley, there is essentially a flat plateau, where the topography is relatively uniform. On the north side of the Lake, elevations range from 120 to 150 metres. The plateau landscape there is characterized by bogs and poorly defined drainage. On the south side of the Lake, the landscape is somewhat more hummocky, ranging from 200 to 260 metres. The highest elevation in the catchment is Mt. Peyton, a distinctive rock outcrop which rises steeply to 487 m a.s.l. at the west end of the Lake. The lowest elevations are 60 m a.s.l., at the east of the catchment near the coast.

1.3.2.7 Climate

This temperate climate is modified continental (Dzikowski et al, 1984). The average annual precipitation is 1181 mm compared to 1400 mm at St. John's. The average total annual degree days above 5°C is 120 to 130, which is the same as at St. John's; there is an average frost-free period of 110 days compared to 130 days in St. John's. The monthly average air temperature is below zero in the period, December to March, reaching a minimum of -11.8°C in February, and a maximum of 21.6°C in July. See the following Table 1.1 for average monthly and annual temperature, total precipitation, snowfall, rainfall, and hours of bright sunshine as measured at Gander International Airport.

The distribution frequency of occurrence of winds in various directions, 1955-80, (Canadian Normals) shows that the average percentage frequency of winds with a westerly component is 60.6%; with an easterly component, 23.6%. Averaged over all months, wind directions, SW, WSW and W are most common at 9.9 to 12.6% each, while NNE, NE and ENE, are least common at 2 to 3% each. The distribution of frequencies in various directions is quite consistent from September to March with W being the most frequent direction. In June, July and August, there is a shift of the prevailing direction to WSW and SW.

The table of wind speeds also shows that maximum hourly speeds were experienced in December, January and February (105 to 107 km/h), while average speeds range from 17.2 in August to 24.4 km/h in January. The distribution of wind speeds in various directions shows little variation in any month; mean wind speeds are similar for all direction classes.

It should be noted that the wind speeds described above are for the Gander airport. The airport lies on the plateau above the Lake valley. It is possible that the winds are magnified at the Lake surface due to the valley effect, especially when they are blowing from westerly directions. Gander Lake is known by local people to be a very windy place. During the field sampling program, swells in the range of 1 - 2 metres were encountered. These were most noticeable in the western end and in the middle of the Lake. These swells were created by winds from the west, at a speed of 25 km/hr. The bluffs provide wind sheltered zones on the windward side of the Lake.

1.3.2.8 History of Scientific Survey

Scientific research of the Gander Lake area began as early as 1874, when Alexander Murray studied the area for the Geological Society. Memorial University has conducted studies of bathymetry, cross-section, and temperature-depth profiles of Gander Lake. Memorial University and the Department of Natural Resources, Geological Survey have and continue to study bedrock, surficial geology, and the geological history of the area.

Fisheries and Oceans Canada has and continues to study the Lake in terms of its ability to support species like Arctic Char and Atlantic Salmon (O'Connell, 1995). A 1991 study showed oxygen at 300m. In September, 1995, O'Connell's sampling indicated that dissolved oxygen was approximately 11-12 mg/l with little difference from surface to bottom and sampling station to sampling station.

1.3.3 Base Map

The digital base map prepared as a reference map for all project mapping, was digitized from the National Topographic System, North American Datum 1927, 1: 50, 000, map sheets 2 D/14, 2 D/15, and 2 D/16, published in 1987. The maps are based on field confirmed aerial photography. They illustrate roads, trails, logging roads, dams, towns and villages, rivers, lakes, elevations, vegetated areas, bogs, and railway beds. A hard copy of the digital base map, showing these features and the designated catchment area, is shown as Figure 1.1. For illustration purposes, the contours are not shown in the Figure.

1.3.4 Bathymetry

A bathymetry map was created by digitizing the existing bathymetry and cross-sections surveyed by Memorial University's Physics Department in 1962 and 1978 respectively. This information was incomplete, particularly with respect to the near shore areas. To improve the data set, additional bathymetry was surveyed at three locations between the shoreline of the Lake and the 100 foot depth contour for seven transects. The sounder provided good resolution at all depths encountered during the survey. In addition, the depth of the Lake was unknown so five locations were surveyed within the 900 foot depth contour to identify the maximum depth of the Lake.

The field program to collect the bathymetry was executed on June 23 and 24 of 1995. A hard copy of the digital bathymetry and new cross-sections resulting from the survey is provided as Figure 1.2. The field survey confirmed the maximum Lake depth at 290 metres.

TABLE 1.1: CLIMATE AVERAGES FOR GANDER INTERNATIONAL AIRPORT

Month	Temperature	Total Precipation	Snowfall	Rainfall	Bright Sunshine
January	-6.8°	112.9 mm	90.0 mm	28.5 mm	69 hours
February	-7.4°	108.1 mm	85.9 mm	23.6 mm	82 hours
March	-3.8°	116.4 mm	75.2 mm	40.8 mm	107 hours
April	1.1°	97.0 mm	49.0 mm	43.4 mm	115 hours
May	6.5°	79.9 mm	13.4 mm	64.7 mm	150 hours
June	11.6°	81.8 mm	3.2 mm	78.3 mm	160 hours
July	16.3°	73.2 mm	0.01 mm	73.2 mm	200 hours
August	15.5°	95.6 mm	0.0 mm	95.6 mm	178 hours
September	11.1°	89.7 mm	0.1mm	89.5 mm	143 hours
October	5.9°	105.0 mm	12.0 mm	91.3 mm	112 hours
November	1.4°	108.6 mm	37.1 mm	70.9 mm	63 hours
December	-3.9°	113.4 mm	77.9 mm	37.9 mm	58 hours
Annual	4.0°	1181.6 mm	443.8 mm	737.9 mm	1437 hours

Source: Environment Canada, Atmospheric Environment Service. Canadian Climate Normals, 1973 and Climate Averages, Gander International Airport: 1937 - 1990.

EXECUTIVE SUMMARY

This executive summary describes the organization of the report, goals and objectives of the study, and an overview of the major conclusions and recommendations of the Watershed Management Plan for Gander Lake and its catchment. It presents the results of the study and future directions are recommended for the study area, in particular, how can Gander Lake continue to provide a reliable drinking water supply for the Towns of Gander, Glenwood and Appleton, while still providing long-term sustainable multi-use options to those who wish to use the catchment (land and water bodies) for natural resource harvesting and extraction, as well as recreation.

REPORT ORGANIZATION

The report is organized in three parts: 1: Data Collection; 2: Modelling; and, 3: Integrated Watershed Management Plan. Part 1 presents and describes the data collected and information gathered. Part 2 summarizes the hydrologic and bathymetric modelling. These two Parts provided the basis for the analysis and the watershed management plan contained in Part 3. Part 4 presents main conclusions and recommendations.

GOAL AND OBJECTIVES

The goal of this study was to develop a watershed management plan for Gander Lake and its catchment that protects the potable water supply of the Towns of Gander, Glenwood, and Appleton, while providing long-term sustainable multiple use by a number of private and public concerns.

The specific objectives of the study, as set out in the terms of reference, are as follows:

[1] Development of a database on:

- (a) the past, present and potential future land uses within the catchment area of Gander Lake;
- (b) the past, present and potential future uses of the Lake;
- (c) the existing and potential pollution sources, the associated pollutants and pollutant loads, and the areas of the catchment affected; and
- (d) the hydrologic, morphologic, thermodynamic, hydrodynamic, and water quality characteristics of the Lake.

[2] Set-up and validation of an existing one-dimensional hydrodynamic/ thermodynamic model to simulate the Lake's water temperature and quality.

[3] Development of watershed management plan for Gander Lake and its catchment, which would include:

- (a) identification of areas of the Lake which are presently, or which could potentially be, adversely affected by conflicting uses of the Lake;
- (b) identification of high risk, moderate risk and low risk areas within the catchment, based on land uses and associated pollutants;

(c) identification of measures to correct or mitigate the problems relating to the pollution of the Lake;

(d) classification of the Lake and its catchment into a number of zones for different types of compatible uses; and

(e) identification of appropriate management and protection strategies to facilitate the long-term and sustainable use of Gander Lake and its catchment area for multiple purposes such as municipal water supply, recreation, etc.

PART 1: DATA COLLECTION AND ANALYSIS

Existing water quality data and information was collected from various agencies, government and otherwise, who collect data or manage land in the catchment area. This was supplemented by a field program to gather water quality data. The field program was conducted in both June and September of 1995.

The field program was designed in consultation with people familiar with the Lake and its catchment, those who would be collecting the data, and those who understood what was needed for hydrological and GIS modelling. Gander Lake is a clean water body - many of the parameters tested were not detectable in the Lake environment. Based on present land use, assumptions were made about likely inputs into the Lake environment.

Forestry is the main land use in the protected catchment of Gander Lake and will continue to be an important economic activity in the area. Forestry activity may result in sediment and erosion, and forestry resource roads are the main source of sediment.

Many people use the rivers, lakes and ponds of the catchment and watershed of Gander River for recreation. The demand for this land use is expected to increase in the future. Cottage development must be managed, so that it does not jeopardize the drinking water supply or the benefit of current wilderness experiences.

Within the protected watershed of Gander Lake lie the Towns of Gander, Glenwood, Appleton, as well as the community of Benton. Most urban growth is in the Town of Gander which includes Canadian Forces Base Gander, and Gander International Airport. While growth in the Town is generally steady (low in 1995), most of Gander's growth occurred by 1960. Gander will most likely continue to grow as it offers central commercial and governmental services to the outlying areas. Key future development includes Gander's Lake Shore Development Scheme and the potential twinning of the Trans Canada Highway.

The Province does not have any soils that are classified as having high capability for agriculture, but some of the best agriculture soils in Newfoundland are located along the Northwest and Southwest Gander Rivers. Agricultural activity is low at present, but these areas may be important for future food production.

PART 2: HYDROLOGIC MODELLING

Hydrologic modelling was used to examine water balance, water circulation patterns, and to simulate water quality and temperature. Three types of computer modelling were used to evaluate Gander Lake: an overall water balance using STELLA; water circulation patterns using the DYNHYD component of WASP; and simulation of water temperature and quality using Dillon and MinLake. The models were also used to test various future scenarios as determined by the proposed future land and lake use information.

Gander Lake has low biological productivity due to low organic input. It also mixes, or turns over, twice a year. The lake environment is clean and has a large capacity to assimilate pollution from land and lake use. However, this could change if development pressure becomes great enough to exceed assimilative capacity. For this reason, Gander Lake and its protected catchment must be treated with sensitivity in land and water development and management.

Modelling showed that the water from Northwest and Southwest Gander Rivers mixes, at least partly, with Gander Lake. This indicates that activities in the watersheds of these rivers can affect the Lake environment and that these watersheds should be included in the protected catchment area.

In Gander Lake, phosphorous is expected to be the nutrient that would eventually, if available at high levels, result in the Lake becoming unsuitable for drinking and for fish habitat. Increased phosphorous levels are associated with eroding sediments carried by stormwater runoff. Phosphorous levels may also be increased when untreated or partially treated sewage and stormwater enters water bodies. Therefore, primary areas of concern are erosion control in land development and management practices, and proper sewage and stormwater management to reduce sediment delivery.

PART 3: INTEGRATED WATERSHED MANAGEMENT PLAN

3A: WATERSHED MANAGEMENT DECISION MODEL

A Geographic Information System (GIS) was used to create a watershed management decision tool, which was used to assess the catchment in terms of sensitivity to land use changes. The study team used what is referred to as a Watershed Management Decision Model. This is a cartographic model that uses maps of environmental conditions to predict the impact of land use change on Gander Lake. The data base of environmental conditions was created in Part 1. Cartographic modelling is a process of overlaying maps to combine the values of features which occur in the same geographic space. The power of this method of land analysis is greatly enhanced when a Geographic Information System (GIS) is used.

The Watershed Management Decision Model was used to predict erosion potential in the catchment. This allowed the land to be classified according to its inherent sensitivity. The inherent sensitivity, when combined with a delivery ratio, allowed for the development of a model predicting how much erosion from each 1 ha area in the catchment reaches Gander Lake. The model was calibrated using water quality data and used to predict the impact of proposed future land use changes.

The steep slopes along Gander Lake are among the most sensitive areas in the catchment. These are particularly sensitive when roads are built or the trees are cut, two of the expected causes of sediment and erosion in the Gander Lake catchment.

The Lake and its shoreline were considered for sensitivity in three ways: lake sensitivity to the catchment; lake sensitivity to a less well mixed east end; and lake sensitivity to the NW and SW Gander Rivers. The expected future sediment delivery predicted by the Watershed Management Decision Model was correlated to expected increases in phosphorous as a result of this increased sediment delivery for all three scenarios. The results indicate that the Lake is sensitive to increased inputs. In particular, to the scenario where circulation of both Rivers throughout the Lake is assumed.

The catchment was also modelled for sensitivity to point source inputs. A map illustrating the best (and worst) locations for a points source discharge was created. The Town of Gander is well situated for point source loadings.

The physical plan prepared for the Gander Lake catchment considered, primarily, the inherent sensitivity of each landscape unit in the catchment, as well as the potential for that landscape unit to deliver sediment (and other nutrients) to the Lake.

3B: PLANNING CONTROLS

The following goals, ranked in order of priority, are recommended for the watershed management plan:

1) maintaining the integrity of the water supplies of Gander, Glenwood and Appleton;
2) maintaining the current trophic status of Gander Lake; and
3) maintaining the integrity of the fish habitat (Atlantic Salmon).

The following key objectives should be the focus of the watershed management plan in order to achieve the above goals:

1) reduce sediment and erosion;
2) determine the effects of the Northwest and Southwest Gander Rivers on the Lake; and
3) control point source inputs.

The plan recommends a variety of approaches to achieving these objectives. Regulatory approaches are recommended for establishing zones, including buffer zones, restricted use areas, and changes to the designated watershed management area. Negotiated approaches are recommended for controlling land use activities, including forestry guidelines, development guidelines, stormwater management guidelines, cottage and recreation development guidelines. Finally, watershed stewardship approaches are recommended for monitoring activities and land use in the Lake and catchment; understanding and resolving water quality issues in the Lake, the Lake catchment, the rivers and the rivers' catchments; maintaining an effective emergency response plan; and, educating to mitigate potential future inputs.

The Gander Lake Watershed Monitoring Committee should be a lead agency in protecting Gander Lake and its catchment.

Key implementation projects include:

- establishing buffer zones and restricted uses areas;
- preparing guidelines for land use development, natural resource extraction and recreation use; and
- fostering watershed stewardship.

The protected watershed area should be expanded to include the catchment areas of the Northwest and Southwest Gander Rivers. This is due to the potential influence of water from these rivers on Gander Lake. Water from Northwest and Southwest Gander Rivers circulates in Gander Lake.

New Provincial guidelines for forestry practice in sensitive areas are recommended. These guidelines should make use of recent research, and be focused on reducing erosion and sedimentation. Road construction and silviculture techniques should be a focus of the guidelines.

Guidelines for development in sensitive areas should be developed. These guidelines should focus on sediment and erosion control, as well as stormwater management to reduce the delivery of sediment to waterbodies . The guidelines should consider both the construction period and long-term inputs of different development types. Techniques to avoid disturbance of the soil (e.g., extensive grading, tree cutting, etc.), together with storm water management to reduce the quantity of runoff, should be the focus of the guidelines, rather than flood control.

Cottage and recreation development guidelines can help users to limit soil disturbance, as well as pollutants from garbage and sewage. Cottage development is potentially a huge impact on the Lake water quality. The focus of the guidelines should be on the proper location of buildings, sewage disposal system, roads, appropriate setbacks, and rules about forest clearing and other activities, such as use of all terrain vehicles, which might disturb the soil.

The long-term water quality monitoring and modelling program should include the following:

1) further research to calibrate the watershed management decision model;
2) further lake circulation modelling and research; and
3) lake water quality monitoring.

1.4 LAKE WATER QUALITY

1.4.1 Existing Information

Following is a list of information and data sources on water quality and quantity, for the Gander Lake area. This information, existing at the beginning of the study, was supplemented by the field program and by interviews with residents and employees of relevant municipal, provincial, and federal governments. The Gander River system is monitored by three hydrometric stations: one on Northwest Gander River, one on Southwest Gander River and one on Gander River.

- Baird, Edgar. 1995. Personal Communication. Longtime Resident.
- Baird, William. 1995. Personal Communication. Town Engineer.
- Card, Herbert. 1995. Personal Communication. Department of Environment, Environmental Management Division.
- Environment Canada, Inland Waters Directorate. Daily discharge data, Gander River at Big Chute, 1979.
- Environment Canada, Inland Waters Directorate. Daily discharge, Gander River at Big Chute, 1979.
- Environment Canada, Inland Waters Directorate. Flow Records for Gander River at Big Chute, 1953-1994 (Digital).
- Environment Canada, Inland Waters Directorate. Flow Records for NW Gander River (Digital, corrupted in transit, reordered).
- Environment Canada, Inland Waters Directorate. Flow Records for SW Gander River (Digital).
- Environment Canada, Inland Waters Directorate. Stream flow summary data, Gander River at Big Chute, 1950-1990.
- Environment Canada, Inland Waters Directorate. Summary water quality data, Gander River near Glenwood, July 1966 - December 1978.
- Environment Canada, Inland Waters Directorate. Water Quality Data for Gander Lake Watershed Monitoring Stations, Historical Record, including downstream to Glenwood. (Digital).
- Ludlow, Darlene. 1980. Water Sampling Program Results: Exploits River, Peters River, Gander River (Glenwood), and Traytown.
- MacLaren Atlantic Limited. June 1973. Sanitary Sewage Disposal Study for the Town of Gander.
- Newfoundland and Labrador, Department of Environment, Environmental Management Division. 1981. Chemical and Bacteriological Analysis of Gander River Water Supply.
- Newfoundland and Labrador, Department of Environment, Environmental Management Division. 1985. Gander River System: A Water Quality Survey.
- Newfoundland and Labrador, Department of Environment, Environmental Management Division. 1990. Beaverwood Sewage Treatment Plant Monitoring.
- Newfoundland and Labrador, Department of Environment, Environmental Management Division. 1993. Report describing complaints of contamination on lower Gander River.
- O'Connell, Dr. Mike. Personal Communication. Department of Fisheries and Oceans, St. John's, Newfoundland.
- Town of Gander, Engineering Department. Water levels, Gander Lake, July 1987 - August 1988.
- Town of Gander, Engineering Department. 1992. Gander Lake: A Study of Inflowing Water Quality.
- Wetzel, Robert G., Limnology, 1975, W.B. Saunders Company.

1.4.2 Sensitivity Analysis

Prior to the field component of the water quality data collection, sensitivity analysis was conducted. The purpose of this analysis was to determine the sensitivity of the MinLake model to various water quality parameters in order to direct the field sampling program.

To perform this, the MinLake model was compiled (FORTRAN compiler) and run with the test files provided. The model was then simplified to a bare minimum and run, gradually adding the various parameters back, and testing the sensitivity of the model to the various parameters.

This work, together with the project team's experience, led to an adjustment of the sampling program. Ortho-phosphorus, total dissolved phosphorus, and chlorophyll were added to the sampling program as a result of the sensitivity analysis. These parameters were required by MinLake.

1.4.3 Water Quality Data Collected with this Study

The field sampling program encountered a number of difficulties during implementation. These were caused by weather, equipment failure, shipping errors and other problems, most of which were beyond the control of the field crew. A summary of the field activities and a survey schedule is included as Table 1.2.

1.4.3.1 Sampling Locations

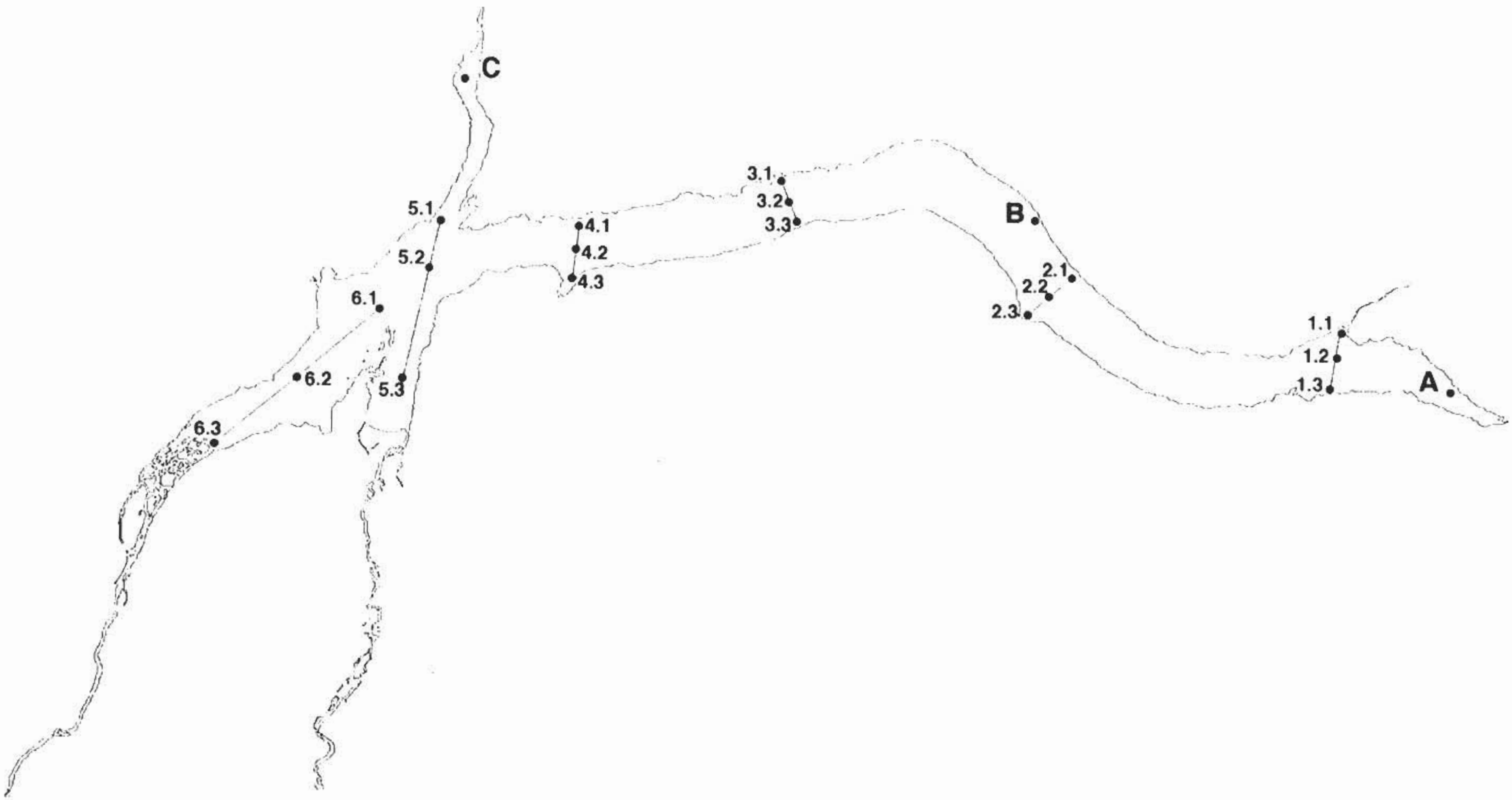
The sampling locations are shown on Figure 1.3, Lake Water Quality Sampling Locations. The locations were selected to provide a representative sampling of the Lake, within the project budget limitations and plan. Most of the locations are part of transects of the Lake, at locations where some influence from the catchment might be anticipated. Other sites were located near the river entrances and outlet.

Following a review of the June sampling results, the September program adjusted some of the sampling locations. Gander Lake generally exhibits a rapid drop off to deep water near the shoreline. The near shore sampling stations were moved closer to shore to ensure that test results were being acquired from the more shallow portion of the Lake, where light might reach the bottom and more biological activity thus occuring. Samples from Locations 1.1, 1.3, 2.3, 3.1, 4.3, 5.3, 6.3, A and C were moved closer to shore, and thus limited to surface samples only. Other sites were maintained.

1.4.3.2 Summary of Data Collected

The samples acquired in the June field program carried out by JWE were analyzed for a large variety of parameters. This list of parameters was a combination of indicators requested in the Terms of Reference, required inputs for the MinLake Model, and other parameters that were identified as potentially informative about the lake water quality.

Table 1.2: Field Activities and Survey Schedule			
Date	**Activity**	**Status**	**Response**
June 8, June 9, 1995	• Completion of initial CTD probe deployment at all locations with suitable depth. • Collection of water samples for coliform analysis completed on June 08, 1995. Collection of samples for chemical parameters completed at all locations on June 09. Where shallow waters were encountered surface samples only were collected. • Collection of bathymetry data, as defined by the original terms of reference, scheduled for this time. JWE personnel to assist subcontractor in this task.	• All CTD profiles completed; however, mechanical problem with the dissolved oxygen probe renders that portion of the data unusable. • All water sample collection for chlorophyll, coliform and chemical analysis completed as required. Samples for coliform analysis (total and fecal) are directed to LEM Laboratory (St. John's) to ensure analysis within 24 hours of collection. Samples for chemical analysis are forwarded to MDS Toronto. • Subcontractor is unable to obtain the necessary positioning and depth recording equipment to complete the bathymetry survey as scheduled.	• A second CTD survey is scheduled for June 23, 24 to redeploy the instrument and collect a second data set. The instrument is to be checked and calibrated by the supplier prior to the next survey. • No action required. • Initial survey determines that JWE sounder is suitable for depths encountered at Gander Lake. Differential GPS is to be obtained for use in positioning for the bathymetry survey.
June 23 June 24, 1995	• Field crew redeploys for completion of the bathymetry survey and recollection of CTD data. CTD has been rechecked by the supplier.	• CTD deployment is completed with samples for Winkler titration collected at 6 locations • Conductivity (S/m); water temperature and depth data from CTD provided to client • Bathymetry data is collected under the direction of subcontractor using a differential GPS (*Trimble Pathfinder*) for positioning and the *Sitex AVS 7* depth sounder on board the sampling Depth soundings were recorded at 10 second intervals and correlated with corrected positions from the differential GP S system. This data was collected on 23/24 June.	• CTD data for DO does not correspond with Winkler titrations, again indicating mechanical problems with the probe. • Data collection is completed; however the subcontractor encounters extensive problems in post processing of the data resulting in delays preparing the bathymetry mapping.
September 07, September 08, 1995	• A larger vessel (eight m) is chartered from Glenwood resident; this vessel provided a more stable platform for sampling under rough conditions encountered on the lake. • Completion of CTD probe deployment at all locations with suitable depth. Probe returned to manufacturer for calibration since June sampling. Revised calibration coefficients are provided by the equipment supplier. • Samples for DO by Winkler titration collected at 6 locations (12 depths) as backup and confirmation of CTD results • Collection of water samples for coliform and chlorophyll analysis completed on September 07, 1995. Collection of samples for chemical parameters completed at all locations on September 08. Where relocation of sampling points to near - shore locations resulted in depths of less than 30 m only surface samples were collected.	• Vessel allows for more efficient and safer sampling. • DO results obtained from the probe do not match results of Winkler titrations. Rechecks of the data by the supplier indicates no discernible problem with the equipment. The data at this point has been provided without correction. • Results of Winkler titrations have been provided in addition to the uncorrected DO probe data • Conductivity (S/m); water temperature and depth data from CTD provided. • Handling error by shipper delays receipt by laboratory; samples are held in airport cooler, and analysis is delayed.	• The Department of Fisheries and Oceans has collected probe data in the same time period (four days prior to September sampling). EDM has made arrangements to obtain this data. Upon receipt it will be combined with the available Winkler data to produce a correction factor for the probe DO's. • Explanation for delay requested from Canadian Airlines but not received to date. Contact with lab confirmed that none of the chemical parameters would be affected by the extended holding time. Results received on October 4, 1995



Lake Water Sampling Locations

Watershed Management Plan for Gander Lake and its Catchment

Figure 1.3

Parameters initially analyzed included: Lead, Bromide, Chloride, Fluoride, Nitrate(as N), Nitrite(as N), Orthophosphate(as P), Sulphate, Aluminum, Barium, Beryllium, Bismuth, Boron, Cadmium, Calcium, Chromium, Cobalt, Copper, Iron, Lead, Magnesium, Manganese, Molybdenum, Nickel, Phosphorus, Potassium, Silver, Sodium, Strontium, Tin, Titanium, Vanadium, Zinc, Chlorophyll A, Chlorophyll B, Chlorophyll C, Carotenoids, Alkalinity(as CaCO3), Anion Sum, Bicarbonate(as CaCO3), Carbonate(as CaCO3), Cation Sum, Conductivity - @25°C, Hardness(as CaCO3), Ion Balance, Langlier Index at 20°C, Langlier Index at 4°C, pH, Saturation pH at 20°C, Saturation pH at 4°C, Total Dissolved Solids(Calculated), Turbidity, Colour, Total Kjeldahl Nitrogen(as N), Total Phosphorus, Total Coliforms, and Fecal Coliforms. A large percentage of the parameters analyzed for in this first test run were found to be non-detectable. The entire results are included in Appendix B.

The June laboratory results were examined and parameters reviewed for inclusion in the September sample testing program. This evaluation was undertaken to adjust limits of quantification for certain parameters, and to add new parameters that subsequent research indicated might be useful. Chlorophyll was restricted to type "A" only, Lead by BFF was eliminated, and limit of quantification (LOQ) for Total Phosphorus was adjusted from 0.06 mg/l to 0.004 mg/l. Silica (SiO2) was added to the scan after the presence of diatom algae was noted as a potentially important indicator of biological activity in the Lake. Silica is associated with diatom algae activity.

The fall sampling run also included testing for Bromodichloromethane, Bromoform, Chloroform, and Dibromochloromethane at Location 2.1, (both surface and deep samples). This location was selected because of its proximity to the airport ditch. All of these parameters were found to be non-detectable.

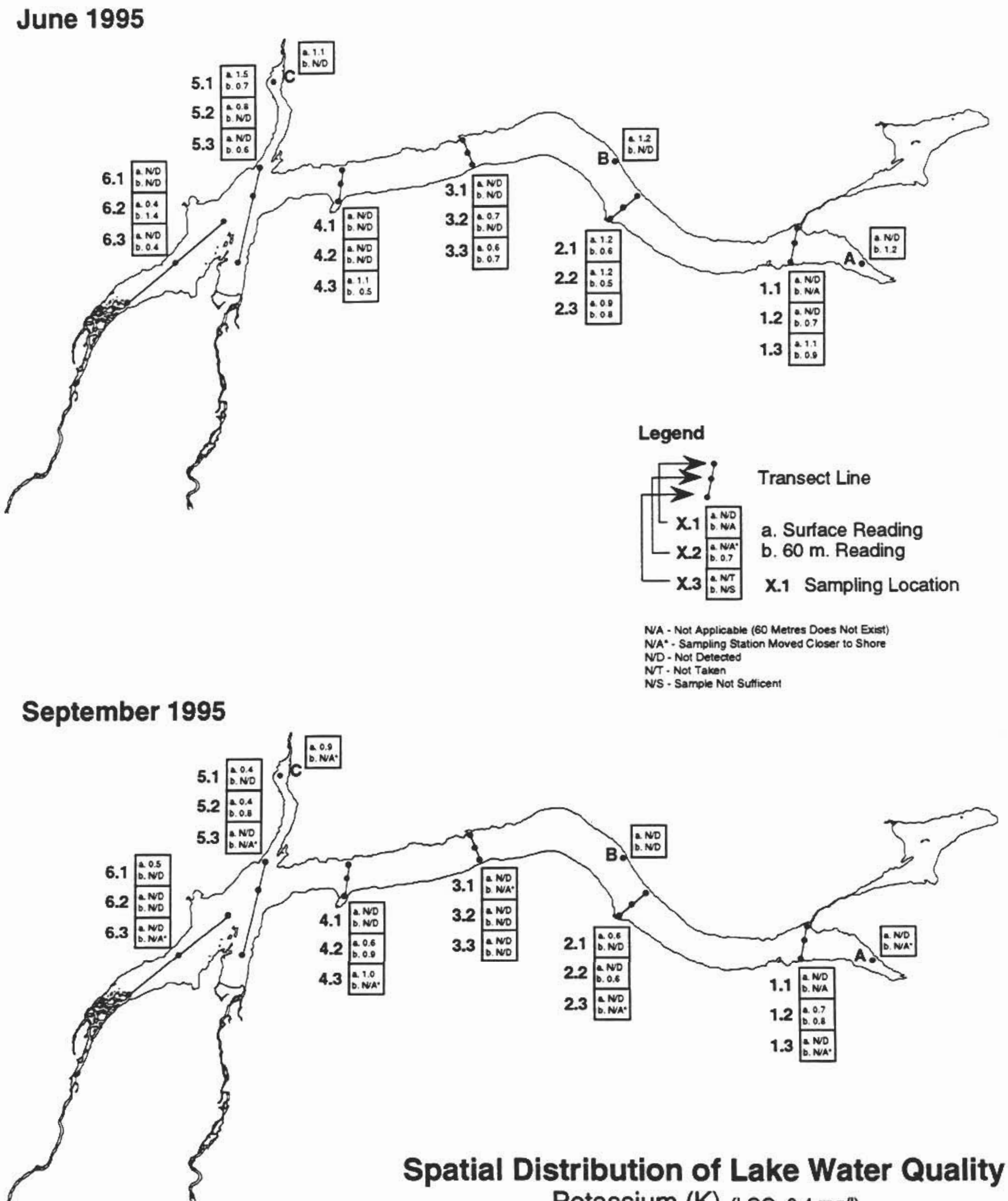
In addition to the water quality samples, a probe was run to the Lake bottom at each sampling location which acquired data on conductivity, temperature and oxygen. Winkler dissolved oxygen tests were performed at varying locations and depths in the water column. At each location the air temperature was recorded and a Secchi disk measurement made.

1.4.4 Summary of Lake Water Quality Results

Figure 1.4 a - h, provides a spatial representation of the data results for quality parameters that were present in the Lake water and that may be used as indicators in establishing relationships between land use and lake water quality.

Probe results for dissolved oxygen were inconsistent with the Winkler data. Collaboration with the Department of Fisheries and Oceans data indicated that the Winkler data was correct. Probe results are provided in Appendix B.

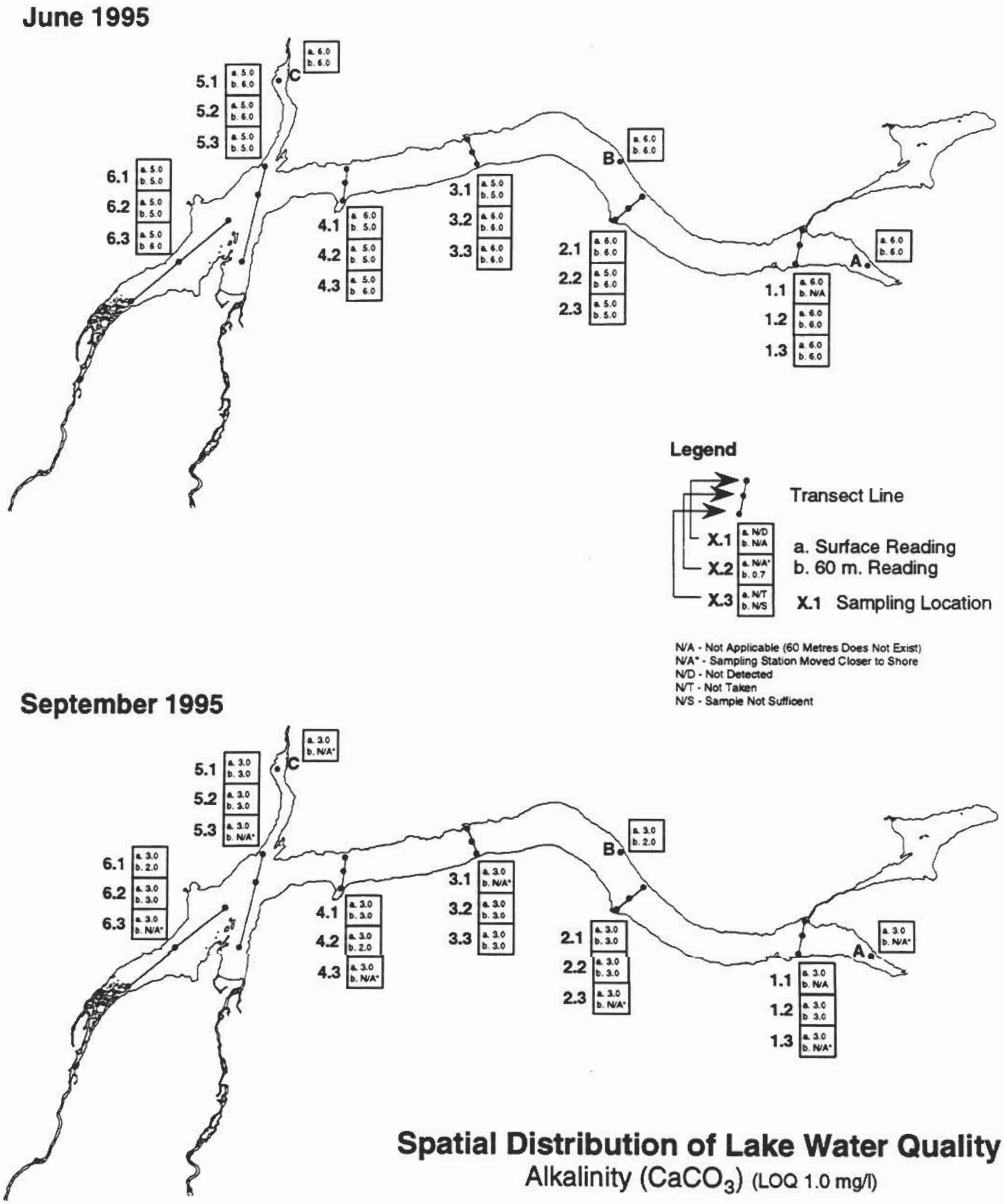
The probe results for temperature and conductivity at the sampling locations are presented in Figure 1.5 a - b. This format shows the change in these parameters with depth at the location sampled. The results of the data analysis receive more attention in Parts 2 and 3 of this study. The presentation of the data provides a good opportunity to make some preliminary observations.



Spatial Distribution of Lake Water Quality
Potassium (K) (LOQ 0.4 mg/l)

Watershed Management Plan for Gander Lake and its Catchment

Figure 1.4 a

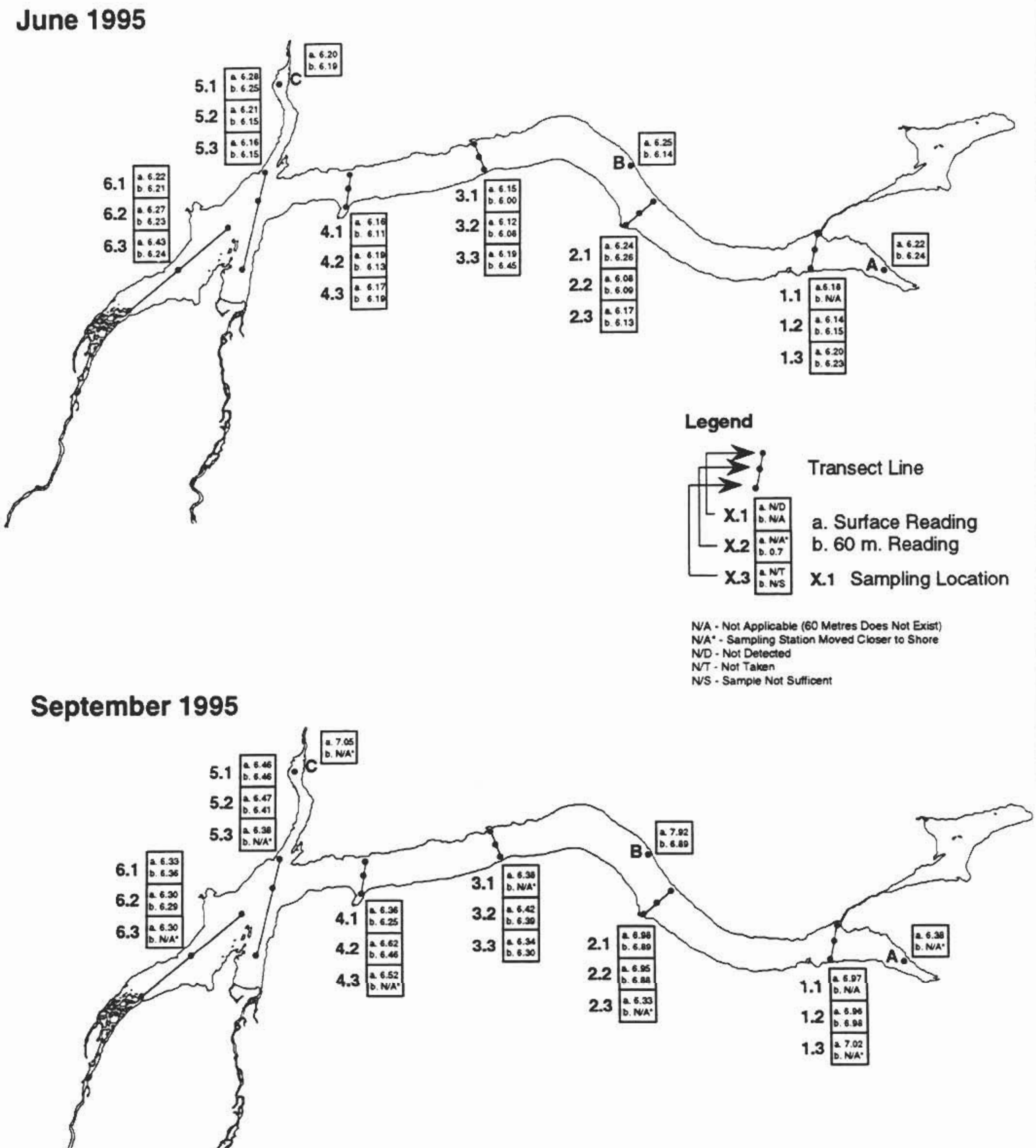


Spatial Distribution of Lake Water Quality

Alkalinity ($CaCO_3$) (LOQ 1.0 mg/l)

Watershed Management Plan for Gander Lake and its Catchment

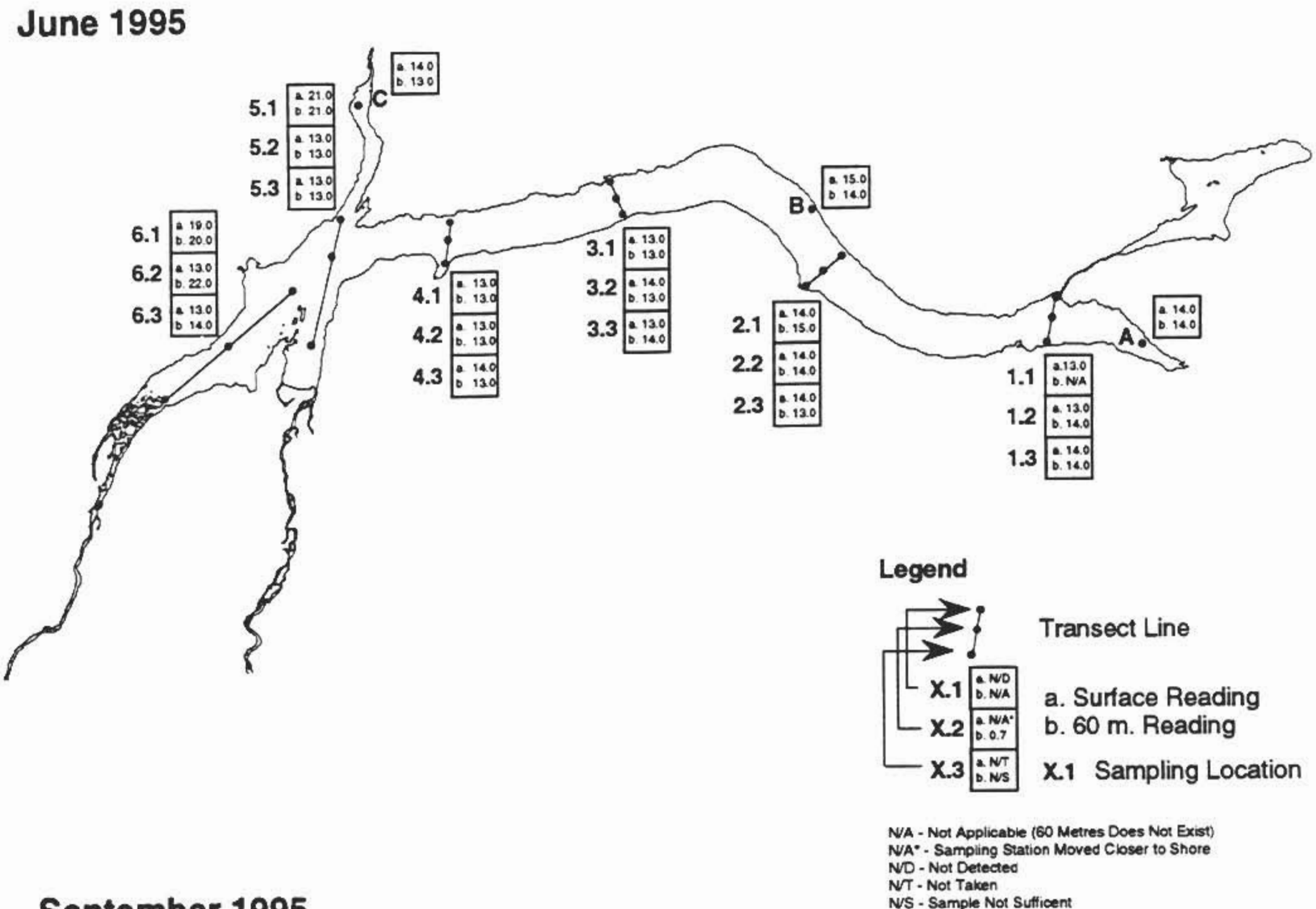
Figure 1.4 b

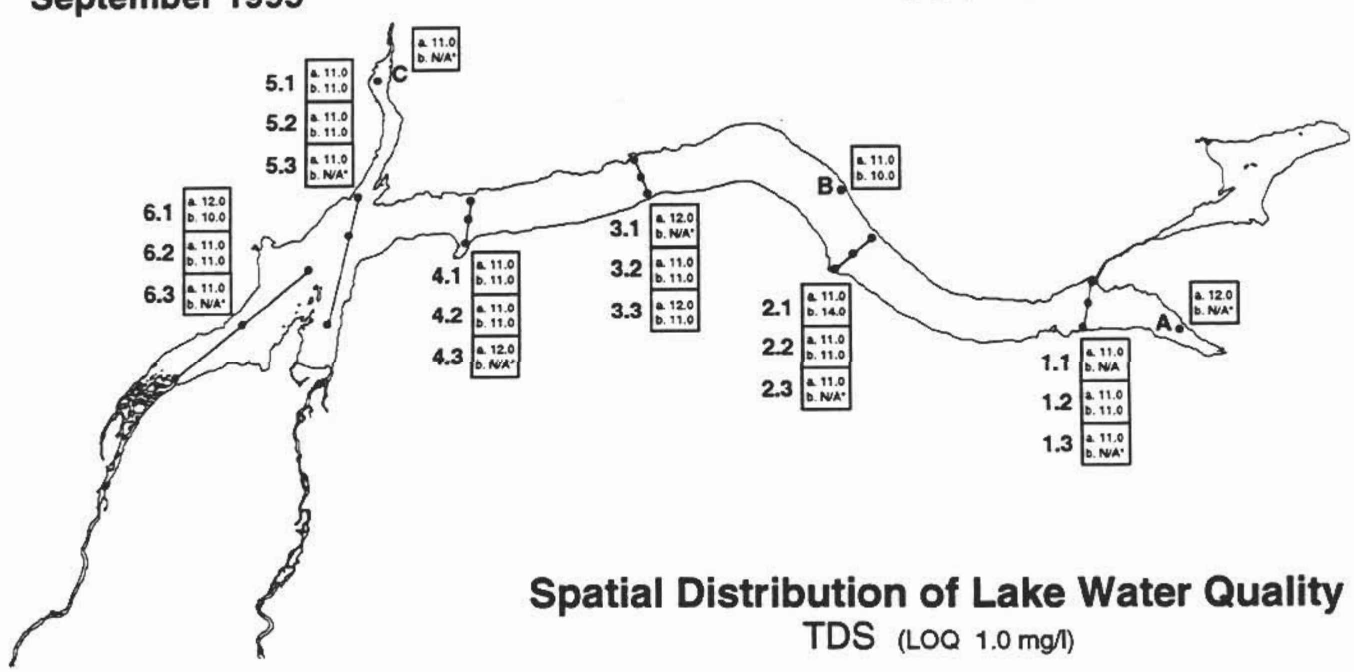


Spatial Distribution of Lake Water Quality
pH

Watershed Management Plan for Gander Lake and its Catchment

Figure 1.4 c



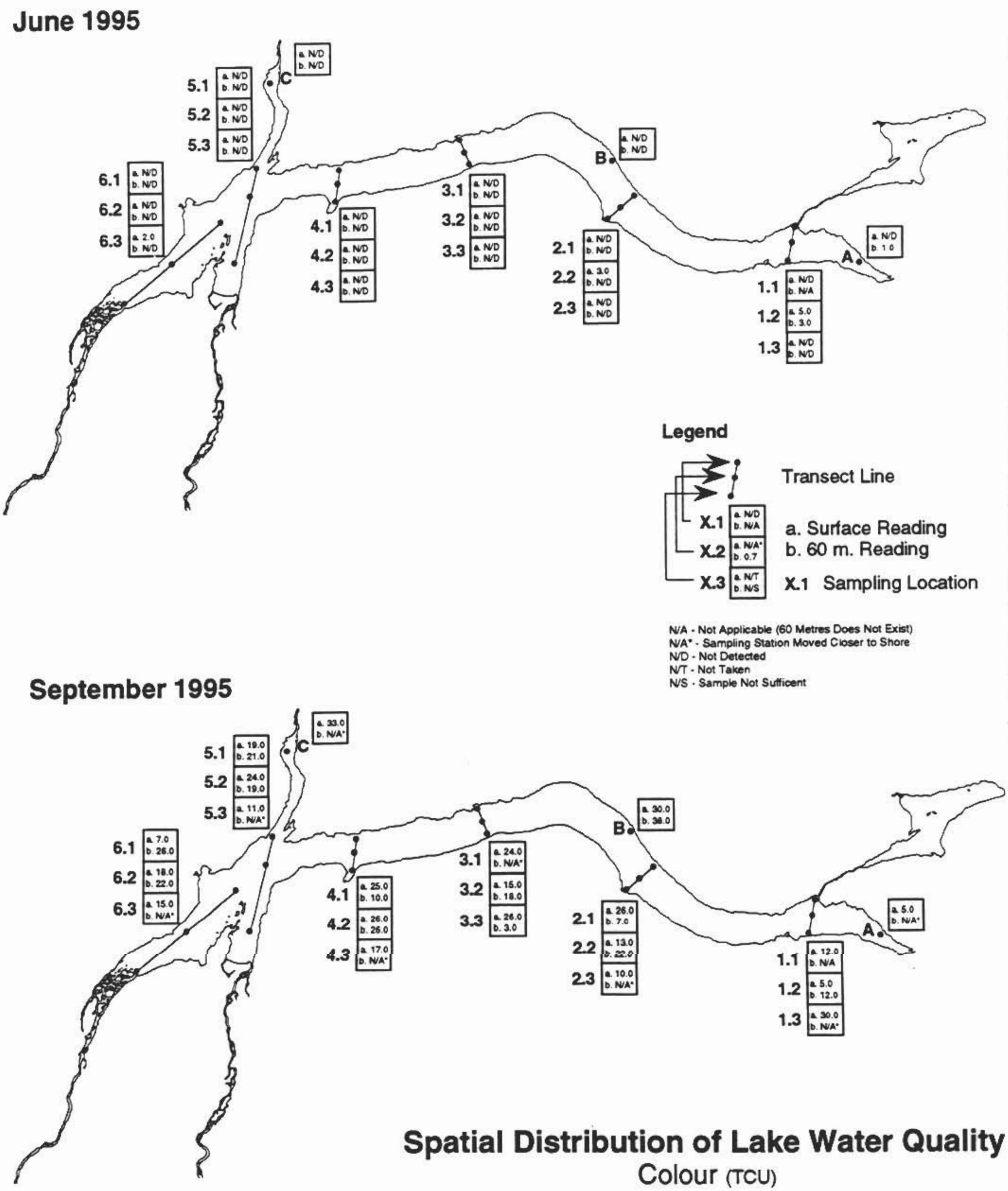


Spatial Distribution of Lake Water Quality

TDS (LOQ 1.0 mg/l)

Watershed Management Plan for Gander Lake and its Catchment

Figure 1.4 d

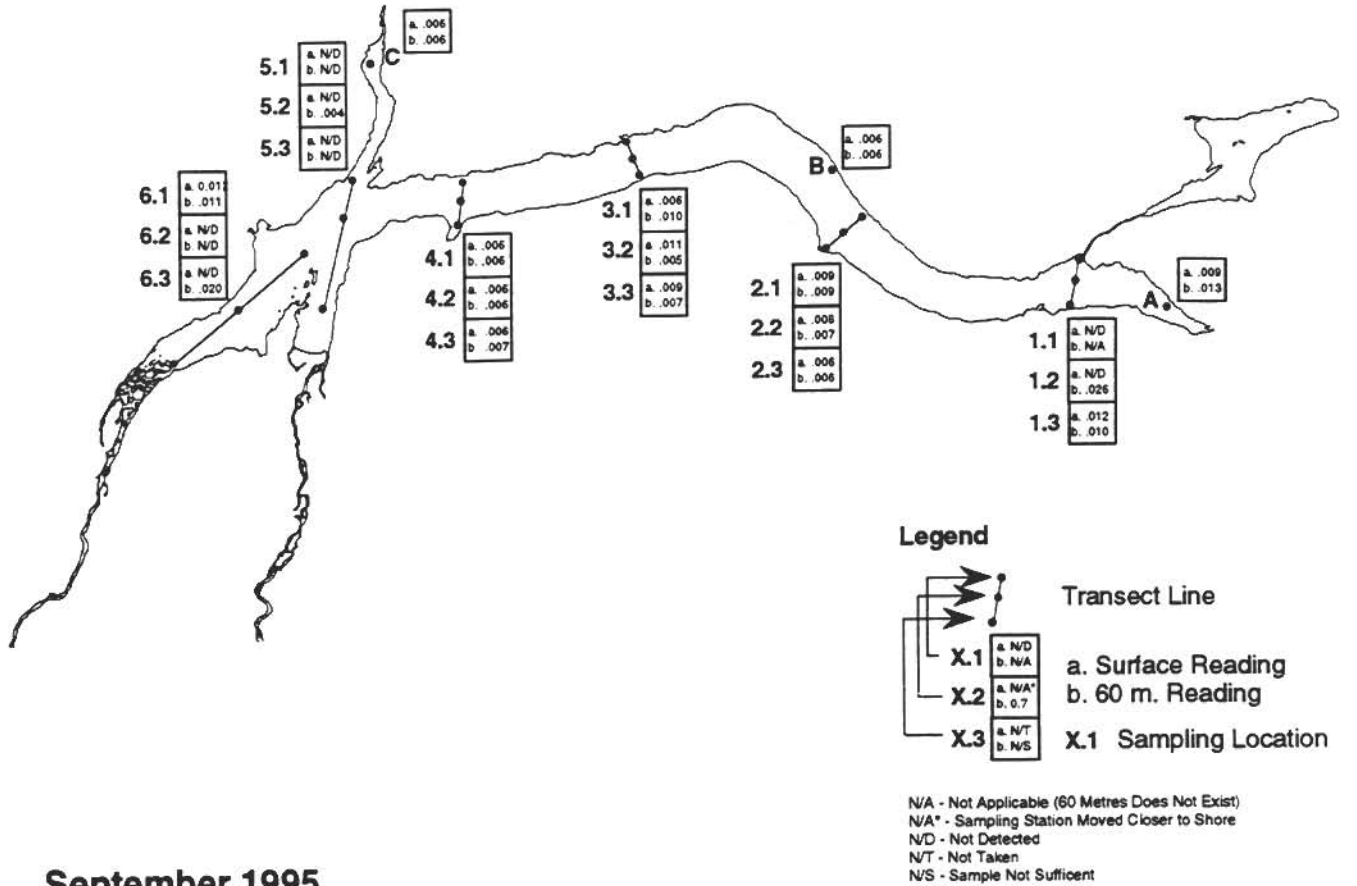


Spatial Distribution of Lake Water Quality
Colour (TCU)

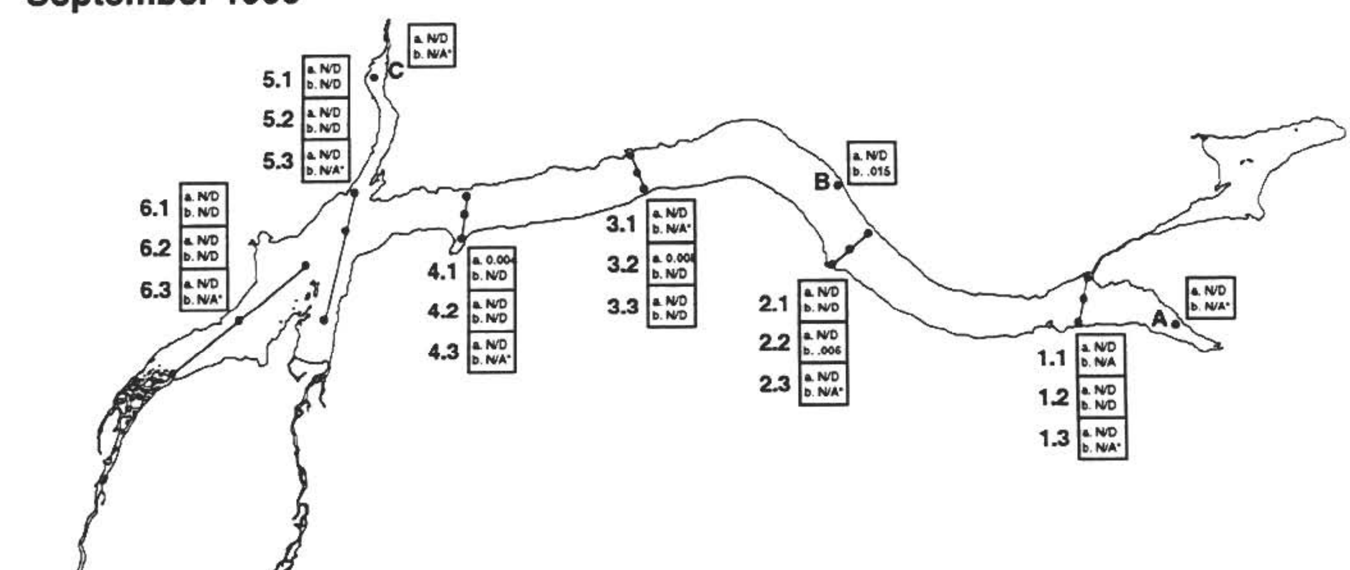
Watershed Management Plan for Gander Lake and its Catchment

Figure 1.4 e

June 1995



September 1995



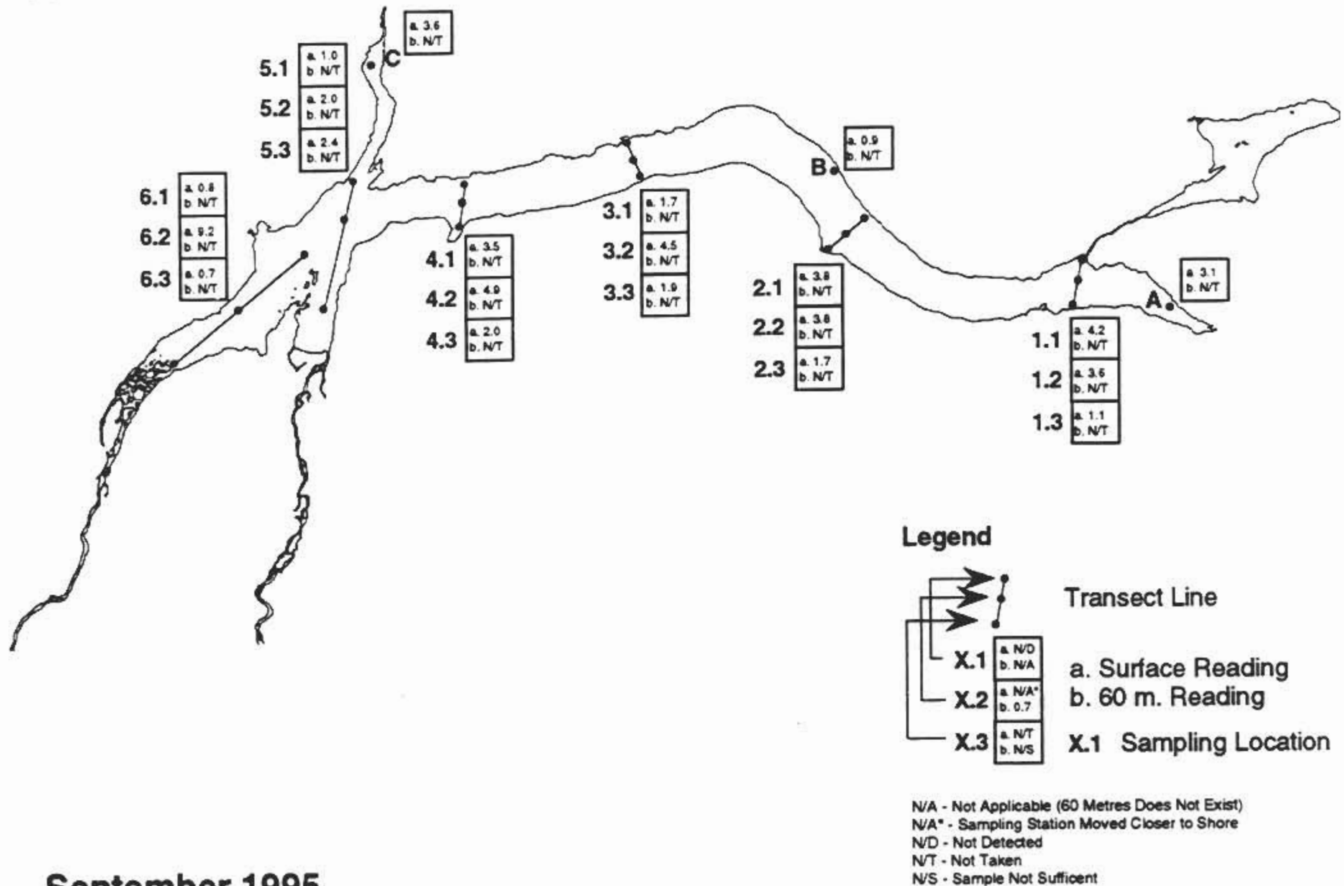
Spatial Distribution of Lake Water Quality

Total P (LOQ 0.004mg/l)

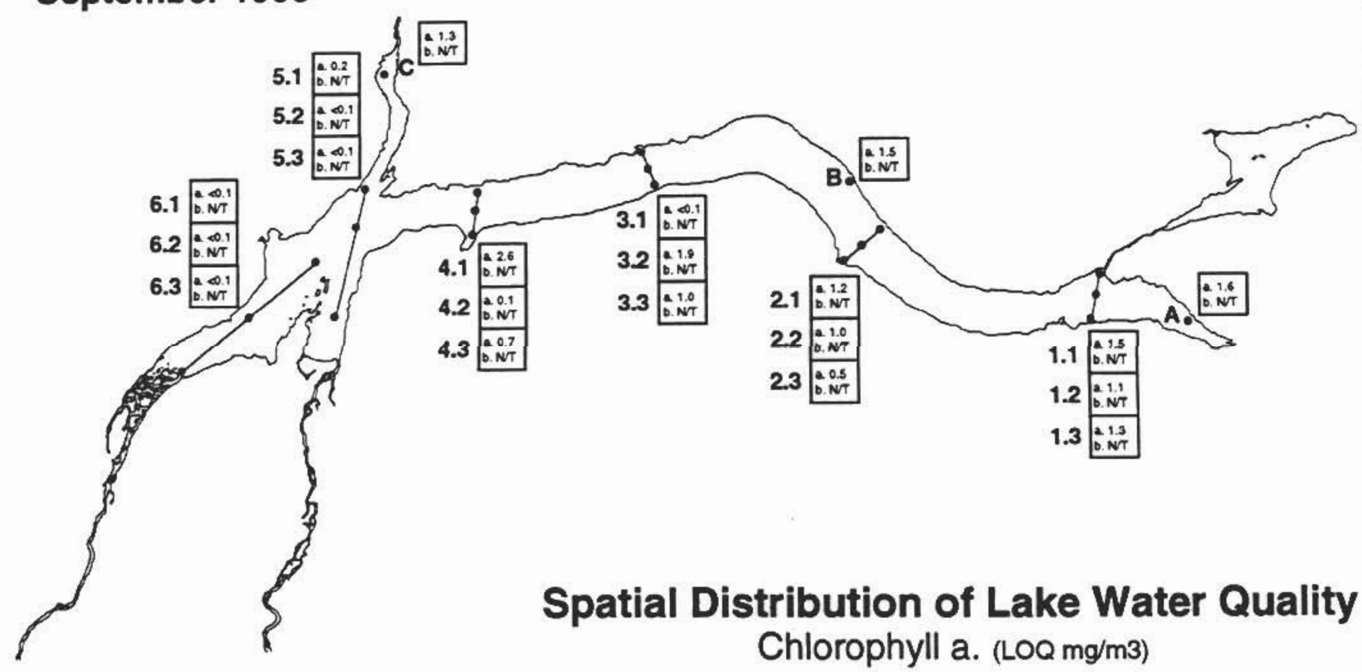
Watershed Management Plan for Gander Lake and its Catchment

Figure 1.4 f

June 1995



September 1995

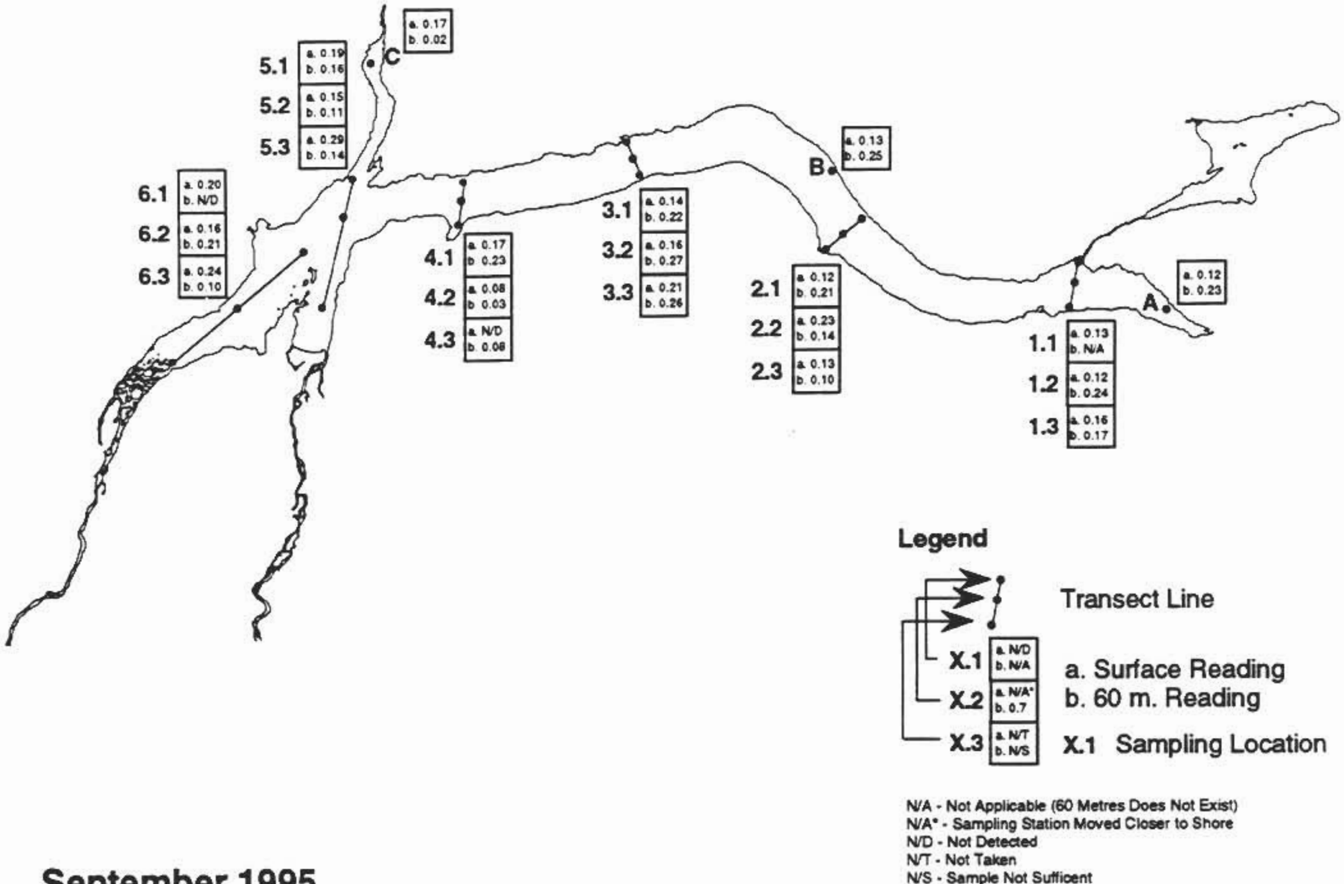


Spatial Distribution of Lake Water Quality
Chlorophyll a. (LOQ mg/m3)

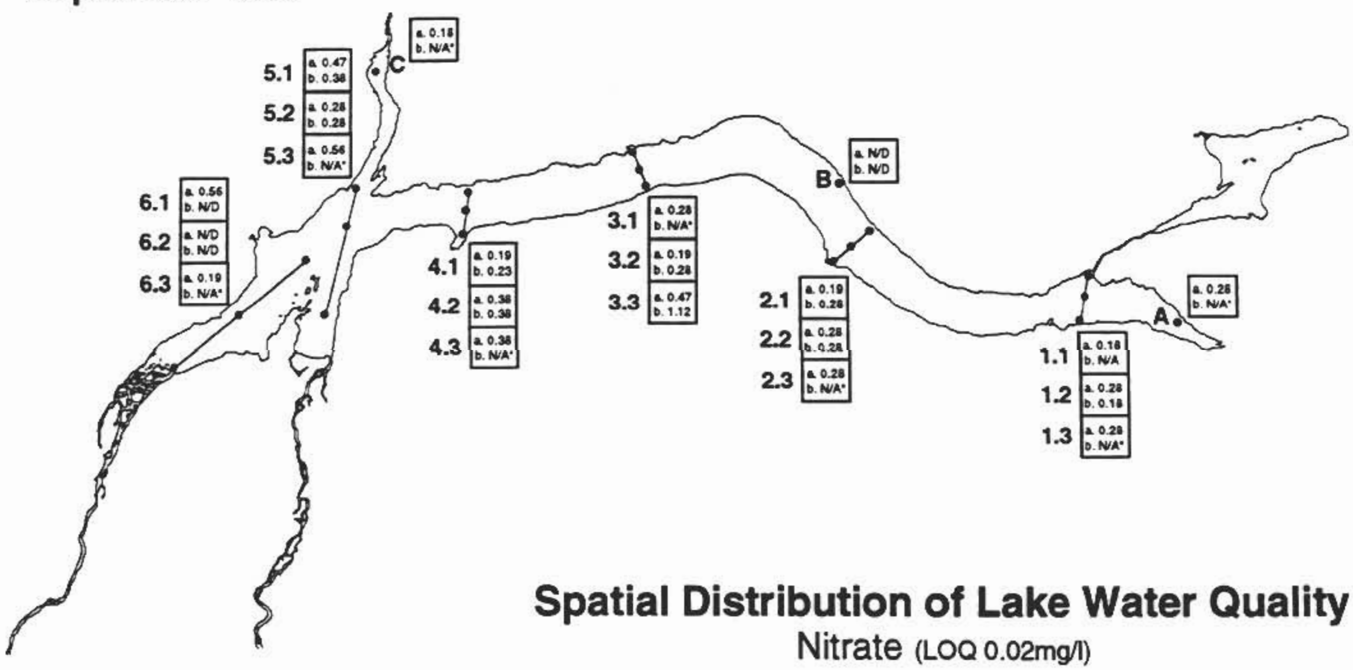
Watershed Management Plan for Gander Lake and its Catchment

Figure 1.4 g

June 1995



September 1995



Spatial Distribution of Lake Water Quality

Nitrate (LOQ 0.02mg/l)

Watershed Management Plan for Gander Lake and its Catchment

Figure 1.4 h

An overview of the analytical results indicates that for most parameters the levels recorded are at, or near the non detect (ND) level. In cases where the parameter is present, levels are low and, for the most part, do not vary widely either between sample depth or location. The absence of any large variance suggests mixing throughout the entire Lake.

The recorded Secchi depth during each of the surveys was limited to 2.5 to 3.5 m and was not significantly affected by surface conditions of the water or light conditions (bright, haze or overcast). Discussions with residents of the area indicate that this lack of clarity is characteristic of Gander Lake and its tributaries. Grab samples taken from September field work indicate that the Lake has a good deal of colour from humic organic sources. In September, Lake colour was 48 TCU in Gander Lake; 82 TCU in Northwest Gander River; and 46 TCU at Appleton.

Analysis for total and fecal coliform in the June survey indicated presence at only one location (6.3). The September sampling indicated the presence of coliform bacteria (primarily) at nine locations: 1.1, 1.2, 2.3, 3.3, 4.2, 4.3, 5.1, 5.2 and 6.3. The increased detection, when compared with June results, is likely a result of moving sample stations closer to shore and the increased presence of cottage owners.

Although present at more locations, levels of coliform bacteria are not high at any location. The higher levels for fecal versus total coliform levels (as seen in the results) is probably explained by the differences in culture media for the two groups. The selective media for fecal coliforms promotes marginally better growth than the broad based media used for culture of total coliforms.

No distinct source of chemical contamination was noted at any location along the lake shoreline or near shore area. The rapid increase in depth within 100 to 300 m of shore serves to dilute point source contamination to below the detection limit for most analytical parameters.

Future sampling for chemical parameters should focus on major inflows to Gander Lake. The analytical parameters should be targeted for the suspect parameters only, as many of the general chemical parameters and analyses included in this program do not occur at levels which are of concern.

Winkler titrations (for dissolved oxygen) in this study, together with dissolved oxygen probe data from DFO (O'Connell, 1995), indicate summer stratification and full turn over. It may be assumed that the Lake turns over twice a year.

Full temperature data indicate a cooler west end and a warmer east end, in Gander Lake. These data are further discussed in Part 2 Modelling.

The data presented in Table 1.3 and the probe data suggest support for the results of the physical modelling (Part II), and indicate some differentiation between spring and summer runoff quality and their Lake water quality impacts. Statistically significant changes in parameter values from June to September are observed for Zinc (decrease); Alkalinity (decrease); pH (increase); Total Dissolved Solids (decrease); and Colour (increase). Some interesting questions are raised by this data that bear discussion by the project study team and steering committee members, including the corresponding increase in pH and colour.

1.4.5 Limnological Discussion

The data results presented in the previous Section indicate that Gander Lake is an Oligotrophic, dimictic lake. It is relatively free of development impacts, and mixes, or "turns over", twice a year.

There are several standard morphometric parameters that are used to describe and classify lakes (Wetzel, 1975):

Maximum Length (l) is the distance on the lake surface between the most distant points on the lake shore. This length is the maximum effective length or fetch for wind on the lake without land interruption. This measurement for Gander Lake is 24,520 m, although it could be argued that the channel like nature of the lake basin will tend to funnel winds around the bend in the lake without significant wind speed loss.

Maximum Breadth (b) is the maximum breadth at right angles to the line of maximum length. For Gander Lake, this is 4,600 m.

The Area (A) of Gander Lake is 112,400,000 m2, and the Volume (V) is approximately 1.686×10^{10} m3. The Maximum Depth (z_m) is 290 m, and the Mean (average) Depth (z_a) is 150 m.

The Relative Depth (z_r) of a lake is its maximum depth as a percentage of the mean diameter. Gander Lake has a Relative Depth of 2.4 % which is within a transition range of normal dimictic lakes and meromictic lakes. Most lakes have a relative depth of less than 2%, while very stable, deep lakes exhibit $z_r > 4\%$.

Shore Line (L) is the perimeter of the lake, or the length of the contact between the lake surface and the land. Gander Lake has a Shore Line of 132,860 m. This measurement is used to calculate the Shore Line Development (D_L). D_L is the ratio of the length of the shore line (L) to the length of the circumference of a circle of area equal to that of the lake (Wetzel, 1975), as represented by the following equation:

$$D_L = \frac{L}{2\pi\sqrt{A/\pi}} \quad (\pi = 3.14)$$

This parameter reflects the potential for development of littoral communities in proportion to the volume of the lake. Most lakes have a D_L of about 2. Gander Lake has a D_L of 3.5 which corresponds to its elongated morphology.

1.5 LAND USE

This section presents a general description of land use past, present, and potential future for the Gander Lake catchment area. Potential and actual pollutants are discussed throughout. Pollutant loading estimates are calculated in Part 3A. Part 3B discusses land tenure and jurisdiction.

The Gander River system forms an interesting configuration in relation to Gander Lake. Northwest Gander River and Southwest Gander River flow in at the same end that the Gander River flows out. The initial hypothesis was that these water bodies might function as a river flowing through, but relatively independent of, Gander Lake. New information indicates that this theory may need to be modified.

If true, the hypothesis would suggest that the difference in water quality and quantity of the outflowing river and the two inflowing rivers should be a result of contributions from the Gander Lake catchment. Environment Canada, Inland Waters Directorate maintains hydrometric stations on Northwest Gander River, Southwest Gander River, and on the Gander River (in the area known as the Outflow), making it possible to estimate changes in volume. Any quality changes in the Gander River, that were not present in the inflowing Rivers, logically should have entered from water bodies or runoff in the catchment. Theoretically, it should be possible to trace this back to land and lake use activities.

The first step in evaluating the effect of land use on water quality was to determine the relevant periods for mapping land use activity. This required identifying relevant time periods where there was both activity in the catchment (as well as mapping/air photos of that activity available), and for which water quality data was available. Figure 1.6 a - b, Summary Time Line of Land and Lake Use and Related Data, was prepared to compare land use activity with data availability. It is also an excellent summary of the historical land and lake use.

Three dates were chosen for land and lake use mapping: 1966, 1990 (present), and future (approximately 2000). 1966 was selected for two reasons: the airport, the Town, and the Trans Canada Highway had been constructed by 1966, and complete aerial photo coverage was available at that time. The land and lake use maps were digitized from overlays made by airphoto interpretation, with the exception of the forest cover information which was digitized from a generalization of the Newfoundland Forestry Service digital database.

The land use maps are presented as Figures 1.7 and 1.8. The lake use maps are presented as Figures 1.10 and 1.11. Figure 1.9 illustrates both potential future land and lake use. The digital database was also provided.

The following summary of land use is intended to supplement the land use maps (Figures 1.7, 1.8, 1.9), and the timeline presented as Figure 1.6 a - b. It describes the major land use activities and related events in the Gander Lake catchment area. Population counts for census years are indicated in Figures 1.6 a - b.

This description of land use is general. Detail on the types of pollutants associated with land use and their potential effects on Gander Lake are discussed in Part III: Integrated Watershed Management Plan. See Table 3.3 for land use types and how they have changed in area from 1966 to present. Part 3A also addresses pollutant loadings from particular types of land use.

1.5.1 Existing Information

Following is a list of sources of information and data sources collected and evaluated on land use for the Gander Lake area.

- Baird, Edgar. Personal Communication. Longtime Resident.
- Baird, William. 1995. Personal Communication. Town Engineer.
- Boland, Joseph. 1995. Personal Communication. Department of Natural Resources, Land Management Division, Gander.
- Bonnell, Brian. 1995. Personal Communication. Western Newfoundland Model Forest.
- Buffinga, Anna. 1995. Personal Communication. Department of Natural Resources, Land Management Division.
- Cheeks, David. 1995. Personal Communication. Newfoundland and Labrador Department of Natural Resources, Newfoundland and Labrador Forest Service.
- D. W. Knight Associates Ltd. 1991. Town of Gander Municipal Plan 1991 - 2001.
- Environment Canada, Canada Land Inventory. Soil Capability for Agriculture. 1:1,000,000 Map Series, Atlantic Provinces.
- Hewitt, Derek. 1995. Personal Communication. Department Natural Resources, Land Management Division, Gander.
- Higdon, Rocky. 1995. Personal Communication. Department of Tourism, Culture, and Recreation, Parks and Natural Areas Division.
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1.5.2 Forestry

Forestry is the land use activity that covers the largest area of Gander Lake's catchment. Forestry is also a significant land use in terms of impact on water quality, and the reason why model forest watersheds are studied.

1.5.2.1 Past - up to 1966

Forestry, in the 1800's, was selective for tall pine trees for masts and timbers for the British Navy. The small rural population cut what was required for fire wood and building materials. A forest fire around the turn of the century removed much vegetation cover.

Old growth, that which remained after the fire and remains in the burned area, was first cut in the early 1950's. Forestry practices at this time included horses and tractors to haul the logs to the rivers. Dams held water to drive logs to Gander Lake and on to Gander River. Logs were loaded on railroad cars at Glenwood for shipment. Air photo interpretation for 1966 indicates that at least six logging dams existed at that time. There were four on Hunts Brook and two on Fifteen Mile Brook.

Water quality problems may have resulted from people living at the logging camps, horse stables, the dams and river drives, and railroad use, as well as forest harvesting and increased runoff.

Construction of the Trans Canada Highway between 1957 and 1965 provided greater access to all areas of the catchment area. Intensive cutting and another forest fire in 1961 left much of the watershed denuded by the mid 1960's. Water quality problems may have resulted from forest fire debris, logging road construction and use, and introduction of motorized vehicles to the forest, as well as the concerns mentioned above (See Figure 1.7, Land Use 1966).

1.5.2.2 Present - 1990

Clear cutting has continued as a dominant logging practice in the catchment area. Large parts of the catchment were clear-cut in the 1980's. Silviculture practices were also introduced in that decade. New practices appear to be quite good (field inspection), with smaller clear cuts, more trees left standing, more shelterwood cuts, and replanting. On the southeast end of the Lake, harvesting was finished this year, 1995 (See Figure 1.8: Land Use 1990).

Trucks are now used to transport logs from the catchment. Horses, tractors, logging camps, and the railroad are no longer used. Water quality problems in Gander Lake may result from forest cover removal, increases in the volume and rate of runoff, and changes in the content of runoff. The increased construction and use of logging roads may also contribute undesired materials to the Lake environment.

Though the Provincial Department of Natural Resources, Forestry Division has general guidelines for cutting buffers around water courses, no further instructions are confirmed for Gander Lake as a protected water supply watershed. Protected water supply watersheds are the jurisdiction of Department of Environment, Water Resources Division.

1.5.2.3 Future

The road on the south side of Gander Lake is planned for extension to just beyond Fifteen Mile Brook where harvesting is upcoming for the next 15 years (Refer to Figure 1.9: Potential Future Land and Lake Use). A large harvest is planned to remove much of the vegetation that remained following the 1961 forest fire. This cut will likely result in similar concerns as mentioned previously.

1.5.3 Urban

The urban areas within the protected watershed area include Canadian Forces Base Gander, Gander International Airport and the Towns of Gander, Glenwood, Appleton, and Benton.

1.5.3.1 Past - up to 1966

The railroad was built through Gander in 1890. Airport construction began in 1936. By 1952, construction of the new town site began, and between 1952 an 1957, the new population, including Canadian Armed Forces personnel, was moved from temporary facilities at the airport to the new Town of Gander. The Trans Canada Highway was built as a gravel road through Gander in 1957 and completed across Newfoundland in 1965. James Paton Memorial Hospital was opened in 1964. Refer to Figure 1.7: Land Use 1966.

The population of Gander increased from 603 in 1941 to 7,183 in 1966. Appleton, Benton, and Glenwood are small communities relative to the Town of Gander. Census counts were not available for these smaller communities, until what we have labeled the present period (see Figures 1.6 a - b).

Two garbage landfills existed in this time period. One was on the pump house road between the 1940's and 1950's. Another, located west of the golf course in a gravel pit on the TCH, was first used in the mid 1960's. Landfills contain waste material that has been contributed from residential, industrial, and commercial uses. These also contain materials left by the Canadian and American Militaries. Landfill runoff and leachate may contaminate ground water resources.

Potentially, the airport discharge ditch may have contained any elements that are present on the runways or at the airport facility. These include sand, salt, oil, grease, fuel, de-icing chemicals, nutrients, and heavy metals. This ditch has been present since 1935 when the Airport was built.

1.5.3.2 Present - 1990

Gander has continued to expand with new subdivisions. The population of the Town peaked in the 1981 census and has remained steady at less than 10,500. The three smaller communities have remained stable with the following populations: Appleton, from 347 in 1971 to 526, Benton hovers around 200, and Glenwood fluctuates above and below 1,000 (See Figures 1.6 a - b).

The landfill west of the golf course, closed in 1970, has been buried and planted over as a picnic park. The Town's new landfill site is off Gander Bay Road, outside the catchment area. Refer to Figure 1.8: Land Use 1990.

The golf course was opened, between the TCH and the Lake, in 1980 and was expanded to nine holes, in 1987. Golf course concerns include herbicides, pesticides, fertilizers, increased runoff, as well as increased nutrients.

During the last several years, increased silt in runoff from the airport was the suspected cause of clogging in the filters in the pumphouse of the Gander Lake water supply. No other problems have been noted, but Transport Canada staff at the Airport monitored the ditch from April 1994 to March 1995. Analysis of the data shows that coliforms, BOD5, pH, glycol, and metals were consistently within acceptable Federal limits for storm sewers. Phenols, oil and grease reached the limit once during the study period. The discharge ditch data is included in Appendix C and discussed in part 3A.

Areas of concern in terms of the Gander water supply are suspended solids and nitrates. Total suspended solids exceeded Federal storm water guidelines consistently from May to December 1994. Since that time, Airport staff have been more careful about activities in the ditch. Because the Airport is closely reflective of general urban patterns (about half grass and half asphalt), the study team used the ditch data to determine likely common currency pollutants for urbanized areas in Gander (see Section 3.4.3.3).

1.5.3.1 Future

No new subdivisions are proposed for the Town of Gander, and Appleton, Benton, and Glenwood do not expect much growth. The golf course plans to expand to 18 holes in the near future (Kelly, 1995). CFB Gander is presently downsizing, and as this is included in the area of the Airport, the Airport ditch may produce even less pollutants. The Town of Gander plans to encourage recreation development in the area between the highway and the Lake. A winter park, including a ski hill down the valley bank is currently under construction. No change in the Airport ditch is anticipated. See Figure 1.9: Potential Future Land and Lake Use.

1.5.4 Agricultural Potential in the River Valleys

Soils and capability mapping are available for the area. Some soils in the designated watershed area are suitable for agriculture, but have not been developed because of timber rights held by pulp and paper, and lack of road accessibility.

1.5.4.1 Past - up to 1966

When this area was inhabited by a rural population, the only farming was probably family vegetable gardens. Wareham's sods, hay, and vegetables, near Benton, has been active since the 1940's or 1950's (see Figure 1.7: Land Use 1966). This farm, less than a hectare, was unlikely to have made any significant contribution to any water quality problem at this time.

1.5.4.2 Present - 1990

Presently, there are three fur farms which appear to be on the border of the watershed management area. Pritchett has been operating since around 1985-86, Thorne since 1985-86, and Spencer since the early 1980's. The main concern presented by these fur farms are about animal waste in runoff.

Sheppard Strawberry Farm has had small farms within the Town of Appleton and recently moved out to the Gander Bay Road to a larger farm. The Provincial Potato Seed Farm produced its first crop in 1975, and plants about 15 acres a year in seed and experimental potato crops. There may be some water quality issues related to silt and runoff. Refer to Figure 1.8: Land Use 1990.

1.5.4.3 Future

The Pelley farm permit, approved in the early 1970's, was revoked based on a suspected rare bird population, and the farmer was given another piece of land as compensation. Pelley has been given approval to develop forage crops and pasture land, but as yet has not proceeded to do so. See Figure 1.9: Potential Future Land and Lake Use.

According to the Canada Land Inventory's soil classification (scale 1:1,000,000) for agricultural capability, Newfoundland has no sizable areas of high capability soils. The best soils in the Province are rated at Class 3 (Class 1 being the highest) which is considered to have moderately severe limitations for raising crops. One piece of Class 3 soil is representative of the Canada Land Inventory map and that is within the catchment of Gander Lake, at the Provincial Potato Seed Farm near Glenwood. Several areas of the Province have Class 4 soils (severe limitations for agriculture) and some of these lie within the catchment area.

Land around Northwest Gander River, Southwest Gander River and Hunts Brook all have soil that is rated as Class 4. At present, none of these areas are farmed, but they are potential food production areas. While no new farms are proposed, it is anticipated that existing commercial farms and the Provincial Potato Seed Farm will continue to operate as they do presently.

The Department of Fisheries, Food, and Agriculture designated a number of pieces of land in Newfoundland as Agricultural Development Areas. These were intended to protect farming areas with relatively high potential for agriculture. One of these areas surrounded a potential farm on the Southwest Gander River. This farm was not developed because the farmer offered the land for sale when he lost equipment in a flood. Presently, parts of the land are owned by outfitters and cottagers.

The Department believes that the Agricultural Development Area on the Southwest Gander River has potential for pasture land and hay production. The river valleys are subject to late spring and early fall frost which limits the type of crop that can be sustained in a commercially viable manner, though many cottagers have garden plots.

Crops such as cereals and corn are sometimes successful, but not reliable, in the area. Class 4 land in this area may also be good for vegetables such as cabbage, turnip, carrots, and potatoes. These require a fairly long growing season, but are fairly resistant to frost. Fruits requiring a shorter season, such as strawberries and raspberries, are also successful in the Gander area (Ricketts, 1995).

1.5.5 Mining

There is no mineral extraction in the catchment up to this point in time, 1995. Gravel extraction has been common since the airport was built in 1936.

1.5.5.1 Past - up to 1966

Gravel extraction probably began in this area when the airport was built in the early 1940's. Since then, gravel was required when the Town and Air Force Base were built later in that decade, and when the Trans Canada Highway was built between 1957 and 1965. This was the most active stage of urban development in the area. Gravel was needed for modern construction, and deposits were exposed and available once the highway was cut through. The main areas of concentration were around the east end of Gander Lake where unconsolidated material can be found. Silt in runoff is a concern where quarrying takes place. See Figure 1.7: Land Use 1966.

1.5.5.2 Present - 1990

There is no mining except for aggregate material, and a little rock crushing. The gravel is not high enough quality to be worth long distance trucking, and many pits are only active when road work is required in the immediate area. Owners of two cement plants extract their own aggregate for local construction work. The material found here is unsuitable for asphalt or gravel, and is mainly used for backfill (see Figure 1.8: Land Use 1990).

Construction material suppliers crush rock to make road gravel and material for asphalt mixing. At a site on Gander Bay Road across from Cobbs Pond, peat and sand are mixed to create topsoil for garden use. The sand is extracted from the unconsolidated deposits at the east end of the Lake. Gravel has also been removed from the east end, for a Gander concrete plant since the 1970's, at a rate of about 300-400 m^3 annually, probably the largest operation in the catchment area.

Pits are located all along the Trans Canada Highway where deposits were exposed during highway construction. Gravel extractors have operated since the 1960's, where deposits are readily available and as fill is needed. None of the pits have been properly closed or revegetated. Potentially, there have been siltation problems in the catchment of Gander Lake throughout this period. No instances have been reported to the Department of Natural Resources, Mineral Lands Division (Sullivan, 1995).

1.5.5.3 Future

Gravel extraction and rock crushing will continue for local construction as needed; no large scale extraction is expected.

Several new mineral finds in the area may not jeopardize water quality, if mined in an environmentally responsible manner. Of concern is an antimony deposit on Northwest Gander River. The proposed mine is outside of the designated catchment area, but may affect water quality in Gander Lake as Northwest Gander River runs into the Lake.

1.6 LAKE USE

Use of Gander Lake includes: extraction for drinking water, recreation activities, and pollution assimilation. Recreation includes use of camps for logging, hunting, fishing, and leisure activities such as gardening. People also conduct the above mentioned activities, as well as boating, berry-picking and swimming on a day trip basis. Pollution assimilation relates mainly to discharge from sewage systems of Benton and Gander. Discharge from all of these sewage systems discharges to Soulis Pond, and then Soulis Brook which leads into Gander Lake. Discharge from both Glenwood and Appleton's sewage treatment plants is discharged into Gander River and flows directly out of the catchment area. Pollutant loading estimates are presented in Part 3A.

1.6.1 Data Collection

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1.6.2 Drinking Water Supply

Gander Lake provides the drinking water supply for the Town of Gander including Gander International Airport, CFB Gander, as well as the Towns of Glenwood and Appleton. Newfoundland uses the Guidelines for Canadian Drinking Water Quality. Water extracted from Gander Lake generally exceeds these guidelines.

Newfoundland and Labrador Department of Health takes samples for fecal coliforms at the Gander Lake pumphouse and these are consistently non-detectable (Matchim, 1996). Environment Canada and Newfoundland and Labrador Department of Environment have tested water quality data at a station on Gander River near Glenwood from 1965 to the present. Newfoundland and Labrador Department of Environment has also sampled several locations on the Gander River because of residents' concerns about the sewage treatment plant discharges in the Gander River. Water quality samples were taken at the Gander Lake pumphouse for this study.

Table 1.4 compares water quality data from Gander Pumphouse with the Guidelines for Canadian Drinking Water Quality. During this study, the Lake water quality at the pumphouse was well within the guidelines. This is true for the other sampling programs at the other locations with few exceptions. Gander Lake's water colour is higher than the guidelines indicate for aesthetic reasons, and this is normal for Newfoundland.

Silt, on occasion, has blocked the screen at the pump house. The Town of Gander Engineering Department believes that this is due to the Airport discharge ditch. Airport staff have monitored the contents of the water from the ditch. The results of the testing are included in Appendix D and discussed in Section 3.4.3.3.

1.6.2.1 Past - up to 1966

Gander Lake was first used as a water supply when the Airport was built in 1935. Transport Canada operated a pump house that eventually served the new Base in 1946, and the Town in 1952.

1.6.2.2 Present - 1990

In 1976, the Town of Gander commissioned a new pump house, on Gander Lake, to replace the old one.

1.6.2.3 Future

Gander Lake will be protected by a land use management plan as prescribed by this study. The Town expects to enjoy its clean water supply at Gander Lake *indefinitely*.

1.6.3 Logging Camps and Cottages

Gander Lake, Southwest Gander River, and especially Northwest Gander River are popular areas for hunting and fishing. Many who participate in these activities use dwellings that range from small shacks to cottages. Though many commercial fishing outfitters have large facilities on the Gander River, only one, on Northwest Gander River, lies within the catchment area. The Royal Canadian Sea Cadets have a training camp in the same area. A full field survey including a complete cottage count within the catchment was beyond the scope of this study.

TABLE 1.4: COMPARISON OF GUIDELINES FOR CANADIAN DRINKING WATER QUALITY AND WATER QUALITY AT GANDER LAKE PUMPHOUSE

Canadian Guidelines		Water Quality Tests at Gander Lake Pumphouse			
		June		September	
Parameter	Limit	Surface	60 m	Surface	60 m
Chloride	<250*	2.08	2.00	2.11	2.10
pH	6.5 - 8.5*	6.25	6.14	7.92	6.89
Total Dissolved Solids	<500*	15.00	14.00	11.00	10.00
Colour	<15 TCU*	N/D	N/D	30.00	38.00
Nitrate	10.0**	0.13	0.25	N/D	N/D

All units are in mg/L except pH and colour.
* indicates Aesthetic Objectives.
** indicates Maximum Acceptable Concentrations
Source: Guidelines for Canadian Drinking Water Quality
EDM Environmental Design and Management Limited, 1996

Local people who fish, within the catchment, do so mostly in the areas of Northwest and Southwest Gander Rivers. These people use a wide range of shelter types: busses, tilts, campers, and cottages. These number over one hundred in the Northwest and Southwest Gander River areas. Presumably, none of the dwellings have proper sewage disposal as this is not regulated. Fecal coliform counts are probably high when use is high. In this area, some of the cottages are suitable for families to stay all summer long as they are well appointed, accessible by road, and close to the communities and Highway.

Moose hunters enjoy the areas to the south of Gander Lake, as the land is more suitable (to moose) than that to the north of the Lake. Many of these outdoor enthusiasts use tilts as opposed to carrying camping gear. These small shelters are typically not used for many months of the year because they are not weather proofed, and because of their location deep in the woods. These areas are mainly used in the Fall moose hunting season, and due to the often poor condition of the woods roads, are not nearly as frequented as Northwest and Southwest Gander Rivers. Proper sewage disposal is unlikely given the capital expense of installing a septic system for a simple hunting shack. Occupancy rates and pollutant loading rates for cottages are estimated in Part III A.

Though logging camps and cottages are located on land, the project team decided to discuss them in this section, lake use, because of their potential effects on water. Essentially, untreated sewage is deposited very near the shore of a water body. Some cottages have a permit for and may have a proper septic system, but Department of Health does not check for compliance.

1.6.3.1 Past - up to 1966

Construction of logging roads in the 1940's and 1950's gave increased access to many areas of the catchment. Claims by squatters who used the west shore of Gander Lake, prior to 1957, have been recognized as legal. Anyone who used cottages before roads were built, did so by boat or across the frozen Lake or Rivers in winter. Illegal squatters have also used the Southwest Gander River since the early 1960's.

The 1966 air photo interpretation showed that at least four logging camps were located in the catchment area. One was south of Gillinghams Pond, one on Fifteen Mile Brook, one west of Fifteen Mile Brook, and another was on the north side of Gander Lake on Soulis Brook near Benton. During the forest fire of 1961, the logging camps around Fifteen Mile Brook were evacuated. Following the forest fire, locals inhabited the logging camps and erected others. See Figure 1.10: Lake Use 1966.

1.6.3.2 Present - 1990

A healthy salmon population and ease of accessibility has resulted in much illegal and a lesser amount of legal cottage development in the catchment area. Campers, parked busses, and cottages are many around Northwest Gander and Southwest Gander Rivers. Department of Natural Resources, Land Management Division conducted a cottage count in this area in 1994.

Of the total 112 cottages along the Northwest Gander River, 28 are legally occupying Crown Land. Four of these have squatters rights. Three are commercial resource based. One is a home gardening lot. Six have long term occupancy permits and six hold cottage leases. Of the remaining structures, over 50% are disposable or transient, including 25 busses, 14 trailers, five campers, and three vans.

Five camps are found along Fifteen Mile Brook and one on Joe's Brook. Most of these are used seasonally for hunting and fishing. Some may now be used as cottages. One commercial outfitter operates at the mouth of the Northwest Gander River. A number of cottages also sit on the east side of Soulis Pond.

There is no way of knowing if the users have on-site septic systems or pit privies. Those who hold legal title for occupancy must have a permit for an on-site system, but the Department of Health staff do not visit to check for compliance. No one has determined how many cottages use what type of system. Indeed, cottages have not been counted except for the Northwest and Southwest Gander Rivers. Site visits suggest that, with the exception of the more substantial cottages, pit privies are common (see Figure 1.11: Lake Use 1990).

1.6.3.3 Future

The Department of Natural Resources, Land Management Division has proposed cottage management areas on Northwest Gander River. Presently, illegal development and on-site systems are not effectively regulated in the catchment area. See Figure 1.9: Potential Future Land and Lake Use.

1.6.4 Fishing

Most fishing activity, within the catchment area, occurs in the Northwest and Southwest Gander Rivers area, the west side of the Lake and in the Gander River. As for the rest of the catchment, people fish at the outlet of Soulis Brook.

1.6.4.1 Past - up to 1966

People may have fished in Gander River for centuries. Archaeological evidence shows that central Newfoundland was well used by Paleo Indians and the Beothuck Indians. The same is likely to be true for Gander River given its high population of Atlantic Salmon.

It would not have taken long for European immigrants, in the area, to notice the bountiful salmon in Gander River. Old settlements exist in the Gander Bay area where the Gander River meets the Atlantic Ocean. These people may not have spent much time inland as far as Gander Lake, until logging operations made this area accessible. Glenwood has been an area for sawmills and log drives since before the turn of the century.

Access may define where fishing occurs, and roads have created access to many parts of Gander Lake. The Trans Canada Highway provided access to Soulis Brook, and the Gander River. In turn, logging roads have expanded since the TCH was built making the Northwest Gander River and Southwest Gander River accessible.

Figure 1.10: Lake Use 1966, shows where humans apparently used the shores of the Lake. Access areas were visible where Northwest Gander River runs into the Lake, at Hunts Brook, across the Highway from the Town of Gander, at Soulis Brook and at the beach in the east end of Gander Lake. Wharves and boats were visible at Fifteen Mile Brook, at Little Harbour and Gillinghams Pond Brook, at Hunts Brook, at the arm of Gander Lake where Southwest Gander River flows in, and in two places on the Town of Gander side of the Lake. Any of these places may have been used for access to fishing areas.

1.6.4.2 Present - 1990

Those who fish here do so mainly in the west part of Gander Lake along with Northwest and Southwest Gander Rivers. There is a fish population in Gander Lake, but it does not compete with Salmon fly fishing on the Rivers. Some fish where Soulis Brook runs into Gander Lake. When people are fishing, they often cause soil erosion on the banks of the water body. They may also leave materials on the ground and in the water.

Due to increased access since 1966, Figure 1.11: Present Lake Use shows increased access to the shores of the Lake. There is further evidence of use around Fifteen Mile Brook, Hunts Brook, and Northwest and Southwest Gander Rivers.

1.6.4.3 Future

There are no expected changes in fishing of the Lake. The Rivers are the areas of concern, and are currently being evaluated by the Department of Natural Resources, who has developed a cottage management plan for the Northwest and Southwest Gander Rivers, and Fisheries and Oceans Canada, who are assessing the levels of the stock. See Figure 1.9: Potential Future Land and Lake Use.

1.6.5 Marinas

1.6.5.1 Past - up to 1966

During the Second World War, a sea plane base was maintained on Gander Lake at the bottom of a road that heads for the Lake just east of the airport. This is the area where the 1985 plane crash occurred. Old crib work is evident at the site. During this time, people also used an area southwest of the Airport for boats. Little Harbour, the marina west of the Town of Gander, has been used for access to Gander Lake for many years as the topography is less steep in this area.

Evidence of boat use was also visible at the outlet of Hunts Brook, Fifteen Mile Brook, Gillinghams Pond Brook, and on the arm of Gander Lake where Southwest Gander River enters (see Figure 1.10: Lake Use 1966). Marinas are sources of materials left by humans, such as, oil, grease and fuel from boats, and any debris that people leave behind.

1.6.5.2 Present - 1990

Many boat and wharf areas may have originated as log drive infrastructure and continued to be used as boat launch areas, as people use boats to get to their cottages in less accessible parts of the Lake. People use the old sea plane base to boat across the Lake to Fifteen Mile Brook. Approximately five boats were noted during a May, 1995 site visit.

Little Harbour, the marina, has about 10 motorized boats, as well as picnics and barbecues (refer to Figure 1.11: Present Lake Use). Some people launch here because of the good access road and wharf facilities. Once again, the water in this area may suffer from input of grease, oil and fuel, as well as any other materials that people leave behind. During the testing for this study, no evidence of pollutant loading were found near Little Harbour or at the old sea plane base.

1.6.5.3 Future

The Town of Gander has been approached about development of a new marina on Gander Lake, but development of such a facility will be discouraged by Town Staff. Therefore, access areas for boats will remain the same. The need for more facilities may increase if Lake use increases. Windy and rough conditions on Gander Lake make it unpopular with boaters. Boating in the Rivers, however, may increase substantially with increased numbers of cottages.

1.6.6 Swimming

1.6.6.1 Past - up to 1966

Presumably, people have always swam in the areas where they do now. Apparently, the Lake is not warm enough for comfortable swimming. The exception to this may be the very shallow east end of the Lake where there is a small beach. Swimming areas show as Lake access on Figure 1.10: Lake Use 1966.

1.6.6.2 Present - 1966 - 1995

People swim in several areas including a beach at the east end of the Lake, and at Little Harbour (where the marina is located). They also swim in Glenwood Provincial Park (between the TCH and the Lake east of Glenwood), but Parks and Natural Areas Division of the Department of Tourism, Culture, and Recreation have never maintained statistics. Numbers of swimmers are unknown, but as stated previously the Lake is too cold for swimming to become a great concern.

1.6.6.3 Future

Presumably, people will continue to swim in the same areas as described above, the beach at the east end and at Little Harbour. As previously stated, Gander Lake is too cold to become a popular swimming area. Part 3A discusses point source pollutants in further detail.

1.6.7 Sewage Treatment Facility Discharges

Sewage effluent, if not treated to tertiary levels, can make water unsafe for humans to drink and even to swim in. None of the Gander area sewage treatment systems treat to a high level, but it appears that there have been no major water quality problems from *sewage discharges*. The Lake may be large enough to dilute sewage without jeopardizing the drinking water supply. Point source pollutant loadings and loading estimates are presented in Part 3A.

1.6.7.1 Past - up to 1966

In the mid 1950's, the Airport, the Base, and the Town of Gander were serviced by a trickling filter sewage treatment plant, located north of the airport. In 1965, the Town of Gander built an Oxigest sewage treatment plant to supplement the Airport plant. This sewage treatment plant, located where the present Beaverwood Sewage Treatment Plant is, exceeded its capacity and had to by-pass flow during rain storms. It discharged into a series of wetlands that empty into Soulis Pond, as the trickling filter plant did. Soulis Pond empties into Gander Lake. See Figure 1.10: Lake Use 1966 for the outlet location of sewage treatment plant.

1.6.7.2 Present - 1990

All of the communities now have sewage treatment systems: Gander, Appleton, and Glenwood with sewage treatment plants and Benton with on-site systems. Gander's system appears to be consistently reliable. It was built in 1987 to replace the facilities operated by the Airport (including CFB Gander) and the Town. The systems in the smaller communities appear to have problems periodically. They are not monitored for effluent quality on a regular basis.

Department of Environment, Environmental Management Division has monitored effluent from Beaverwood (Gander). Data collected in 1989 and 1990 indicate that Beaverwood is operating well. As the effluent leaves the plant it moves through a series of wetlands before entering the headwaters of Soulis Pond.

The Town of Gander's system empties into the headwaters of Soulis Pond which empties into Soulis Brook at Gander Lake. Benton's on-site systems are along Soulis Brook, and may percolate into the water if systems fail. This makes Soulis Brook and consequently the east end of Gander Lake most vulnerable to problems from sewage effluent input.

During field work in May of 1995, staff noted evidence of a Diatom algae bloom in Soulis Brook. Similar incidents have been noted in Gander River, and probably resulted from sewage effluent from Glenwood and Appleton (Card, 1995).

In 1973, MacLaren Atlantic Limited tested several areas, including Soulis Brook, as part of a sewage disposal study. An abbreviated table of MacLaren's data is shown in Appendix C. All parameters tested during the study (May 1973) were below acceptable limits. Dissolved oxygen, BOD5, suspended solids, pH, metals, bacteria, and nutrients, all evidence of human sewage discharge, were all below Canadian drinking water guidelines.

1.6.7.3 Present - 1990

No upgrades to the sewage treatment plants are currently proposed. Population growth is low in the catchment area except for the Town of Gander. This may change as Newfoundland has a net migration rate and CFB Gander is currently being downsized.

1.7 HAZARDOUS MATERIALS

The designated water supply watershed of Gander Lake protects a potable water supply. Spills of hazardous material within the watershed area threaten public health, natural resources and economic activity based on them, and fish and wildlife habitat.

Potential sources of contaminants accompany normal daily human activities. The following sections describe potential sources of contaminants with a view to developing an action plan outlined prior to an emergency occurrence. The emergency response plan is included in Part III.

1.7.1 Trans Canada Highway

The Trans Canada Highway is the main transportation corridor in Newfoundland. It runs through the protected catchment along much of Gander Lake. Countless imported materials and products enter the island via ports like St. John's, Port Aux Basques, and Argentia, and are distributed by truck to other parts of the island. Many of these trucks pass through the Gander Lake catchment daily.

Environment Canada maintains data of all reported oil spills. The data base shows that land transportation was the most common cause of spills (19%) in Atlantic Canada in the period between 1974 and 1988 (Environment Canada, January 1992).

In the event of a highway accident within the watershed, any contents of a shipment or the truck fuel itself are potential sources of pollution. In most areas of the catchment, spilled hazardous materials could be handled on land before entering the Lake. The bridge that crosses Soulis Brook on the Trans Canada Highway is one exception. If an accident occurs in this area, the potential of material entering the Lake is high. Soulis Brook Bridge area will require contingency planning.

A second area of concern is at the east end of Gander Lake where the Trans Canada Highway is very near the Lake. This area should be treated in a similar way to the Bridge at Soulis Brook.

1.7.2 Gander International Airport

Gander International Airport, completely inside the protected watershed, poses several potential hazards. Spills at the airport or runway facilities could enter the catchment or the Lake. The airport storm water runoff ditch, which runs under the TCH and directly into the Lake, could effectively carry any materials.

Planes that arrive to and depart from Gander do so by one of the airport's three runways, two of which use routes that go directly over the Lake. In the event of a crash near the airport, any contents of the plane could easily enter the catchment and the Lake.

Environment Canada's records show that spills due to airplane crashes (2%) are not common in Atlantic Canada (Environment Canada, January 1992). However, planes are potentially huge sources of fuel and material when they do crash.

Canadian airports have contingency plans and airports are responsible for spills originating from their facilities. In the event of a major incident, other agencies may need to assist the airport to protect natural resources and the integrity of the public water supply.

1.7.3 Fuel Storage

Storage of fuels in the catchment is a potential source of contaminant. According to Environment Canada's data base, storage tank leaks, at 17%, were the second leading cause of spills in Atlantic Canada during the period between 1974 and 1988 (Environment Canada, January 1992). These include underground and above ground storage tanks, and are attributable to tank leaks, fuel line defects, and tank overflows.

Underground tanks, many of which are associated with gas stations, often deteriorate, causing groundwater and surface water problems. There are five operating gas stations and one former gas station on the Trans Canada Highway within the concentrated area of Gander. There is another gas station on Bennett Drive in Gander, and one in both Glenwood and Appleton.

Above ground storage tanks also pose potential leaks of hazardous substances. Such tanks are numerous in household storage of furnace fuels, and industrial storage of chemicals. Like underground storage tanks, these may experience slow leaks that build up over time, or accidents where a large volume is spilled in a short period of time. While slow gas leaks are not generally considered environmental emergencies, there may be a large problem by the time a leak is detected. Gas stations are now being carefully monitored, but older operations may represent long term environmental liabilities.

Most provinces have new regulations concerning gas station storage tanks. Under the program, old tanks are to be replaced by double lined tanks and equipment is placed in the ground to monitor on an ongoing basis. This, along with training in response and clean up techniques, greatly reduces the likelihood of gas station fuel leaks.

1.7.4 Canadian Forces Base Gander

Canadian Forces Base Gander, located southwest of the Gander Airport, also has several large pieces of land within the catchment area. Military operations and exercises may pose environmental threats to the catchment and the Lake environment.

The Base has been operational since 1954, but the area and the airport have been used for military purposes since 1935. Gander was an active air base in World War II. Typically, operations at such bases have involved indiscriminate storage and disposal of hazardous materials. Local lore suggests that during the Second World War, planes and trucks were left on the ice of Gander Lake for disposal, so that when the ice thawed, the machines fell into the Lake.

Canadian Forces Bases have contingency plans, and should have good records of their former disposal sites (CFB Gander recently had a complete environmental audit). Access to these plans would be helpful to determine areas of potential hazards and where remediation work may be required.

The Atlantic Provinces, in conjunction with Environment Canada, Environmental Protection Branch, have developed the Atlantic Canada Regional Environmental Emergency Team Contingency Plan (REET). The focus is technical and scientific, providing advice and assistance. The full team is not involved, as a rule, but certain agencies have responsibilities in emergencies of any scale. REET is fully described in Part III, Section 3.14, where the emergency response plan is described.

- Environment Canada, Environmental Protection Branch. December 1994. Atlantic Regional Environmental Emergency Team Contingency Plan (REET).
- Environment Canada, Environmental Protection Branch. 1990. A Summary of Trends Relating to Spills of Oil and Other Hazardous Materials in the Atlantic Region 1986-1988.

PART 2: WATER MODELLING

2.1 INTRODUCTION

Three types of modelling were employed: an overall water balance for the Lake, modelling of water circulation patterns in the Lake, and a simulation of water temperature and quality. The computer software used to construct these models included: STELLA for the water balance; the DYNHYD component of WASP for water circulation patterns, and Dillon and MinLake for water temperature and water quality simulation.

The models were set up to achieve the following objectives:

A. What is the overall balance and real time representation of water flow in the Lake?

B. Is the runoff from the Northwest and Southwest Gander Rivers confined to the western portion and the Outflow, or does it circulate through the central and eastern portions of the Lake?

The Terms of Reference for this Study and the Proposal both assumed the first scenario. If the runoff from the two rivers was confined to the western end of the Lake, then residence time in the main body of the Lake will be considerably longer, and assimilative capacity, correspondingly reduced, compared to the situation where the runoff generally circulates through the body of the Lake. Given the importance of circulation in terms of its effect on residence time, additional effort was put into this task in terms of modelling with DYNHYD.

C. What is the assimilative capacity of the Lake?

In terms of phosphorus and the Vollenweider diagram for lake trophic status, assimilative capacity increases with the aerial water loading (metres per year), i.e., the cumulative depth of water arriving at each square metre of lake surface per year. Aerial water loading is equivalent to the Lake's mean depth divided by the residence time. Thus assimilative capacity for phosphorus is indicated to increase with depth of the lake and with turnover rate.

D. What is the present state of the Lake is in terms of chemistry? biology? fisheries?

The models were also used to test various future scenarios as determined by the proposed future land and lake use information (documented in Part 1) and as proposed in the physical plan for *watershed management detailed in Part 3 of this project. In Part 3, the objective of the model's* use was to determine what the prognosis for Gander Lake's water quality would be under various watershed land use scenarios and management scenarios.

2.2 METHODOLOGY

The modelling approach used was to integrate existing field observations, new field observations and water quality modelling to address the objectives detailed above.

2.2.1 Existing Observations

In addition to a review of the existing water quality and quantity data collected (refer to Part 1, Section 1.4), discussions were undertaken with local residents, the Federal Departments of Fisheries and Oceans, and the Department of Environment as sources of existing experiential knowledge and field data. The information gathered was utilized to provide both a preliminary assessment of the likely state of the Lake now (Objective 2.1 D, above), and as a check on new data and modelling results.

2.2.2 Water Balance

The water balance was constructed using STELLA. It allows a dynamic simulation of inputs and outputs to Gander Lake, and a record of how the Lake volume changes over the period of time the model is set to simulate. This balance was developed based on monthly averages over the available period of record for all data. It is adaptable to different periods of record, time steps, and knowns and unknowns.

A water balance is an arithmetic expression of the hydrologic cycle in a lake. It is normally expressed through the simple equation:

$$(Ic + Io + Ig + P + R) - (E + Gs + Oc + W) = \Delta S/\Delta t$$

where;

Ic = Channel Influent
Io = Overland Influent
Ig = Groundwater Influent
P = Precipitation
R = Return Flow
E = Evapotranspiration
Gs = Seepage Loss
Oc = Channel Outflow
W = Withdrawal Flow
S = Lake Storage at time t
t = Time Interval

In this case, water for drinking and irrigation is considered to be equal to the return flow from sewage treatment and agricultural runoff, thus eliminating R and W.

Groundwater Influent is considered as part of the Overland Influent and no loss to the bedrock was assumed from the Lake bottom, thus eliminating Ig and Gs. This is because of the nature of the surficial geology (Section 1.3.2.4) which is highly permeable and shallow, and the bedrock geology, which exhibits fracturing only near the surface of the rock (G. Bursey, FracFlow Consultants, Pers. Comm.). These characteristics, combined with the slopes of the catchment, mean that most of the water that is not lost as evapotranspiration reaches the Lake, either as surface runoff, or as shallow groundwater flow at relatively high velocities (5 to 15 feet per day).

Given that this balance uses monthly mean data, the groundwater component of the flow becomes less important. The losses can, therefore, almost be totally ascribed to evapotranspiration. The balance was therefore expressed as:

$$(Ic + Io + P) - (E + Oc) = \Delta S/\Delta t$$

2.2.3 Horizontal Circulation

Horizontal circulation was addressed by identifying driving forces, evaluating them, consulting residents, making limited field observations, and, for qualitative corroboration, applying the hydrodynamic model, DYNHYD (U.S. EPA).

Two obvious driving forces for horizontal circulation are gravity flow due to head associated with runoff, and wind stress. The wind stress driving force was evaluated by compiling the cumulative wind travel from daily average winds and converting this to the resultant wind-driven drift of Lake water. The field observations consisted of measuring the wind with a hand-held anemometer and measuring the wind drift along the leeward shore of the Lake by tracking the drift of oranges.

DYNHYD was fitted to Gander Lake and run with and without wind stress. The required inputs include lake morphometry, average runoff, and average wind speed and direction. This one-layer, two-dimensional model was applied to an epilimnion taken to be 50 m deep, with wind from the WSW at 25 km/h introduced halfway through a two-day simulation. Such winds occurred on June 19 and 20, 1995. The corresponding mixed layer depth was taken from the MinLake output for those dates, described below.

2.2.4 Vertical Circulation

Vertical circulation on the seasonal scale was evaluated based on temperature and dissolved oxygen observations, and on theory. Besides the seasonal time scale of spring and autumn overturns, there are shorter time and space scales associated with development and decay of thermoclines through wind mixing. These were addressed using the MinLake dynamic model.

2.2.5 Water Quality

Water quality issues were addressed by integrating field observations, models and projected plans.

<u>2.2.5.1. Field Observations</u>

As reported in Part 1.

<u>2.2.5.2 Modelling 950927</u>

The objectives of this modelling were two-fold, diagnostic and prognostic. A model can be useful in identifying the dominant processes operative - the diagnostic application. Then too, the model can be a guide for policy by simulating outcomes from various possible future scenarios - the prognostic application (applied in Part 3).

Our approach was to begin with a relatively simple, steady-state water quality model (modified Dillon-Rigler, Dillon et al, 1986) and then proceed to a more complex model (MinLake).

The Dillon model is a steady-state model that is highly efficient for summarizing at a general level the trophic state of the Lake in terms of phosphorus - both present case and future projections. For a more detailed look at the evolution of the state of the Lake through a season in terms of temperature and dissolved oxygen, the dynamic model was applied. (MinLake is also capable of simulating phosphorus, nitrogen and algae as they evolve through the growing season; these parameters were not simulated in this study).

A limitation of the MinLake model is that it requires fetch to be entered as part of the compiling process (it is not a parameter that can be adjusted). This means that the model must be compiled for a specific location. For the purposes of this project, a location 500 m off shore opposite the Town of Gander was selected. This was considered an ideal location because it is near the intake pipe for the Town of Gander, as well as near the discharge from Fifteen Mile Brook, a subwatershed that is proposed for logging in the future.

2.2.5.3 Model Inputs

Both models require morphometry information - watershed areas, lake surface areas, and bathymetry (at least, average depth); the Dillon model, for the whole lake, MinLake for the five-kilometre reach off the Town of Gander. The models required information on runoff; annual average for Dillon (taken as 70% of precipitation) and representative daily values for MinLake (inflow to the model domain was taken to be 50 m^3s^{-1}, as representing average wind-drift transport eastward in the upper layer). The Dillon model required phosphorus loading information. (Rates of P leaching were tabulated. Average values corresponding to land use [.030 g m^{-2} y^{-1} for residential areas, .0078 g m^{-2} y^{-1} for bogs and forests more than 15% clearned, 0.005 g m^{-2} y^{-1} for forested land, 0.025 g m^{-2} y^{-1} for precipitation directly on the lake surface; Hart et al, 1978] and for human populations [0.8 kg (of which 30% is assumed retained in sludge) $capita^{-1}$ y^{-1}; Dillon et al, 1986]) were applied in the Dillon model.

Concentrations of phosphorus in runoff (characteristic values of 9 mg m^{-3} were taken from Environment Canada archives for water quality data on the Northwest Gander River) were specified for MinLake, even though phosphorus was not strictly modelled. More detail on loading rates for each land use is included in Part 3. MinLake inputs also included: initial conditions and field data for temperature and dissolved oxygen profiles (initial conditions for the start of simulation, May 1, were presumed to be temperatures of 4 °C dissolved oxygen's of 10 mg L^{-1} throughout the water column. Field data from surveys on June 23 and September 7 were also entered for comparison with simulated values); daily average weather information including winds, precipitation, air temperature, and radiation (weather information, including hours of bright sunshine, was taken from the Monthly Meteorological Summary for Gander International Airport); daily runoff quality (temperature, oxygen, phosphorus, suspended solids (representative water quality parameter values were abstracted from Environment Canada archives for the Northwest Gander River; temperature values vary with season, suspended solids were set at 2 mg L^{-1}, phosphorus at 0.009 mg L^{-1}, and dissolved oxygen at 7 mg L^{-1}).

The Dillon model was slightly modified to provide the phosphorus concentration averaged over all four seasons. The MinLake model was also modified slightly to print out results for depths greater than 99 m.

2.2.5.4 Model Outputs

The Dillon model produces estimates of annual average lake phosphorus, turnover time and the time-scale for the lake to respond to a change in phosphorus loading. The sources of phosphorus can also be ranked in importance. Initially, a scenario for the direct catchment was developed. Later, in Part 3, scenarios for the whole basin of Gander Lake (existing situation), the direct catchment (future land use) and the eastern one-third of the Lake (existing and future) land use were developed. These scenarios correspond to the situation where NW/SW Gander River water circulates throughout the Lake, River waters flow straight to the Outlet, and where the eastern end is relatively isolated with little exchange, respectively. The reasons for developing these scenarios are described fully in Section 3.6, Lake Sensitivity.

The MinLake model produced temperature and dissolved oxygen profiles, as well as net heat flux at two-day intervals over the warm season. So, for example, the effects of storms on mixed layer depth is simulated.

2.2.5.5 Validation Checks

To check that the particular model is appropriate for the situation, model output was compared with historical data.

2.2.5.6 Calibration

The Dillon model was not re-calibrated to fit Gander Lake data -literature values for loading rates were used. The MinLake model was calibrated. BODK20, the detrital decay rate was set at the upper end of its range - 0.1 day^{-1}. YCHO2, the mass ratio of dissolved oxygen produced from photosynthesis and oxygen utilization in respiration was doubled from the nominal value in order to counteract high simulated oxygen concentrations associated with algae growth in warm water in August.

2.2.5.7 Verification

To verify the MinLake model, simulated results were compared with observations. The Dillon model is not verified; a second year's phosphorus data would be required.

2.2.5.8 Sensitivity Runs

The following parameters were tested for sensitivity in terms of the effect on dissolved oxygen and temperature profiles: inflow rates, inflow oxygen concentration. Sensitivity of lake phosphorus was explored through running the various scenarios described above.

2.3 RESULTS & DISCUSSION

2.3.1 Water Balance

The balance was developed using data for the period of record for precipitation and river flow. Figure 2.2 illustrates the Monthly Mean Precipitation for Gander International Airport. The simulation run was then used to develop a mass relationship between precipitation and runoff for the entire watershed by assuming that ΔS was constant, thus allowing the balance to solve for an overall average runoff relationship for the entire area. The result was 0.68, or that 68% of the precipitation falling on the watershed ended up in Gander River. This work involved measurement of the watershed areas for the Southwest Gander River, the Northwest Gander River, and the areas in each of these watersheds that are below the gauge location, but tributary to the Lake. This information is presented on Figure 2.1 Watershed Areas.

Flow records for the Northwest and Southwest Rivers are only available for a limited period of time. In order to better represent a balance, the period 1988 to 1990 was selected to develop the water balance that was used to calculate the relative portion of surface runoff from overland flow, or smaller streams, that reaches the Lake. This area is referred to as the "catchment".

The water balance constructed is represented as a diagram in Figure 2.5. Using the annual empirical relationship of a 68% runoff from precipitation for the entire year would result in misleading results for the months where precipitation is in the form of snow (no runoff) and when runoff is from snow melt. A monthly set of coefficients was therefore calculated from the balance and is presented in Table 2.1. This shows that in some months there is more runoff than precipitation, which is reasonable and matches Atlantic Canadians' knowledge of spring snow melt runoff.

The monthly runoff coefficients in Table 2.1 are calibrated to reproduce actual results for the period of the balance using precipitation from the Gander Atmospheric Station (Figure 2.2) and flow in the Gander River at Big Chute (Figures 2.3 and 2.4). For the purposes of this study, they are extrapolated for use as a guide to the expected runoff from land within the watershed for a precipitation event in that particular month.

Table 2.1 Monthly Runoff Coefficients

Month	Runoff Coefficient
January	0.24
February	0.19
March	0.82
April	1.97
May	2.86
June	0.91
July	0.69
August	0.17
September	0.08
October	0.18
November	0.40
December	0.80

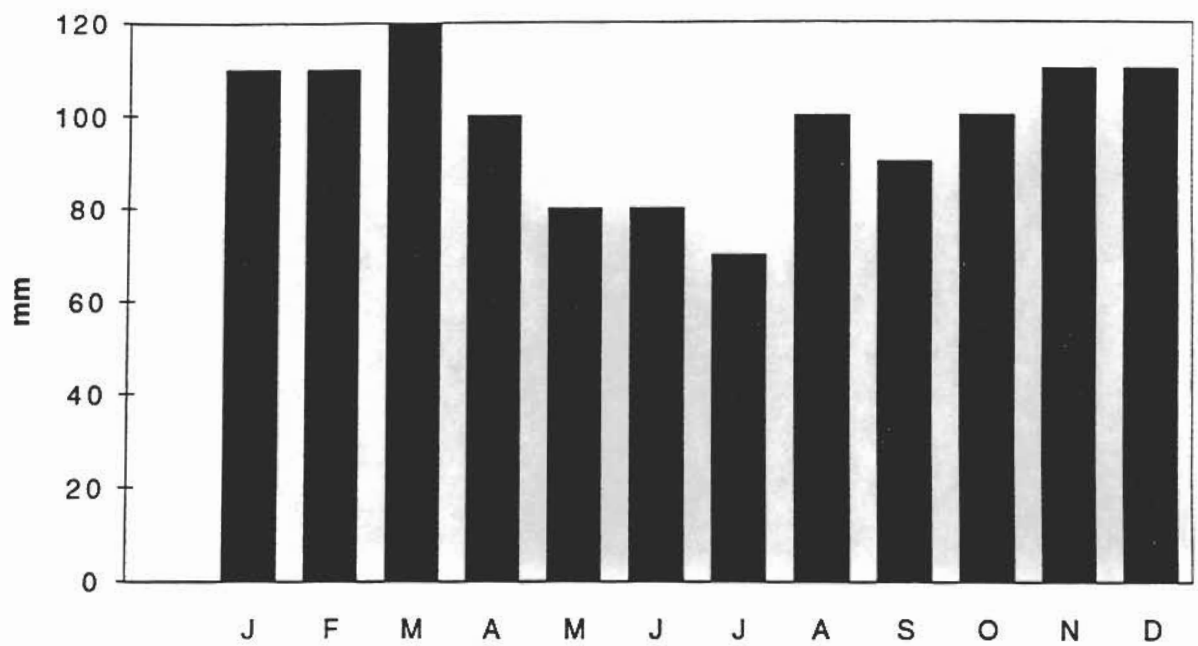


Figure 2.2 **Monthly Mean Precipitation for Gander International Airport**

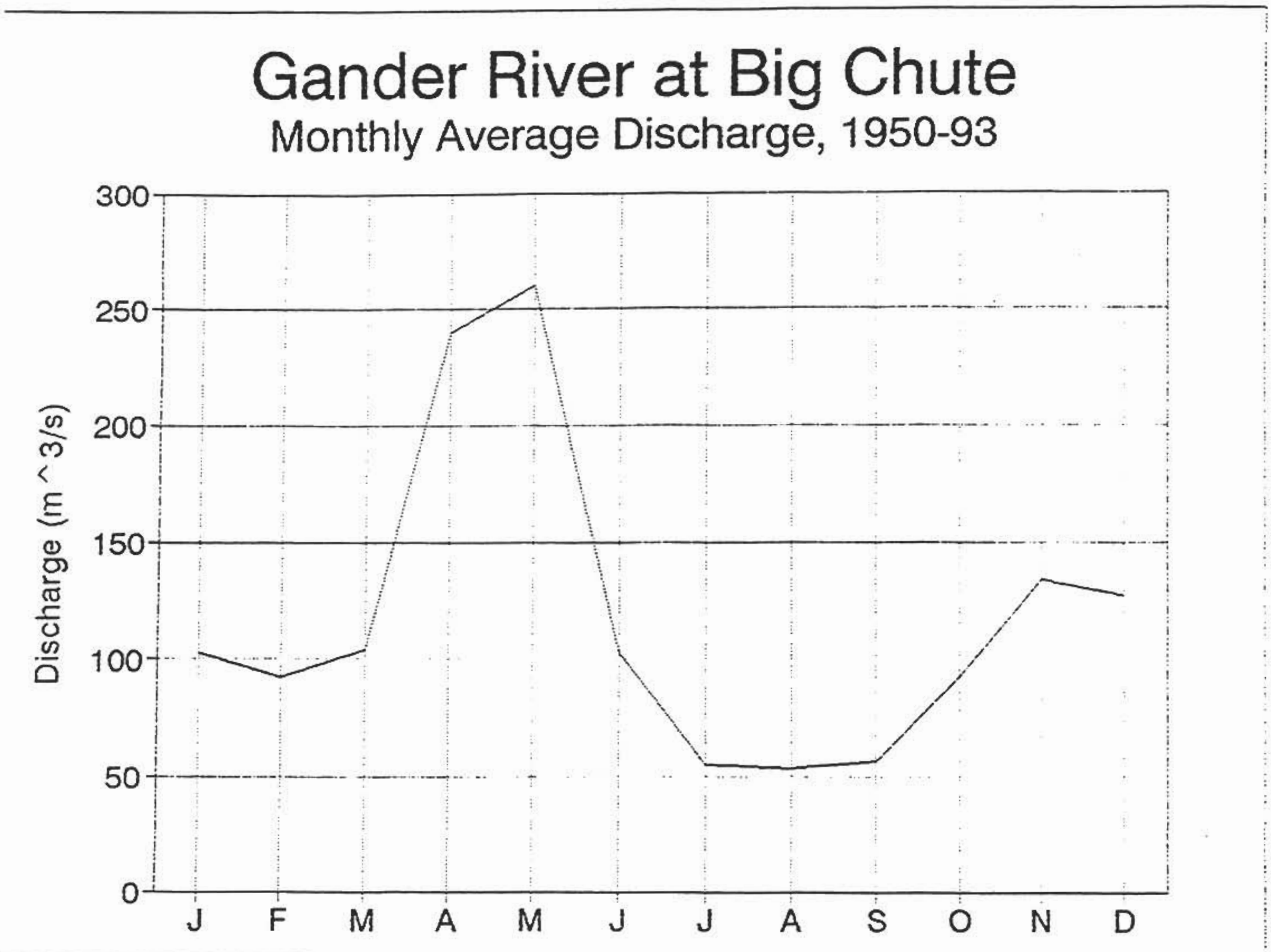


Figure 2.3 Gander River at Big Chute: Monthly Average Discharge

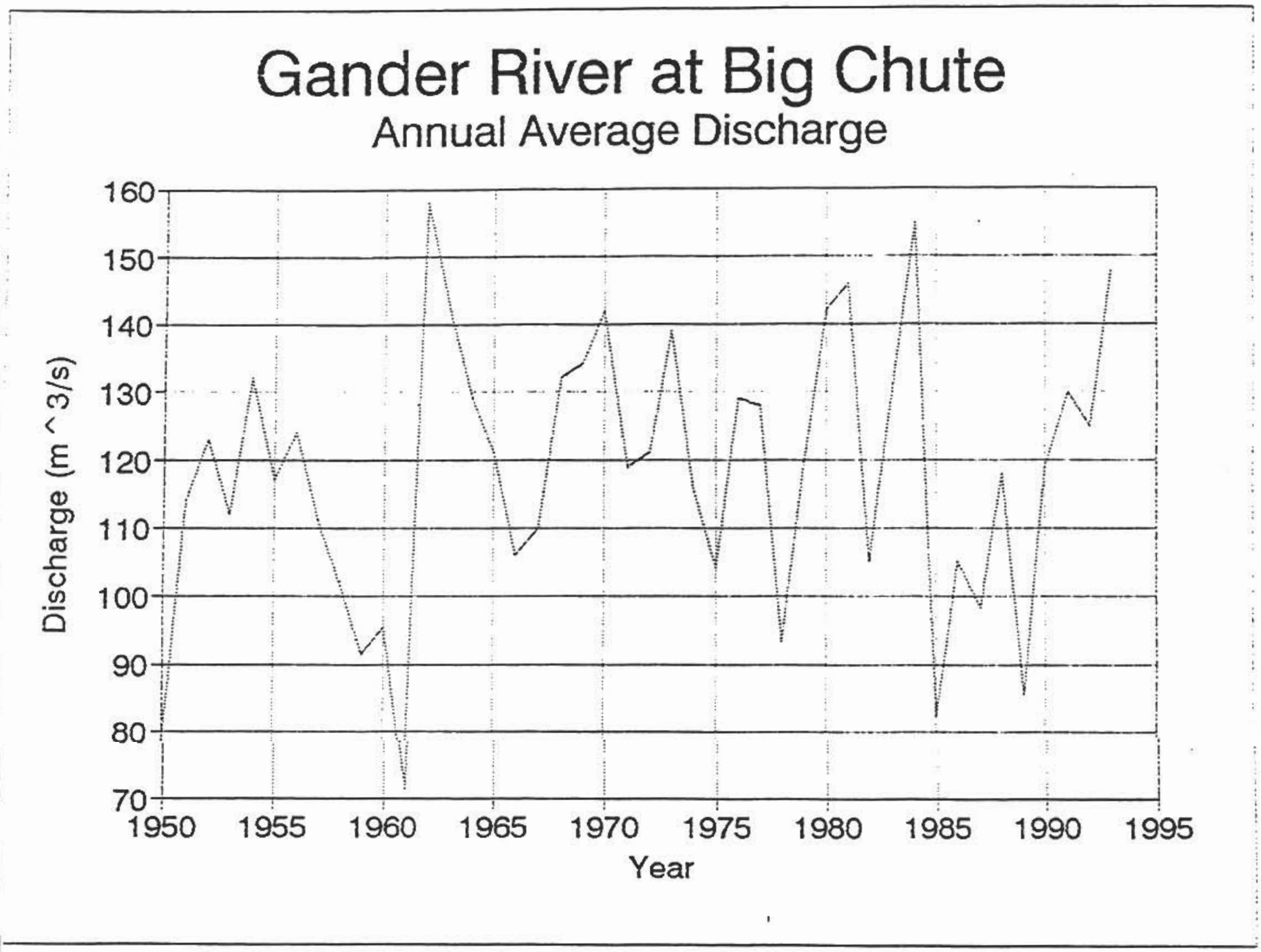


Figure 2.4 Gander River at Big Chute: Annual Average Discharge

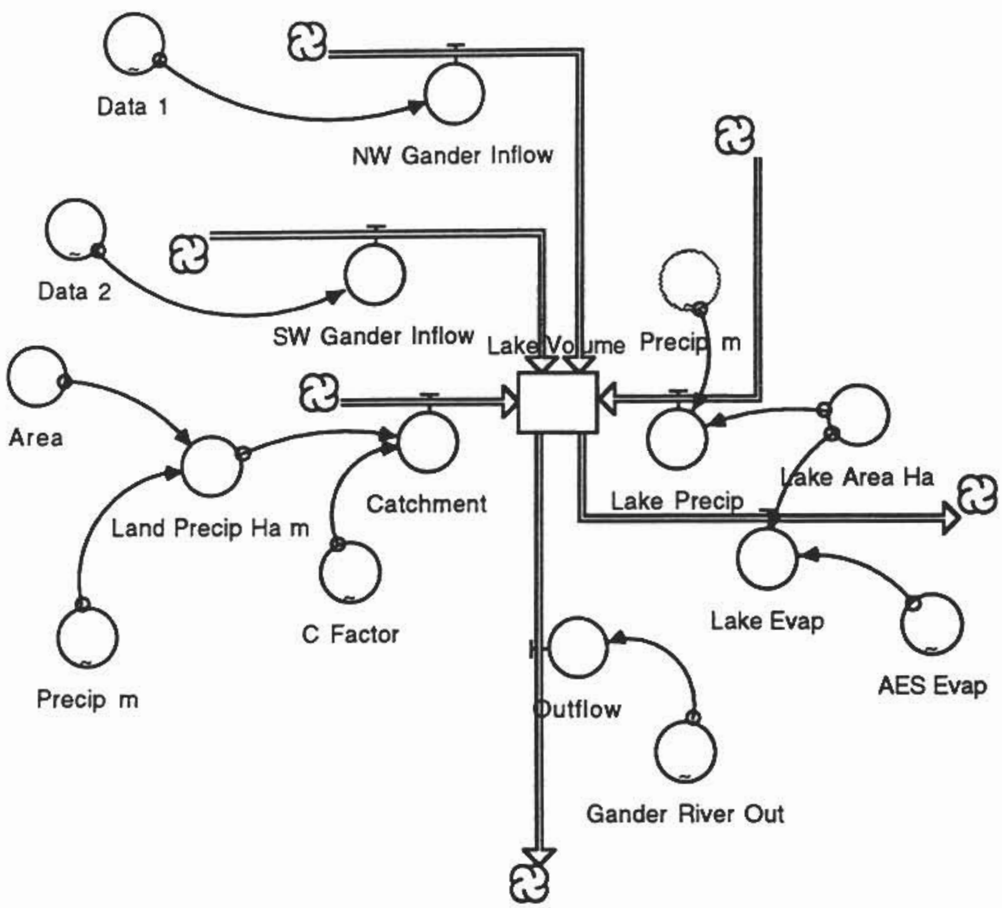


Figure 2.5 Water Balance Diagram

Without flow measurements at the inlet to the Lake from a part of the catchment where land use is mapped, it is not possible to develop better precipitation-runoff relationships based on varying land use that can be calibrated. This water balance, therefore, offers only a broad confirmation as to the relative level of influence runoff from the catchment will have on Lake water quality.

The graph and table in Figure 2.6 provide the results of the water balance run for the period 1988 to 1990. The fluctuation of the Lake storage (a monthly average) is illustrated on Figure 2.7.

The balance as currently arranged illustrates the relative importance of the inflows from the Northwest and Southwest Gander Rivers on the downstream flow in Gander River, as compared to the input from Gander Lake and its catchment (only 10 to 12% of the flow in Gander River is from the Gander Lake catchment). It also illustrates the enormity of the volume of Gander Lake in comparison to the monthly and annual volume of runoff that enters it. A theoretical flushing time for Gander Lake, in terms of catchment runoff, is approximately 18 years.

Sensitivity analysis for the runoff coefficient (Figure 2.8) indicates the level of importance the catchment runoff has when looking at the flow in Gander River. It also indicates the relative sensitivity of the flow from the direct catchment to a runoff coefficient. In each case, "C" has been varied from 0.5 to 1.0. Comparing the Lake volume with monthly and annual contributions of surface runoff to the Lake also gives a good appreciation for the level of dilution and probable flushing interval of Gander Lake, that, taken together, point to the Lake having a significant diluting capacity for input pollutants, a conclusion that is supported by the field data.

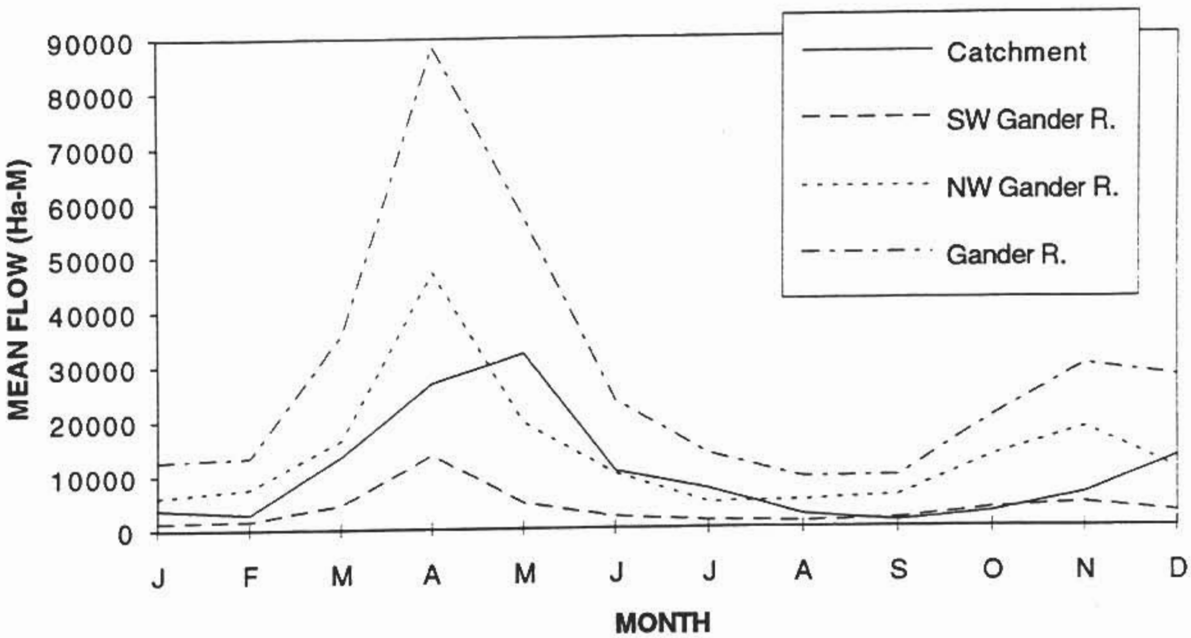
The goal in this section was to develop good "rule of thumb" relationships for the hydrologic characteristics within the catchment, and set a broad model framework for subsequent future research. Both the MinLake model, and this water balance, allow for continued enhancement as detailed information becomes available.

Future work may require that a sub-catchment within the Gander Lake watershed be monitored for flow and several key quality parameters, in order to better define the relationship between land use and lake water quality. Until such data is available, the work undertaken in Part 3, using the standard "expected" water quality impacts will only be a first cut at developing an understanding of the behavior of this watershed.

2.3.2 Horizontal Circulation

Figures 2.9 and 2.10 show temperatures observed on June 23 and 24, 1995 and *simulated for Line 2 (transect 2), respectively. The striking feature in Figure 2.9 is that,* compared to those of other field survey lines, Line 1 temperatures are relatively warm, even at 70 m depth while Line 5 and 6 temperatures are among the cooler set. The most likely interpretation for this is that surface water which is warming in June (Figure 2.9) is accumulated at the downwind end of the Lake.

Again for the September survey, the temperature profiles (Figure 2.13) show temperatures warmer at the eastern end of the Lake, especially in the depth range from 10 m to 50 m. Also, the thermocline deepens from 15 m in the west to 30 m in the east. Comparing northern stations to central and southern stations, averaged over all six lines of sampling, the southern stations tend to be slightly warmer (Figure 2.13). Our interpretation is that warm surface waters are accumulating at the eastern end of the Lake, with a return flow on the south side on average.



Months	Catchment	Lake Precip	NW Gander Inflow	SW Gander Inflow	Outflow
1	3801.92	1268.66	6151.00	1365.00	12571.00
2	2881.89	1214.72	7542.00	1685.00	13310.00
3	13392.60	1307.99	16454.00	4449.00	35542.00
4	26812.41	1089.99	47088.00	13625.00	88560.00
5	32063.48	897.84	19365.00	4696.00	57050.00
6	10444.62	919.19	9945.00	2122.00	23250.00
7	7086.93	822.55	4587.00	1327.00	13490.00
8	2280.37	1074.26	4974.00	1079.00	9142.00
9	1006.89	1007.96	5811.00	1526.00	9314.00
10	2651.92	1179.89	12919.00	3313.00	20133.00
11	6095.20	1220.34	18006.00	4311.00	29583.00
12	12729.20	1274.28	10606.00	2678.00	27346.00

Figure 2.6 Water Balance Output

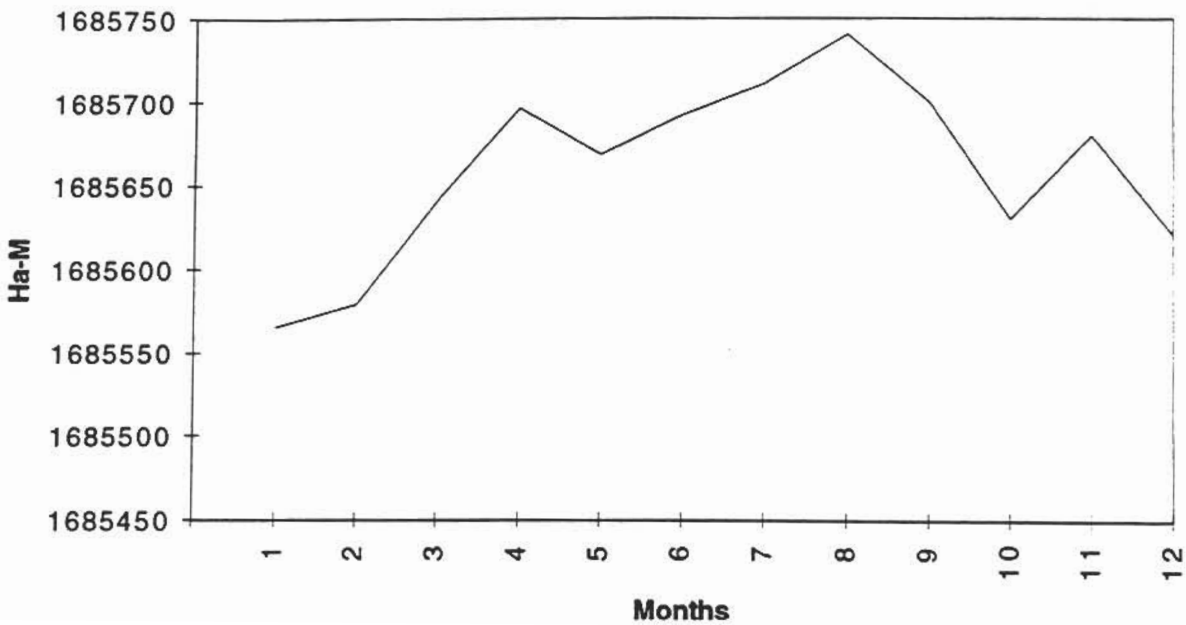
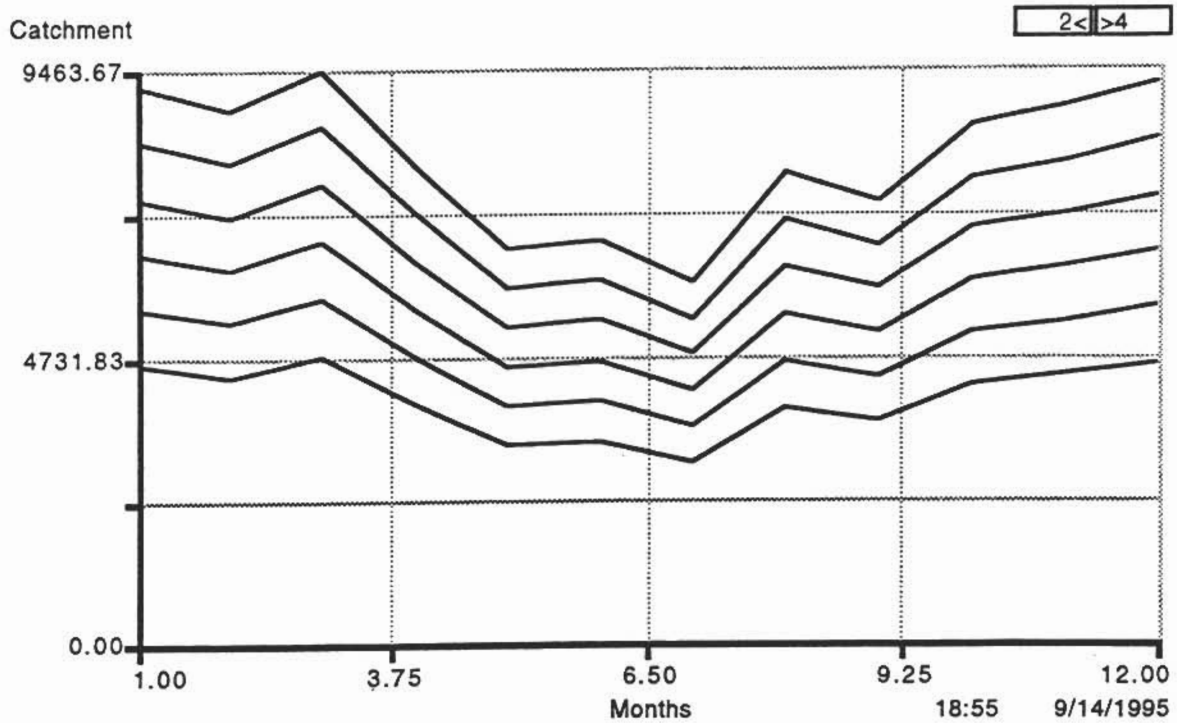
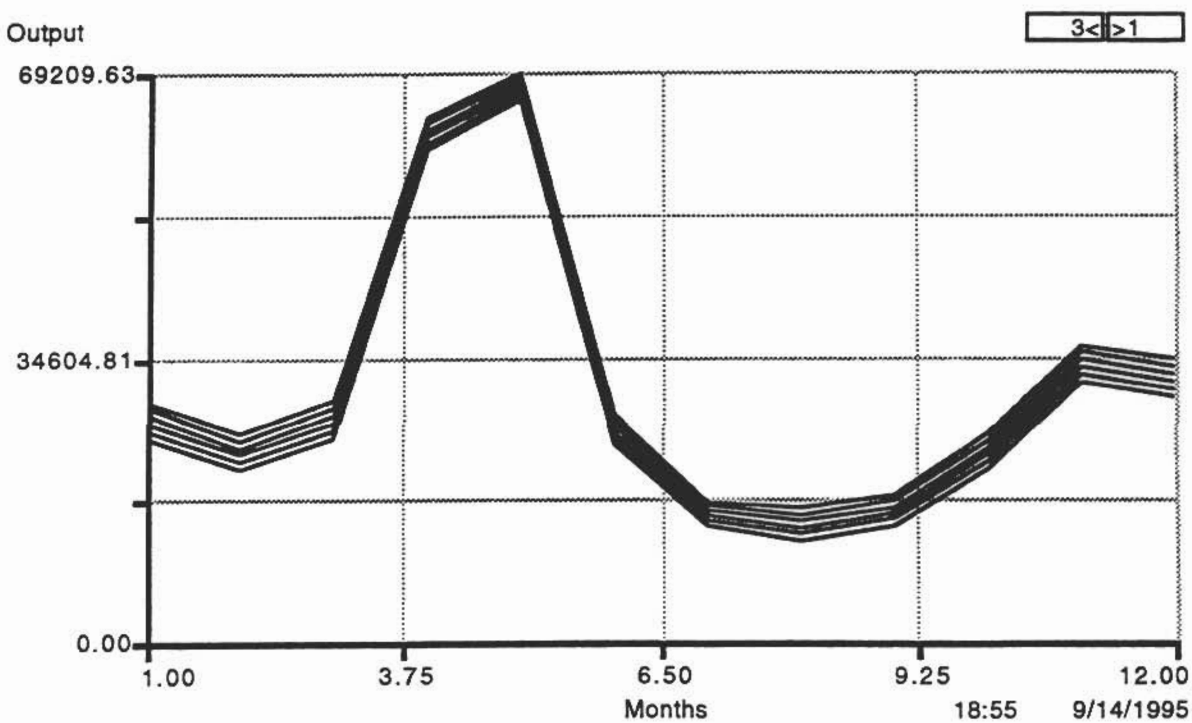


Figure 2.7 Lake Storage Fluctuation



Sensitivity Analysis of Runoff Coefficient - Catchment Contribution
(All Units in Ha-M, Ha, M)



Sensitivity Analysis of Runoff Coefficient - Outflow to Gander River
(All Units in Ha-M, Ha, M)

Figure 2.8 Water Balance Sensitivity Analysis

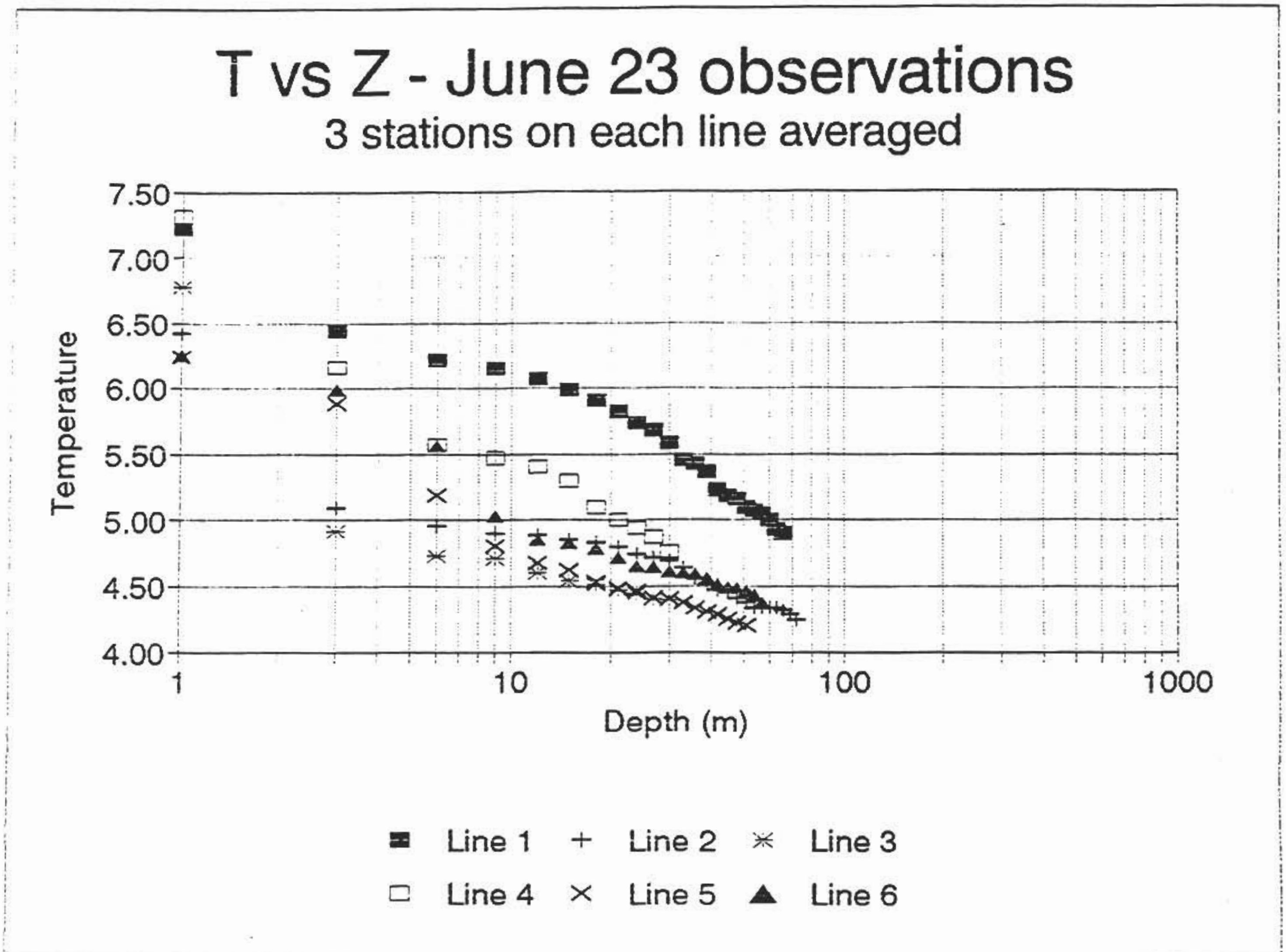


Figure 2.9 **Observed Depth Profiles of Temperature, June 23, 24, 1995 (averaged for each depth across three stations on the same line)**

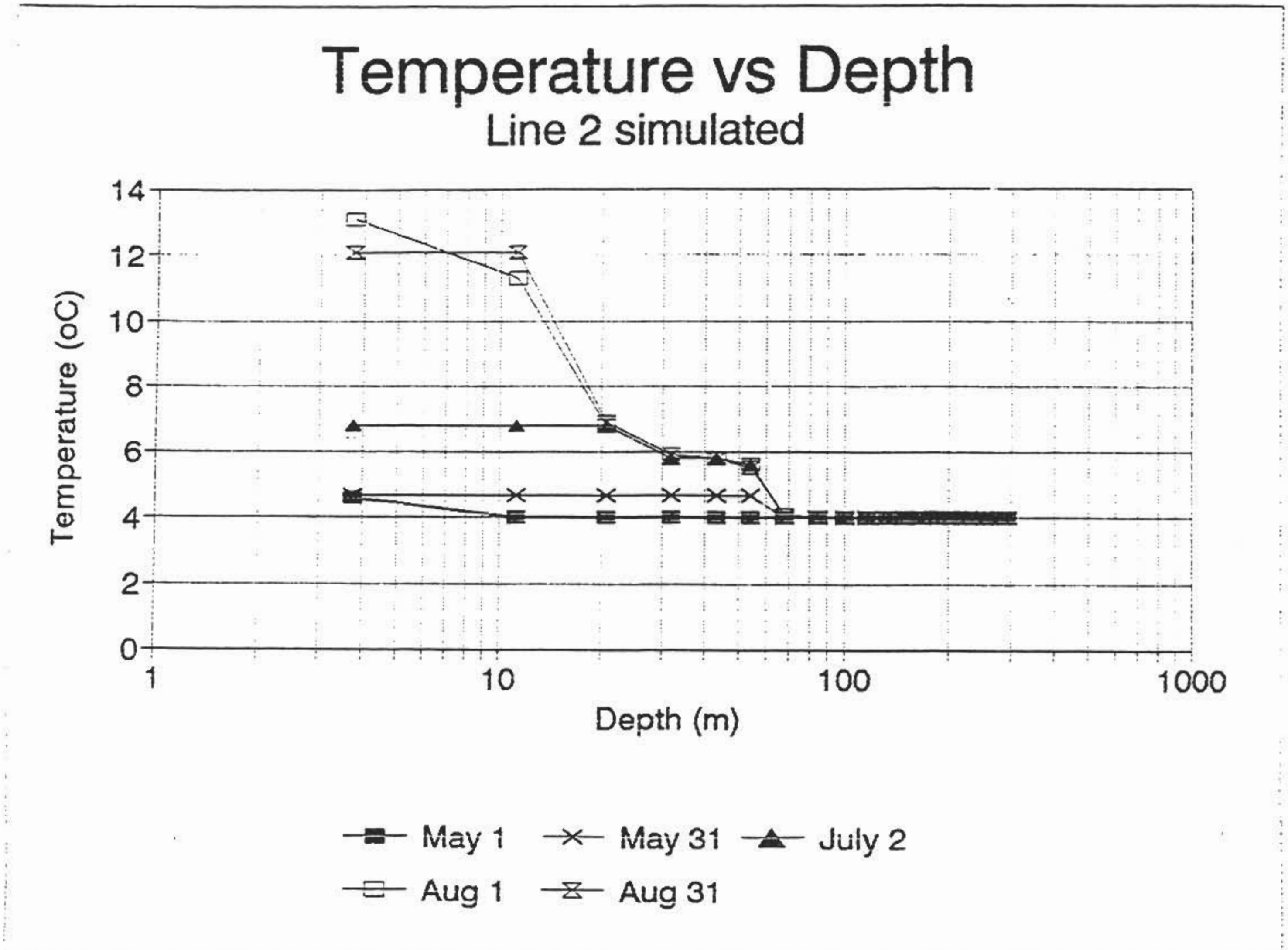


Figure 2.10 **Simulated (MinLake) Depth Profiles of Temperature through Spring and Summer, 1995**

This pattern is also observed in other water quality data sets, where mixing appears to be occurring in the upper layer but not at depth (60 metres). Refer to Spatial Distribution of Lake Water Quality maps, Figures 1.4 a-h (Part 1).

Limited field observations of currents were made on September 24, 1995 at Line 4 and the Pumping Station. In each case, winds were measured to be WSW at 8 to 10 km/h. Oranges placed 20 m offshore near the northern (leeward) shore drifted eastward at approximately 10 cm/s. This is consistent with the 3% rule for surface drift, i.e., that the surface water itself drifts at 3% of the wind speed.

Another set of observations were made during the September 24 field visit. A visual comparison of colours in water samples collected in the Northwest Gander River, in the Lake proper, and at the Outflow, showed that the Outflow water exhibited the lighter colour of the Lake, rather than the darker colour of the Northwest Gander River water. This suggests that the Outflow is conveying water from the Lake, rather than directly from the two large Rivers.

Imagining that the predominant flow of surface water is eastward in response to the winds, then a collection of floatables should be apparent at the eastern end of the Lake. In January, 1996, this test was discussed with Mr. Bill Baird. He travelled to the eastern end of the Lake and observed, amongst the ice, several logs, some large, accumulated there.

The two candidates as driving forces for horizontal circulation are gravity due to buoyant river inflows, and wind stress. Discharge from the Gander River Outflow is shown in monthly and annual averages in Figures 2.3 and 2.4, respectively. In the absence of wind, or under ice cover in the winter, it is to be expected that runoff from the two major inflowing rivers would flow directly across the western end of the Lake in a strong flow (~50 $m^3\ s^{-1}$ in summer) to the Outflow, and that runoff from the smaller streams inflowing to the central and eastern portions of Gander Lake would flow westward to the Outflow in a weak flow (~3 $m^3\ s^{-1}$). (This exchange transport is taken as the stream input from the central and eastern Lake subcatchments. The area is estimated as ~140 km^2, with average precipitation in summer of 80 mm $month^{-1}$, for a monthly runoff [where 70% is taken to runoff] of $0.8 \times 10^7\ m^3$ or 3 $m^3\ s^{-1}$.)

However, winds are typically rather strong in Gander, and with a persistent eastward component. As described in Section 1.3.2.7, winds are most frequently from the W, WSW and SW sectors, at speeds averaging 21.5 to 22.5 km/h on an annual basis. The resultant east/west component of hourly winds for the months May to August, 1955-80, amounts to approximately 4000 km/month eastward. Using the relationship that the upper layer will drift at approximately 1% of the wind speed (whereas the surface drifts at 3% of wind speed), this implies that, in the absence of ice cover, water from the western end of the Lake will be exposed to a wind stress component such that the water drifts eastward at a rate of transport:

$$40\ km\ month^{-1} \times 1\ km\ width \times 1\ m\ depth\ or\ {\sim}15\ m^3\ s^{-1}.$$

This is comparable to the summer runoff of 50 m^3s^{-1}. Thus, a substantial fraction of the runoff can be expected to drift downwind, traversing the lake in approximately one month. Moreover, the Lake is expected to be relatively well exchanged horizontally compared to the situation in the absence of wind. This is because the exchange transport of ~15 to 50 m^3s^{-1} in each direction much exceeds the local catchment runoff of 3 m^3s^{-1} (one-way).

Assuming that the horizontal circulation is confined to the upper layer, the eastward drift due to wind stress acting on the surface of the Lake implies that a gravity return flow also occurs. This return flow probably occurs near the wind-sheltered shore. This corresponds to the experience of residents boating on the Lake (Bill Baird, pers. comm.) and is consistent with results of the hydrodynamic simulation (Figure 2.11). This Figure shows the simulated flows in the epilimnion (taken to be 50 m deep), with wind from the WSW at 25 km/h introduced halfway through the two-day simulation. In the calm conditions of the first day, the flows are, as expected, 50 m^3s^{-1} through the west end of the Lake and 50 m^3s^{-1} through the Outflow, while flows along the north and south sides of the central portion of the Lake are negligible. With the onset of WSW winds, the flow through the west end increases to more than 50 m^3s^{-1}, the flow through the Outflow remains approximately 50 m^3s^{-1}, the north side flow becomes more than 50 m^3s^{-1} to the eastward, and the south side flow, an approximately equivalent return-flow westward.

Further evidence of the phenomena of a lake with a current going in two directions is found in Alexander Murray's Report for 1874 - Survey of the Gander River and Lake. In his report, Mr. Murray commented that, while on Gander Lake, "I observed on one occasion, at the entrance to the main river arm, that the current ran *towards* the river at the rate of about half a mile an hour" (italics are the author's).

The overall result is that, because of relatively strong and persistent westerly component winds, Lake water circulates in a broad drift to the eastward with a return flow. Thus, buoyant (summer) runoff entering the Lake at the western end is likely to circulate through the Lake in the epilimnion, rather than flowing out of the Lake directly.

2.3.3 Vertical Circulation

Dissolved oxygen and temperature data throughout the water column from August, 1991 and August 1995 (DFO: pers. comm. Michael O'Connell), as well as our own field data in early September, indicate that the Lake is well oxygenated (10-12 mg L^{-1}) throughout the water column, and that temperatures in the hypolimnion are 4 °C, the temperature of maximum density. These data strongly suggest that overturn occurred in the previous spring. From theory, we also expect an autumn turnover, i.e., that Gander Lake is dimictic, and overturns when vertical stability is reduced to zero as the surface layer warms to, or cools to the temperature of maximum density, 4 °C.

Field observations made as part of this study in June and September, 1995, confirm the development of thermoclines in spring and summer as expected (refer to Figure 1.5 a-b, Lake Temperature and Conductivity Profiles). Thermoclines are evidence of restricted vertical circulation. In this case, the thermocline was observed at approximately 35 m.

It is most likely that Gander Lake exhibits a body seiche which causes the Lake level to vary, and which could account for variability in the depth of the thermocline. A body seiche is a wave, caused by the movement of water, essentially sloshing back and forth as in a bath tub. While no measures of a seiche were conducted, a Lake of this size and shape is likely to exhibit a seiche. Evidence of a seiche is found in Alexander Murray's 1874 Report. "While on this lake we were much struck by observing an irregular or spasmodic rise and fall of the water's level, without any apparent atmospheric cause. With a very steady barometer, and during an interval of calm and hot weather, the level of the surface was noticed to vary some 5 or 6 inches in the course of a day....

Charles Francis, the Indian guide, who was then in my employ, told me he had often witnessed this phenomenon, and that at the extreme eastern end of the lake he had once perceived a rise and fall in one day of fully a foot".

The model MinLake, with weather data and runoff as inputs, also simulates temperature profiles in reasonable agreement with observations (Figure 2.11).

These results - temperature, dissolved oxygen, mixed layer depth and dimicticity - are similar to conditions observed at Red Indian Lake, a 150 m deep lake in the neighbouring Exploits River watershed (Morry and Cole, 1977) and at Western Brook Pond, Gros Morne National Park, Newfoundland (Kerekes, 1990). A description of Western Brook Pond is included in Appendix E, for comparison.

2.3.4 Water Quality

Dissolved oxygen is a key indicator of water quality, for example, for fish and other aquatic animals. Observations of dissolved oxygen, from DFO (to 300 m) and from field sampling associated with this project (to 60 m), indicate that dissolved oxygen levels are uniformly high (10 to 12 mg L^{-1}). Model results (MinLake, Figure 2.12) are consistent with the data.

Our initial approach to water quality and lake trophic state is cast in terms of phosphorus using the Dillon model. Phosphorus is expected to be the limiting nutrient in Gander Lake. Phosphorus flux is typically associated with eroding sediments.

The Dillon model indicates that the areal water loading (the depth of water arriving per unit area of the Lake each year), is 30 m y^{-1} considering the whole basin, 6 m y^{-1} if just the catchment or the eastern end are considered. Theoretical turnover rates are 0.25 y^{-1} and 0.04 y^{-1}, respectively.

Of the three sources of phosphorus, we have taken the anthropogenic source to be small (Benton and cottages), due to uptake in the wetlands around Soulis Pond. The precipitation source directly onto the Lake, using rates determined in Nova Scotia, is likely to be reasonably accurate, leaving the leaching of phosphorus from the land to be determined. We have given rates of leaching of phosphorus for forests and logs, etc., but those rates do not include recently clear-cut forests and regenerating forests. In this regard, our loading rates needed to be increased.

Based on measurement of suspended particulates in a New England stream (Borman and Likens 1979), where suspended sediment loadings were 33 kg ha^{-1} y^{-1}, 190 kg ha^{-1} y^{-1} and 380 kg ha^{-1} y^{-1} in areas of undisturbed forest, young regenerating forest, and recently clear-cut forest, respectively.

We have distinguished the areas of undisturbed forest from those burnt-over, regenerating or recently clear cut (Table 3.3), and we have increased the loading for the latter areas to 40 mg m^{-2} y^{-1} from 5 mg m^{-2} y^{-1}.

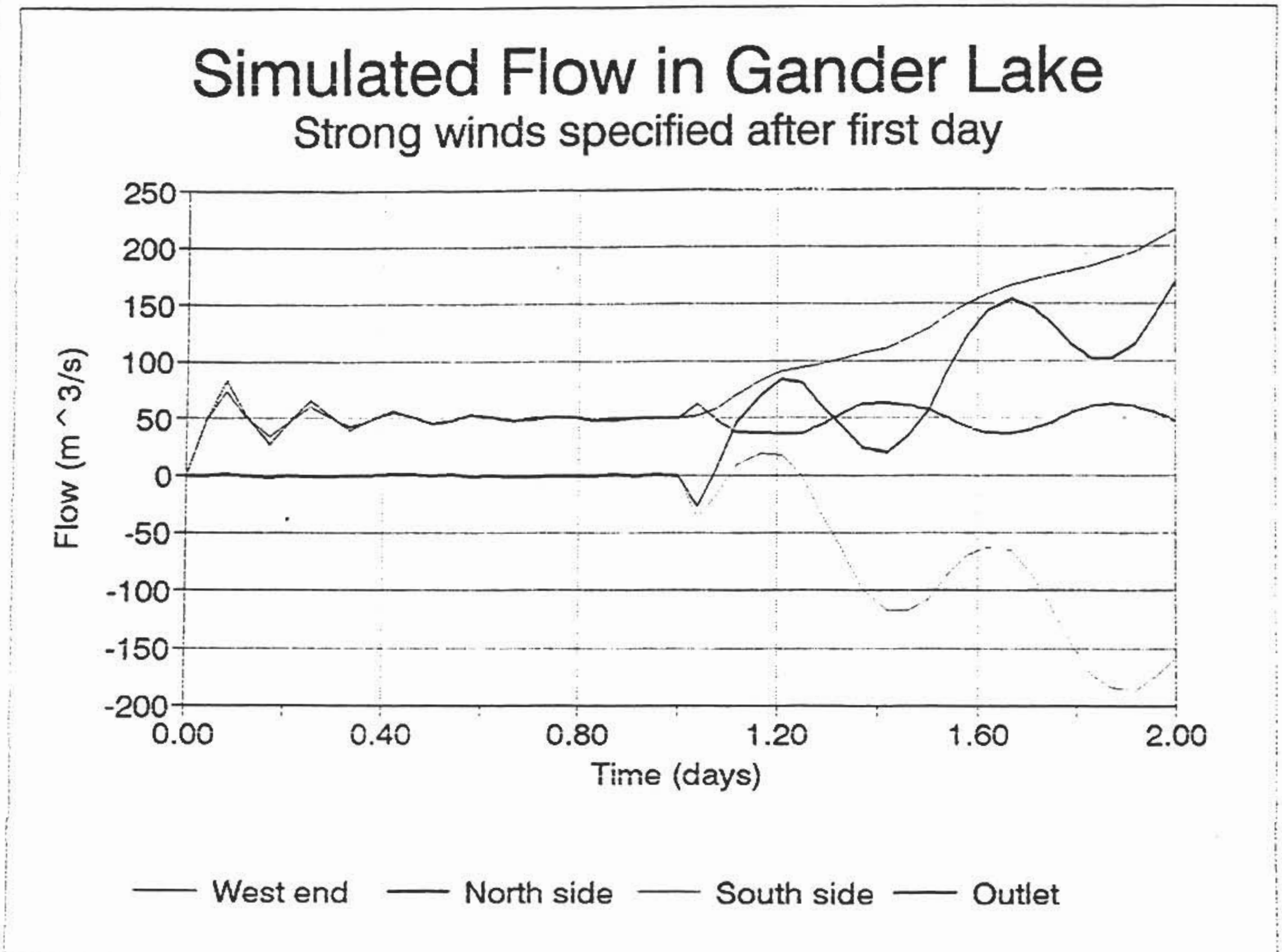


Figure 2.11 **Simulated (WASP) Wind Drift Currents in Gander Lake just after Onset of WSW Winds of 25 km/h (Non-equilibrated)**

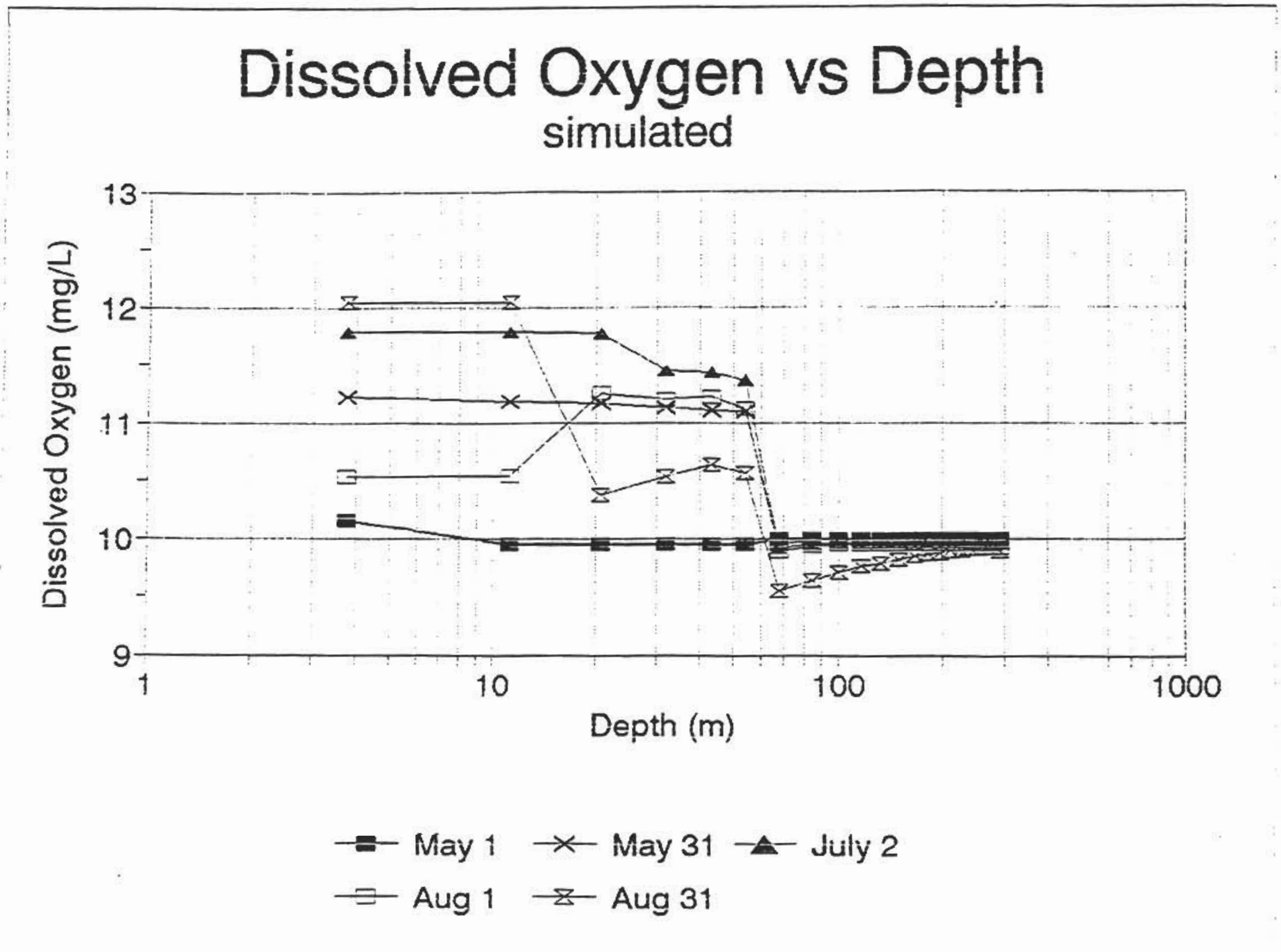


Figure 2.12 **Simulated (MinLake) Depth Profiles of Dissolved Oxygen through Spring and Summer, 1995**

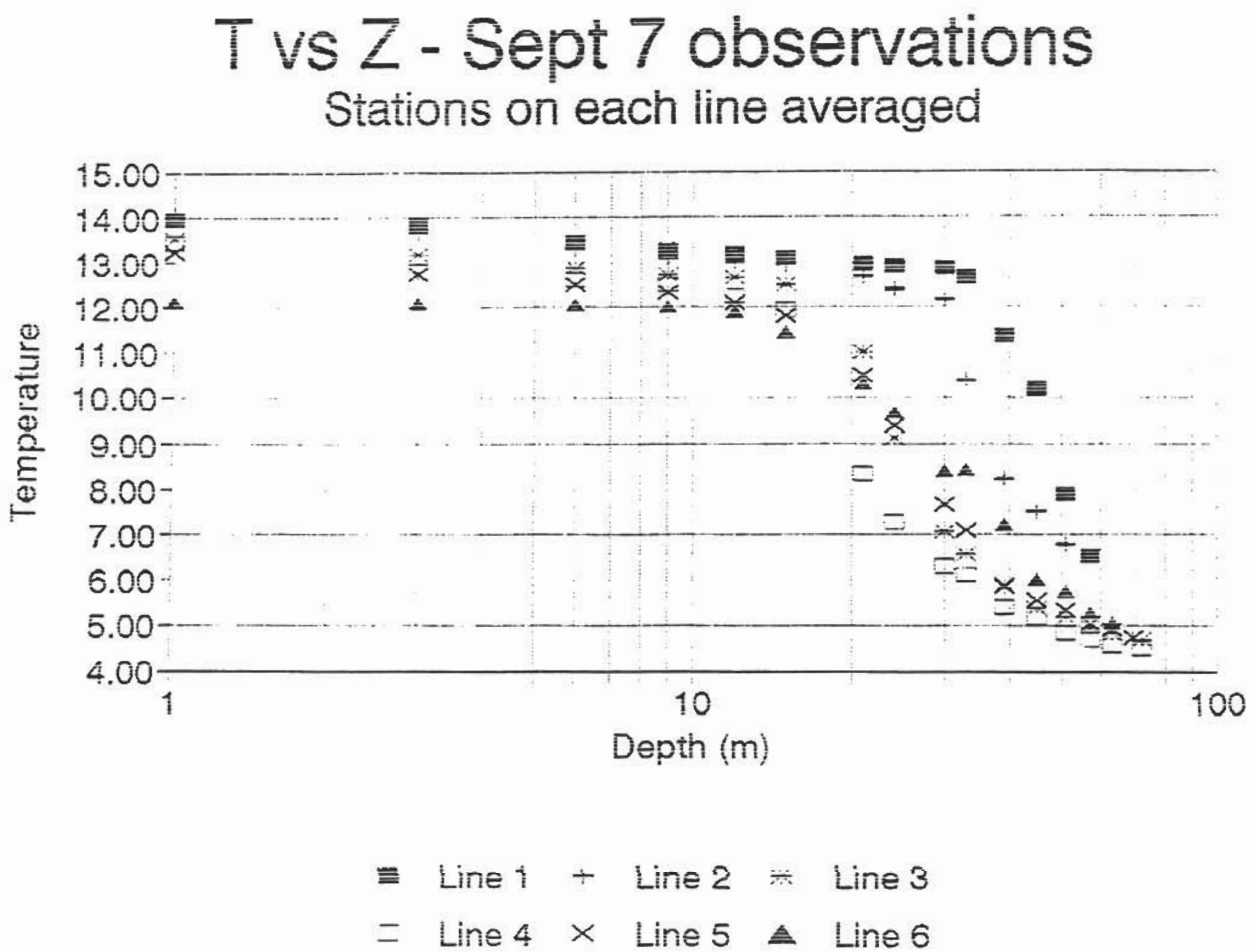


Figure 2.13 Observed Depth Profiles of Temperature, September 7, 1995 (averaged for each depth across three stations on the same line)

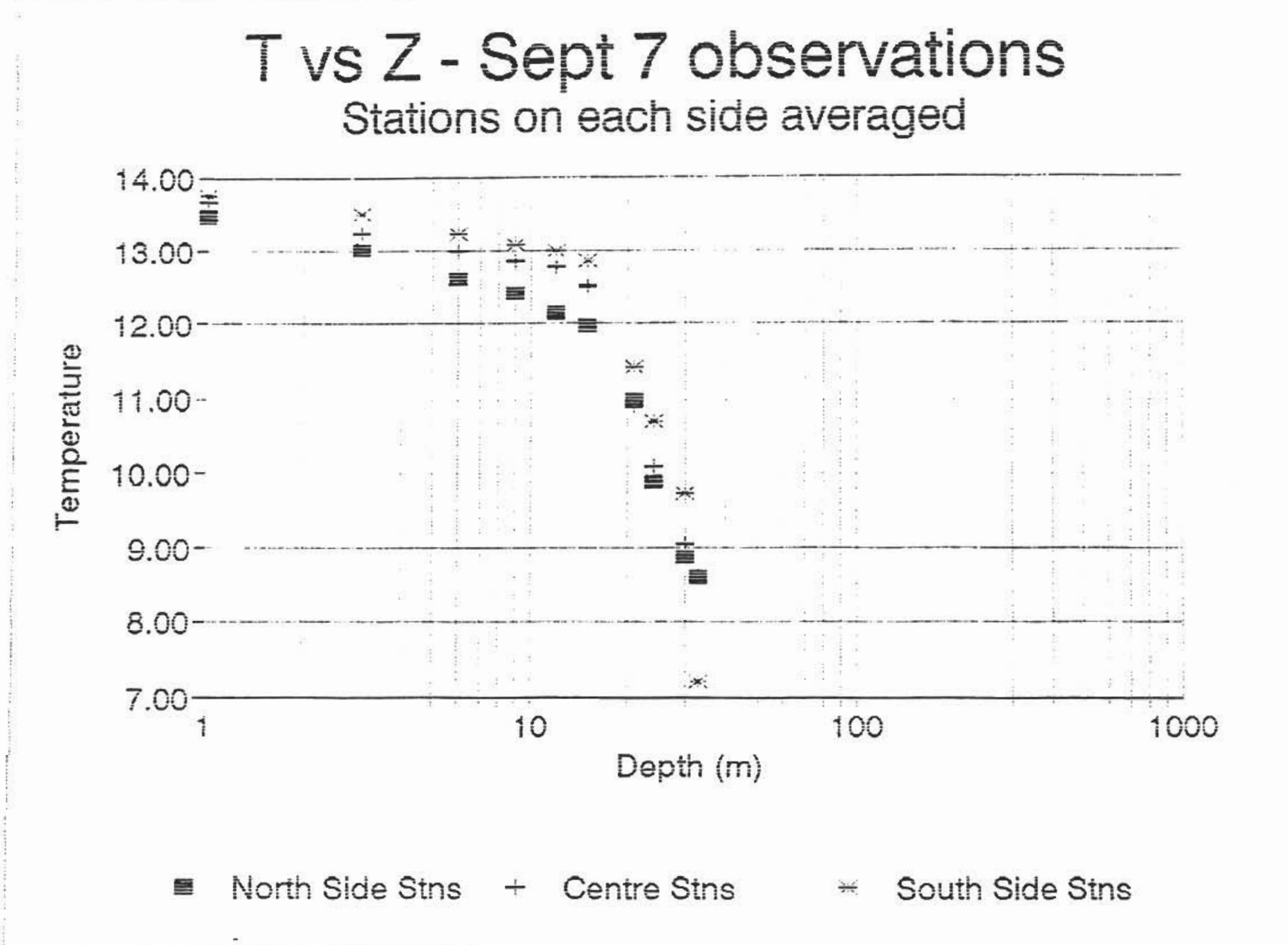


Figure 2.14 Observed Depth Profiles of Temperature, September 7, 1995 (averaged for each depth across six survey lines for northside station, center stations, and southside stations)

Results of phosphorus modelling are given in Figures 2.15, 2.16 and 2.17. The future scenarios differ from existing scenarios in that there is an increase in P-loading as a result of future land use activities (refer to Sections 3.5 and 3.6).

From Figure 2.17, if the entire basin is considered, the Lake has a relatively low residence time and the fraction of P settling is small, hence the Lake concentration of P is relatively large - 9.9 mg m^{-3}. The average P concentration observed in the upper 60 m of the water column in June and September, 1995, was 6.2 mg m^{-3}, assuming non-detectable concentrations were just below the level of detection. This is taken as a lower bound estimate since P concentrations are expected to be higher at depth.

If only the direct catchment or the eastern 40% of the catchment are considered, the residence time is higher, the fraction of P settling out is 0.7 instead of 0.3, and the P concentration of the Lake is predicted to be just 5.6 or 5.7 mg m-3.

For the future scenarios, the increased P-loading is reflected in higher projected lake concentrations, although not to the point where the trophic state becomes mesotrophic (Figures 2.15 and 2.16).

2.4 CONCLUSIONS

2.4.1 Present State of the Lake

Based on integration of the available data and modelling results, Gander Lake is now oligotrophic and in good condition generally.

2.4.2 Lake Assimilative Capacity

Based on wind statistics, current observations, temperature observations and model simulations, the model predicts that a substantial fraction of runoff from the NW and SW Gander Rivers circulates through the epilimnion of the central and eastern regions of the Lake. Thus, the quality of Gander Lake, even in the central and eastern portions, is not independent of the water quality of the Northwest and Southwest Gander Rivers.

Further work to more fully explore the circulation of the two Rivers is essential to understanding the sensitivity of the Lake. If the model is correct, then for the central and eastern regions of the Lake, the residence time is shorter than might otherwise have been anticipated in the absence of winds, the aerial water loading is higher, and the assimilative capacity is greater than if the runoff from the large Rivers were confined to the western region of the Lake. However, the Rivers both have large catchments, so under the relatively complete circulation scenario, Lake water quality is highly dependent on water quality in the River basins, and potential phosphorous discharges from land use activities there.

Phosphorus is expected to be the limiting nutrient in Gander Lake. Phosphorus flux is typically associated with eroding sediments. Quantitative assessments of assimilative capacity for phosphorus indicate that there is reserve capacity at present. The Lake capacity for phosphorus (as a key indicator) has been explored for two possible future scenarios. Lake phosphorus is sensitivity to land use in forests and bogs, though not for cottages.

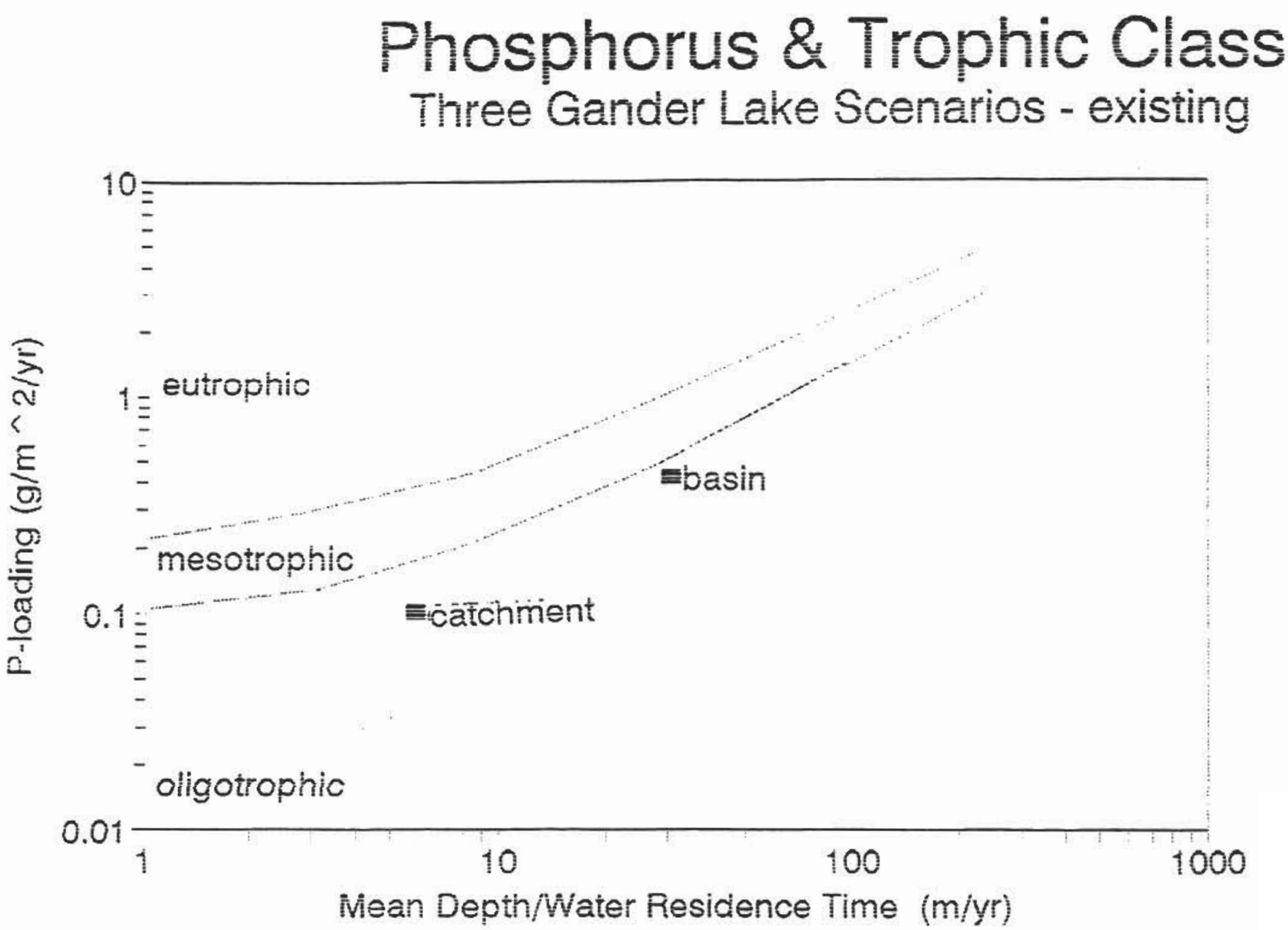


Figure 2.15 Vollenweider Diagram for Gander Lake, Present Condition

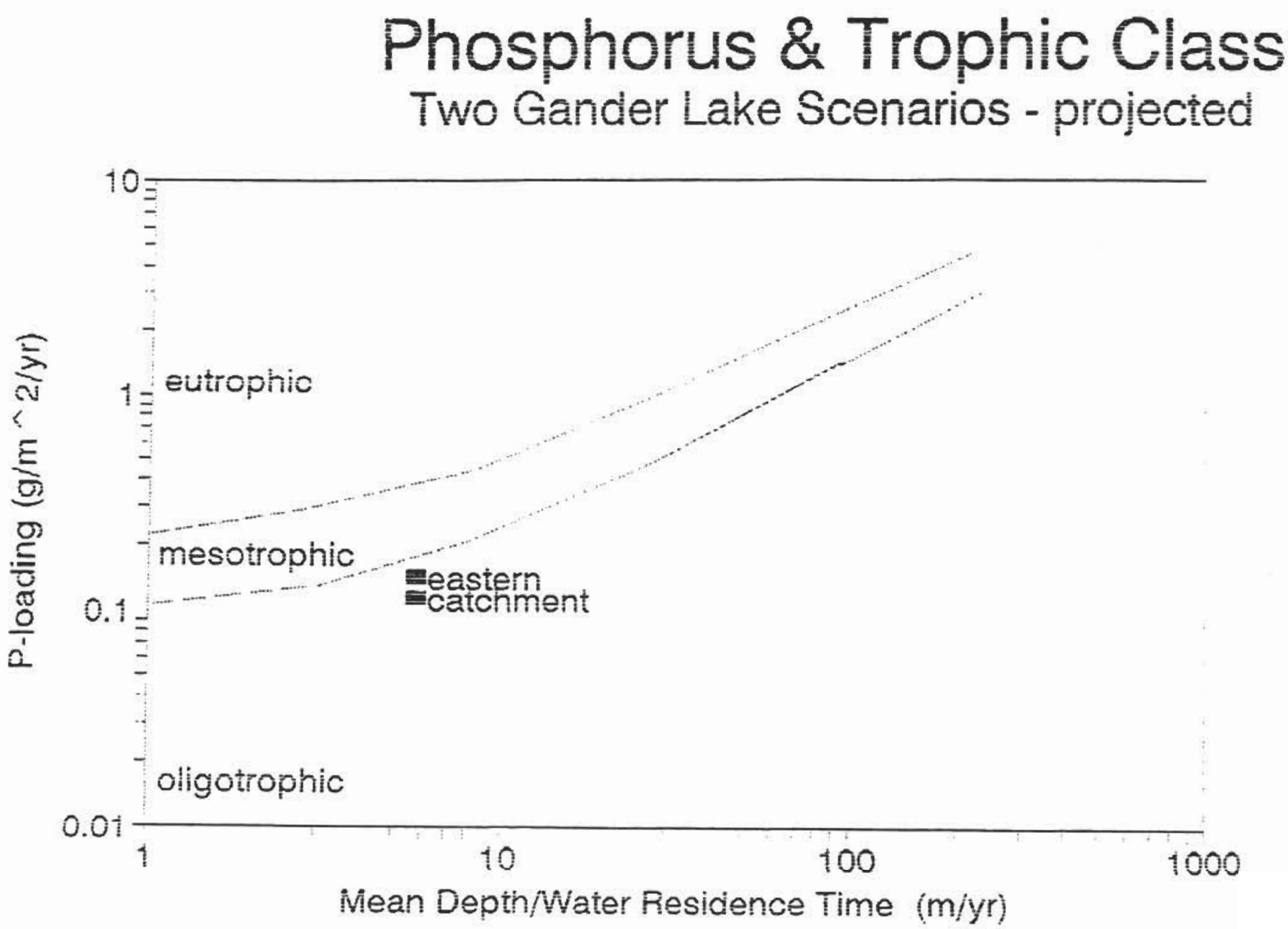


Figure 2.16 Vollenweider Diagram for Gander Lake, Projected Future Scenarios

Scenario	Sources (kg/y) watershed	precip	sewage	Concentrations (mg/m^3) streams	lake	Fraction of P settling
EXISTING						
entire basin	45000	2800	130	10.5	9.9	C.3
catchment	8600	2800	130	10.6	5.6	C.7
eastern end	3500	1100	130	10.3	5.7	C.7
FUTURE						
catchment	9900	2800	130	12.3	6.3	0.7
eastern end	5200	1100	130	16.1	7.9	0.7

Table 2.2: Simulated Phosphorous Balance for Various Scenarios (Dillon Model) - source strengths, resulting P concentrations and fraction retained in the Lake

2.5 REFERENCES

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PART 3: INTEGRATED WATERSHED MANAGEMENT PLAN

Part 3 includes two sections: 3A: Watershed Management Decision Model, and 3B: Planning Controls. Section 3A includes the development, calibration and application of a GIS based cartographic model of the catchment, in order to assess the sensitivity of the catchment to land use changes. This work utilizes data and conclusions drawn in the previous work sections, Part 1: Data Collection, and Part 2: Water Modelling. The final result of Part 3A is a physical plan of the catchment illustrating levels and locations for appropriate land uses. Part 3B is then a series of recommended planning actions derived from the physical plan and previous work.

3A: WATERSHED MANAGEMENT DECISION MODEL

3.1 INTRODUCTION

3.1.1 Cartographic Models

The Watershed Management Decision Model is a cartographic model that uses maps of environmental conditions in the catchment to predict the impact of land use change on Gander Lake. The model developed relies on the cartographic modelling techniques (map analysis method) developed by Tomlin (1990) and Steinitz (1989). The model developed uses, as precedent, models developed by others to: (1) predict the impact of forested ecosystems and development on lake water quality (Binford 1989), (2) determine the amount of soil loss at the watershed level (Mellerowicz et al. 1994, Coote et al. 1992), and (3) predict the potential of soil erosion and non-point source sediment to impact on water bodies (Snell 1985).

Cartographic modelling is a systematic means of scoring maps and then combining those maps in a logical manner. Maps scores may be either actual numbers (e.g., a soil map scored assigned the actual value for soil permeability to each soil type), or maps may be scored according to order (e.g., soils assigned a value representing whether the soil type had high (1), medium (2) or low (3) permeability). Once maps have been scored, they may be combined in a meaningful manner. If actual numbers are available, equations may be solved by combining (mathematically) maps of the different variables in the equation. If ordering is used to score, then the maps resulting from the combination indicate the final level of concern (e.g., high, medium and low).

Cartographic models using numbers are not necessarily more accurate for planning level decisions. The advantage of scoring according to order is that variables may be included for which there are no scientifically justifiable numbers, but which nevertheless are known to impact on the result. Once created, the model may be used to represent future scenarios, thus informing a final catchment management plan showing the types, levels and locations of permissible activities, and compatible land uses in various zones of the catchment.

3.1.2 Model Premise

The model created is premised on the assumption that disturbance of soil, its mobilization, and subsequent deposition in surface waters is the primary delivery mechanism of phosphorus and other non-point source pollutants into Gander Lake. This is a standard assumption for non-urbanized catchments. Soil is a primary source of phosphorus. In addition, phosphorus which is released from organic matter tends to attach itself to soil particles. Thus, eroding soil itself, as well as dirt washed from streets and other areas, tends to carry a significant phosphorus load. The model created is only useful for largely non-urbanized catchments where this assumption holds true.

Validation that the assumption holds true for Gander Lake is provided by (1) calculations of total annual phosphorus loading to Gander Lake, which were prepared for input in the Dillon model (Section 2.3.4), and (2) the percentage of the assumed amount of sediment delivered to the Lake which is phosphorus (Section 3.3.3.1).

These calculations suggest that approximately 35,000 kg/yr of phosphorus is exported from the catchment to the Lake, and of that, approximately 5,000 kg/yr remains in the water column. Point source contributions (largely from cottages and sewage treatment plants) are only able to account for approximately 200 kg/yr (Section 3.3), and are thus insignificant relative to the non-point source contributions. Note that, the second largest phosphorus contribution is from the atmosphere, calculated at 2,800 kg/year for the Dillon model (Section 2.3.4).

3.2 METHODOLOGY

The Watershed Management Decision Model is a straight forward, but powerful means of quantifying the impact of various land uses. The method implicitly considers the range of impacts resulting from different land uses, how the impacts change with respect to variations in landscape units, and how these factors combine to affect water quality in Gander Lake.

The method is based upon the Universal Soil Loss Equation (USLE). The USLE, by far the most widely used method for predicting soil loss, was developed by Wischmeier and Smith (1965). The USLE has been used primarily in agriculture to predict soil loss from fields. In recent years, it has been applied to other land uses, including forestry and urban and suburban development. To date, there has been only limited application of the USLE to regional scale planning, although the approach has significant merit (Binford 1989, Rees 1996).

The USLE is:

$$A = RKLSCP$$

where, A = soil loss (tons/ac/year);
R = the rainfall erosivity index;
K = the soil erodibility index;
L = the hillslope-length factor;
S = the hillslope-gradient factor;
C = the cropping-management factor; and
P = the erosion-control practice factor.

The model was executed in MapFactory, a grid cell geographic information system (GIS). The method is applicable to any grid cell GIS (e.g., SPANS, GRASS, OSUMap) or any vector GIS (e.g., ArcINFO, CARIS) capable of cartographic modelling.

The grid cell resolution for the Gander catchment was set at 1 hectare (each grid cell in the GIS is 100 x 100 meters).

3.2.1 Inherent Sensitivity

The first step was to classify the catchment according to the first four variables in the USLE. This required creating a map layer in the GIS for each variable. These map layers include: R, the rainfall erosivity (specific to the rainfall in the Gander area and constant over the entire catchment); K, the soil erodibility factor (defined according to soil type); and LS (the hillslope-gradient/length factor) which is a measure of the potential energy inherent in the hillslope steepness and length (location specific).

The first four factors, R,K,L and S, are constants in each grid cell across the catchment. They are all factors which do not vary with time. They are all based upon inherent features: the type of rainfall received in Gander, the slope of the landscape and the geological soil type. They are all factors for which there is relatively complete data.

The Inherent Sensitivity Map was created by solving the USLE in each grid cell (1 hectare area) across the entire catchment. For the purposes of the Inherent Sensitivity Map (Figure 3.2), the C (cover) and P (erosion control practice) factors are kept constant at 1.0. A C value of 1.0 occurs when there is no cover (bare soil) and a P value of 1.0 occurs when no erosion control practices are utilized. Thus, the Inherent Sensitivity Map is a map of erosion risk, where the values in each cell represent the amount of erosion which would occur in that 1 ha grid cell if there was bare soil (the value is therefore independent of land use type and erosion control practices).

The method is consistent with that used by Coote et al. (1992) in preparing the Water Erosion Risk Map of the Maritime Provinces. This map was prepared to provide information about the areas in the Provinces which are most susceptible to erosion, recognizing that erosion by rainfall is a serious issue in eastern Canada.

This method is an excellent measure of erosion risk, irrespective of land use type or level. As such, the first four factors in the USLE represent a sort of "thumb print" of the catchment, an essentially consistent risk pattern unique to the watershed.

3.2.2 Sediment Production

Actual sediment production in the catchment was estimated by assigning C values to the different land use types mapped in Figure 1.8, Land Use 1990. The C-value map was then multiplied in the GIS with the other factor maps (R, K, L, and S). Sediment production is thus the predicted annual erosion from each 1 ha cell in the catchment, given the present land uses.

C and P values are variables in the USLE that represent the effect of different agricultural crops (cover types) and erosion control practices. The USLE has been used to estimate sediment production for many land uses other than agriculture, although literature values are not as well developed for these other land uses. P factors were developed for agriculture where they are used to account for the application of specific erosion control practices (such as contour tilling, or terracing). For most other applications of the USLE, the C and P are considered together as a CP factor (Binford 1989, Mellerowicz 1994). This essentially implies a factor of 1 for the P value (no specific erosion control factor). The CP factor is sometimes shortened to just a C factor (the P is dropped from the equation).

3.2.3 Sediment Delivery

Erosion occurs equally across the catchment. However, it is not delivered equally to the Lake. Sediment closer to a water body or on steep slopes is delivered preferentially, while sediment uphill of a bog or depression or on flatter slopes is trapped within the catchment. This difference may be expressed as a delivery ratio.

The delivery ratio map is a map layer which assigns a value to each grid cell according to its ability to contribute sediment to a water body (the delivery ratio is the percentage of the sediment likely to be delivered to a water body). The delivery ratio map was then multiplied by the Sediment Production Map, in order to estimate the amount of sediment from each hectare in the catchment that might actually be expected to be delivered to the Lake.

The Sediment Delivery map was then summed across the entire catchment, to estimate the total amount of sediment likely to be delivered to the Lake from the catchment.

$$Sd = \sum_{1}^{n} ((RKLSC) \times D)$$

where,

n = number of grid cells
Sd = approximate sediment delivery to Gander Lake (kg/ha/yr).
RKLSC = Universal Soil Loss Equation (kg/ha/yr), defined above.
D = delivery ratio (percentage)

3.2.4 Model Calibration

The model was difficult to calibrate because there were two calibration variables; both the C and D variables have a great deal of uncertainty associated with them. In order to calibrate the model, the final result (the total amount of sediment expected to be delivered to Gander Lake from the catchment) was first determined. Then the C and D variables were adjusted to achieve that result. C values applied were very close to literature values, adjusted slightly to account for conditions viewed during the field visit. D values were primarily used to calibrate the model.

The final result (total kg/yr of sediment delivered to Gander Lake) was estimated in two ways.

3.2.4.1 Sediment Delivery Estimated from Suspended Solids

First, general values of expected suspended solids loadings from the various land uses were multiplied by the actual catchment area in each land use. These values were obtained from the literature and from data at the Gander airport ditch, which is the only data record available for runoff from the catchment. When summed across the catchment, this resulted in a total expected suspended solids loading. The suspended solids loading was added to the amount of soil assumed to be lost to sediment (estimated from particle size analysis information on the soils found in the catchment), to achieve a total expected sediment delivery from the catchment.

$$Sd = \left(\sum_{1}^{n} (\text{Land Use Export Value} \times \text{Area})\right) + \text{Sediment Loss}$$

where,

n = number of land uses
Sd = first approximation of total sediment delivery (kg/ha/yr)

The suspended solids loading assumed by this calculation was then translated into a concentration using the total annual catchment flow predicted by the water balance (developed in Part 2). This concentration was compared to the water quality data collected in Part 1 for reasonableness.

Sd was also compared to expected total sediment production values for a catchment of this size and level of urbanization in the North Atlantic Region.

3.2.4.2 Sediment Delivery Estimated from Nutrients

The total expected sediment delivery was also approximated using phosphorous loadings. Phosphorus loadings were considered in two ways.

First, general export values of phosphorus loadings from different land uses in Nova Scotia (and from data at the Gander airport ditch) were multiplied by the catchment area in each land use. When summed across the catchment, a second estimate of the total amount of phosphorus delivered was achieved. The total expected export value was then compared to that from samples in the Gander Airport Ditch for reasonableness.

$$Pt = \left(\sum_{1}^{n} (\text{Land Use Export Value} \times \text{Area}) \right)$$

where, n = number of land uses

Second, the percentage of phosphorus in the suspended solids was estimated based upon an analysis of catchment soils. This percentage was then multiplied by the total amount of sediment delivered (Sd, above) to determine a total amount of phosphorus delivered to the Lake from the catchment.

Estimates of anthropogenic phosphorus were made using point sources information, including cottage areas and the amount of sewage discharged from Benton (and potentially some small remainder from Gander) into Soulis Brook. Given the overall level of calibration, these discharges proved to be insignificant. Estimates of atmospheric source phosphorus were obtained from Part 2 (Dillon model).

The total amount of phosphorus delivered to Gander Lake was then calculated by summing that delivered from the catchment, the atmosphere, and from anthropogenic sources. This total was converted into an expected concentration in Gander Lake using, the total annual catchment flow, predicted by the water balance (Part 2), and the expected phosphorous loss to detritus (from the Dillon model, Part 2). This concentration was compared to water quality data collected in Part 1 for reasonableness.

$$Pc\ (kg) = Ps \times TSS$$
$$Pt\ (kg) = Pc + Pat + Pan$$
$$[P] = Pt \times \text{Catchment Flow} \times \%Pd$$

where,
- Pc = amount of phosphorus from the catchment
- Ps = % phosphorous in the suspended solids
- TSS = predicted suspended solids loadings (above)
- Pt = total phosphorus delivered to the Lake (kg)
- Pat = phosphorus from the atmosphere
- Pan = anthropogenic source phosphorus
- [P] = final phosphorus concentration expected in Gander Lake
- Pd = % phosphorus lost to detritus

3.2.5 Future Sediment Delivery

Following the calibration exercise, which utilized the present day land use coverage, the model was run using the future land use coverage. C values were applied to the future land use map and the model was run in order to anticipate the effect of proposed land use changes in the catchment.

3.2.6 Lake Sensitivity

A final task in this section was to delineate the catchment, the Lake and its shoreline in terms of their sensitivity, and from that, prepare a physical plan for watershed management. Lake sensitivity was considered in three different ways.

3.2.6.1 Lake Sensitivity to the Catchment

Gander Lake was considered in terms of its sensitivity to activities occurring within its catchment.

The expected future sediment delivery predicted by the Watershed Management Decision Model, was correlated to expected increases in phosphorus as a result of this increased sediment. The predicted increase in phosphorus was substituted in the Dillon model constructed in Part 2 to predict the overall effect of land use changes anticipated in the next five years on Lake water quality.

In addition, the Gander Lake catchment was modelled for its sensitivity to point source inputs. A map of the catchment illustrating those areas at furthest distance from the Lake and any catchment water course was created, where distance from a water body was used as the best measure for locating any potentially hazardous material or polluting land use type.

3.2.6.2 Lake Sensitivity to a Less Well Mixed East End

The circulation modelling performed in Part 2 predicted that at least some water from the NW and SW Gander Rivers circulates throughout the Lake. This work, however, was not conclusively validated by field work, and some question remains as to the amount and extent of river water circulation.

A conservative scenario would be that very little water from the rivers circulates to the east end of the Lake, making this area more sensitive to inputs (little mixing and dilution) and trophic state change.

To develop this scenario, the catchment was divided into two sections; one section draining towards the east end of the Lake, the other section draining towards the western part of the Lake. Using the Watershed Decision Model, together with the Future Land Use map, the future sediment delivery to this potentially sensitive eastern end of the Lake was calculated. This future sediment delivery was then substituted into the Dillon model, and the Dillon model was modified to assume no interaction between the eastern and western parts of the Lake. The Dillon model was used to estimate potential impacts on trophic state in the eastern end of the Lake.

3.2.6.3 Lake Sensitivity to the NW and SW Gander Rivers

Alternatively, the circulation model (Part 2) may be correct, and there is significant circulation of river water in the Lake. If this is the case, then Gander Lake is sensitive to any land use change in the entire watershed (both the Lake catchment and the catchments of the NW and SW Gander Rivers).

A worst case scenario is that land use changes within the River's catchments, together with that anticipated in the Lake's catchment, is sufficient to affect the water quality in the Lake. To develop this scenario, the Dillon model was configured to assume complete circulation of river water. The model was then used to predict the amount of phosphorus necessary to change the Lake's trophic state. This amount was correlated back to the Lake catchment, in order to determine approximately how much change within the River's catchments might trigger a noticeable change in Lake water quality.

3.2.7 Physical Plan for Watershed Management

The physical plan prepared for the Gander catchment considered the Inherent Sensitivity of the catchment and the potential sensitivity of the Lake.

The first factor, potential to contribute sediment, utilized the Inherent Sensitivity of the Catchment (as described above in Section 3.2.1, using the first four factors in the USLE: R, K, L, S). (Note that, the potential to contribute is irrespective of land use in this map, and values represent a worst case scenario). The inherent sensitivity map was then multiplied by the Delivery Ratio Map, also described above (Section 3.2.3.). This resulted in a map illustrating the maximum potential of any 1 ha catchment area to contribute sediment to the Lake.

The second factor, Lake sensitivity, considered where each subcatchment was discharging into the Lake, and the various Lake sensitivities, as described above (Section 3.2.6.) Taken together, these two sensitivities (catchment and Lake) were used to delineate a final physical plan for the catchment where areas were zoned according to the type and level of appropriate activities.

3.3 EXPECTED EXPORT VALUES FROM THE CATCHMENT

The Watershed Management Decision Model was calibrated using expected export values of sediment and phosphorous. These export values were derived from the literature, and from work conducted in Part 1 and Part 2.

This section describes the expected export of sediment, phosphorous and other pollutants from the Gander Lake catchment. These materials are described as non-point source (derived from the various land uses in the catchment) and point source (derived from specific discharges into water).

3.3.1 Expected Non-Point Source Loadings from the Catchment

Land use type is the most sensitive variable in determining how much pollutant a given land area will contribute. Many studies have attributed different pollutant loadings solely on cover type alone (this was the assumption used in the water quality modelling in Part 2). Together with the area measurements of the different land uses in the catchment (Table 3.1: Land Use Areas), general literature export values may be used to determine the overall catchment loading of various parameters.

Watershed Management Plan for Gander Lake and its Catchment

TABLE 3.1: LAND USE AREAS

Land Uses	Past Land Use (1966) (ha)	Present Land Use (1990) (ha)	Future Land Use (2000) (ha)
Land Cleared for Development	485	534	534
Development	320	438	438
Gravel Pits	90	154	154
Recent Clear Cut	3963	5424	3,944
Brush/Regenerating	9293	4521	9,945
Burn	12029	1510	1,510
Blowdown	0	3693	3,693
Forest	42654	49838	45,785
Unvegetated/Exposed Bedrock	462	3193	3,193
Clearing for Recreation	0	0	109
Bog	7945	7945	7,945
Ponds	3157	3157	3,157
Total Area	80407	80407	80407

Different land uses contribute different amounts of sediment and nutrients. Measurements have been made of average concentrations of various pollutants in water in other areas. These general export values are summarized in Table 3.2: Land Use and Expected Export Values. The literature review and interviews with people involved with the Western Newfoundland Model Forest revealed that no research of this sort has been conducted in Newfoundland. The values in Table 3.2 compare pollutant export values from the various land uses found in the catchment of Gander Lake. The key land uses and their expected pollutant export values, are described below.

3.3.1.1 Forestry

Forestry is the most extensive landuse in the Gander Lake catchment. Water quality indications of forest cutting include, but are not limited to, increases in: aluminum, nitrates, phosphorus, potassium, and suspended solids.

New England deforestation experiments have yielded useful figures. Borman and Likens (1979) suggest that forestry activity may result in a loss of aluminum at a rate of up to 21.1 kg/ha/yr during the first three years following deforestation. The same experiments indicate nitrate loss at 114.1 kg/ha/yr; and potassium loss at 30.3 kg/ha/yr. Pre-deforestation, in the same experimental forest, sediment yield was measured at an average of 33 kg/ha/yr (over 8 years). The maximum annual loading, following clear cutting, was measured at 380 kg/ha/yr. Note also, that erosion from the disturbed watershed was minimized, since there was no road building or damage to stream corridors by log skidding. Throughout the study period, nutrient measurements were highest during the second year following completion of the clearcut. This study did not address phosphorus loading.

Higher erosion values have been found when roads and stream disruption are taken into account. Megahan and Kidd (1972), studying a harvested pines ponderosa watershed in Idaho, with an average slope of 70%, found a six year average erosion loss of 4000 kg/ha/yr, compared with 90 kg/ha/yr from an uncut reference watershed. Haupt and Kidd (1965) reported a much smaller loss when good logging practices are followed on a similar forest type in Ohio, having a 35-55% slope. The five year post harvest sediment loss was 120 kg/ha/yr, compared with essentially zero on an uncut reference site. These two studies clearly illustrate the effect of slope and forestry practice on soil erosion.

Model forests in Nova Scotia have not yet calculated as conclusive results as New England, but preliminary results have yielded qualitative if not quantitative results. Research results suggest that total phosphorus lost through forestry activity is 0.054 kg/ha/yr, and suspended solids loss ranges from 10-100 kg/ha/yr. Western Newfoundland Model Forest researchers are presently studying the impacts of clearcutting on sediment loading.

3.3.1.2 Urban Development

Relatively good pollutant export values for urban development are available. Two aspects of development must be considered: the actual dwelling on the landscape and the discharge of sewage. Sewage discharges are considered a point source, and discussed in Section 3.3.2, below.

Even without considering sewage contributions, developed areas contribute phosphorus, suspended solids, and bacteria (mainly from pet excrement) in storm water runoff. Concentrations increase with increased amounts of impervious surfaces and construction activity.

Watershed Management Plan for Gander Lake and its Catchment

TABLE 3.2: LAND USE AND EXPECT EXPORT VALUES

Land Use	Suspended Solids - kg/ha/yr		Total Phosphorus - kg/ha/yr	
	New England	Nova Scotia	New England	Nova Scotia
Forested	33	10-100 (low)		0.054
15 % cleared		low-medium		0.078
Agriculture/Golf		medium-high		0.108
Residential Unserviced		500		0.7
Development		500-1000		1.1
Land Cleared for Development		low-high		low-high
Gravel Pits		low-high		low-high
Recent Clearcut	380			
Brush/Regenerating	190			

Sources:
New England: Borman and Likens (1979).
Nova Scotia: Centre for Water Resources (CWRS), as cited by Vaughan Engineering (1993).

Phosphorus content in urban runoff has little relevance to the phosphorus content of local soil. Urban dwellers import topsoil and fertilize their gardens. These activities contribute organic material and sediment to overland flow. All earth moving associated with construction will increase sediment loss by approximately 50 times for the first year after construction. Phosphorus, which clings to soil particles, ends up in water bodies along with the soil sediment. Garbage is another contributor from the urban environment. Average literature values are shown in Table 3.2.

3.3.1.3 Airport Ditch

Engineering staff at the Gander International Airport monitored water quality in the ditch from April 1994 to March 1995 (see Table 3.3: Pollutant Loadings, Gander Airport Ditch; Appendix C contains data from the ditch).

These samples allow for some calibration of the general literature values. In Table 3.5, the area assumed to be drained by the ditch includes approximately 4.5 km^2 (runways, buildings, grassy medians, and CFB Gander). Monthly runoff coefficients developed in Part 2, were assumed to be representative of the Airport drainage area. Because no other data are available, the 1994-1995 data were assumed to be typical for the Gander Airport discharge ditch. The drainage area includes about 40% "developed" and "cleared" areas and about 60% forest.

The resulting numbers in Table 3.3 indicate that runoff at Gander Airport is similar to urban runoff in Nova Scotia. For example, the Vaughan Engineering study found that an urban catchment the size of Gander Airport would produce between 225,000 and 450,000 kg/yr of suspended solids. The estimate for the Airport runoff area is approximately 146,860 kg/yr of suspended solids. Given that the airport catchment is only 40% "developed", this value may be increased to correspond with a 100% urbanized catchment, to approximately 380,000 kg/yr. This value is consistent with the Nova Scotia data, and suggests that the Nova Scotia values may be applied to the Gander catchment.

Total phosphorous from an urbanized area of this size in Nova Scotia would be about 495 kg/yr. From the Gander Airport ditch data, we estimated about 123 kg/yr. Again, this value may be increased to account for the forested component of the area, resulting in approximately 320 kg/yr. This number is less than the Nova Scotia value (about 3/5). This lower export may be explained by the lower soil fertility in Newfoundland (see Table 3.4).

3.3.2 Expected Point Source Loadings from the Catchment

Point source contributions are those that can be attributed to a specific water discharge, such as an effluent outfall from a factory or sewage treatment plant. Point source loadings, considered in this project, include: sewage treatment discharges; a marina; cottages and camps; and a swimming area.

TABLE 3.3: POLLUTANT LOADINGS, GANDER AIRPORT DITCH, APRIL 1994 - MARCH 1995

Month	Mean Precipitation* (mm)	Runoff Coefficient*	Area (km2)	Calculated Flow (litres)	Measured Concentration (mg/l)				Estimated Loading (kg/month)			
					TSS	Total Phosphorus	Ammonia	Nitrates	TSS	Total Phosphorus	Ammonia	Nitrates
April	97.00	1.97	4.50	859905000	6.00	0.03	0.90	2.45	5159.43	25.80	773.91	2106.77
May	79.90	2.86	4.50	1028313000	17.50	0.01	1.39	2.48	17995.48	10.28	1429.36	2550.22
June	81.80	0.91	4.50	334971000	8.25	0.01	0.69	3.30	2763.51	3.35	231.13	1105.40
July	73.20	0.69	4.50	227286000	7.50	0.06	0.40	3.75	1704.65	13.64	90.91	852.32
August	95.60	0.17	4.50	73134000	60.75	0.01	0.33	1.55	4442.89	0.73	24.13	113.36
September	89.70	0.08	4.50	32292000	191.75	0.13	0.22	2.48	6191.99	4.20	7.10	80.08
October	105.00	0.18	4.50	85050000	47.00	0.05	0.15	2.48	3997.35	4.25	12.76	210.92
November	108.60	0.40	4.50	195480000	13.20	0.01	0.29	1.85	2580.34	1.95	56.69	361.64
December	113.40	0.80	4.50	408240000	18.67	0.01	0.21	1.13	7621.84	4.08	85.73	461.31
January	112.90	0.24	4.50	121932000	3.75	0.02	6.53	1.45	457.25	2.44	796.22	176.80
February	108.10	0.19	4.50	92425500	1.50	0.05	5.71	1.50	138.64	4.62	527.75	138.64
March	116.40	0.82	4.50	429516000	4.00	0.05	22.59	3.10	1718.06	21.48	9702.77	1331.50
Annual	1181.60	0.78	4.50	4125261000	35.60	0.03	2.90	2.37	146859.29	123.76	11963.26	9776.87
kg/ha/yr									**326.35**	**0.28**	**26.59**	**21.73**

* From water balance calculation; average monthly runoff coefficient for the overall catchment (Section 2.3).

Source: Gander International Airport, Safety and Technical Services, 1995

TABLE 3.4: CHARACTERISTICS OF GANDER AREA SOILS

Soil Series	Soil Type	% of Catchment in Soil Type	Average Percentages Per Soil Type (top 25 cm)							
			N	P	P*	K	Ca	Mg	Na	Mn
Py, Tn	Orthic-Ferro Humic Podzol (low fertility)	25	0.57	0.05	0.07	0.18	0.50	0.27	0.03	0.07
Bn, Bu, Ep, Fb, Ga, Gb, Gw, Sp, Sw, Wg	Orthic Humo-Ferric Podzol (high fertility)	67	1.01	0.08	0.12	0.34	0.83	0.19	0.07	0.10
Bo, Ho, Su	Orthic Gleysol, (high fertility)	8	1.23	0.09	0.16	0.23	0.78	0.31	0.08	0.07
Average Catchment Values			0.92	0.07	0.11	0.29	0.74	0.22	0.06	0.09

*Phosphorous percentage of the smallest particle sizes within the soil type (assumed to comprise the majority of SS)

Source: B. A. Roberts, 1983

3.3.2.1 Town of Gander Sewage

Serviced areas are those which are on central water and sewer services. In the Towns of Glenwood, Appleton, and most of Gander, sewage is collected by pipe and treated prior to discharge. The part of Gander (Gander Bay Road) that is unserviced is outside the catchment area. Appleton and Glenwood discharge into Gander River at the Trans Canada crossing, and do not affect the catchment area. Thus, the only sewage treatment systems discharging into the catchment are those of the Town of Gander and Benton's treatment system).

The primary water quality concerns associated with sewage treatment plant effluents include increased levels of phosphorus, suspended solids, and bacteria. Effluent water quality data (inconsistent) are available for the Gander sewage treatment plant for the period between December 1989 and April 1992 (Newfoundland and Labrador, Department of Environment, 1995). The data indicate that the discharges have increased levels of phosphorous, suspended solids bacteria, and other parameters.

After discharge, the treatment plant effluent flows through a long series of wetlands that form the head waters of Soulis Pond, which flows via Soulis Brook into Gander Lake. This long distance should degrade the remaining pollutants prior to entry into Gander Lake. The sewage treatment plant effluent water quality data (Newfoundland and Labrador, Department of Environment, 1995) also included samples taken at Soulis Brook near where it enters Gander Lake. This data showed only slightly elevated levels of these parameters (see Appendix C: Point Source Discharge Data). Considering that at the time of that study Benton was without sewage treatment, it is a fair assumption that the Beaverwood plant has little quantifiable impact on the water quality of Gander Lake.

Note also, that during the 1995 sampling programs for this study, no evidence of elevated levels of any of the parameters tested, was found in the area of the Lake near Soulis Brook.

3.3.2.2 Benton Sewage Treatment System

In the past, the community of Benton, located on Soulis Brook near the outlet of Soulis Pond in the north eastern end of the catchment area, was largely on individual sewage disposal systems. This posed problems as the area has a high water table and sewage resurfaced in road side ditches. Presumably sewage was also entering Soulis Brook and eventually Gander Lake (Benton Local Area Plan Review 1989).

By 1986, the community had sewer mains connected to two 13,600 gallon septic tanks. Since that time, another septic tank has been added and the effluent is sent to a new artificial wetland and then into natural wetlands which drain into Gander Lake. Samples taken at the Benton disposal area and at points where the stream enters Gander Lake, in 1994, show that fecal coliforms are not significantly reduced between the time they leave the disposal site to when they enter Gander Lake (Newfoundland and Labrador, Department of Environment 1994).

No measurements of other pollutants were available for the Benton system. However, if the fecal coliforms did not change from the time the effluent left the treatment system, it may be assumed that other pollutants were also present at the outfall. The following estimate is the maximum phosphorous that could enter Gander Lake from Benton's sewage treatment system.

The normal loading for phosphorous in sewage in the literature prior to 1975 was 1.59 kg/person/year. We have assumed that the number should be modified to 0.79 kg/person/year (50%). Clark, Viessman and Hammer (1977) indicates that since phosphate detergents have been eliminated, phosphorous in sewage is likely to be reduced by half. The population of Benton, at the latest census in 1991, was 188. By multiplying this number by 0.79 kg/person/year, we have estimated that the phosphorous content of Benton's sewage is approximately 150 kg/yr.

3.3.2.3 Cottages

Cottages are responsible for suspended solids, bacteria, and phosphorous contributions to the Lake.

The Land Management Branch (1994) conducted a survey of cottage development in the Northwest and Southwest Gander River because this is the main area of demand and, therefore, concern. In the NW/SW Gander River area, there are 112 structures or shelters. Assumptions about occupancy were made as follows. In Newfoundland, recreational cottages are usually inhabited on weekends from May 24 weekend to Labour Day: approximately 15 weekends (30 days) or 0.08 year. We have assumed that approximately four people stay at a time. We assumed the same number of people (four) for the hunting/fishing camps. Hunters usually spend about one week at a time about four times a year (28 days) or 0.08 year. So, we have four people for .08 year.

The previously described phosphorous number, 0.79 kg/person/yr, was multiplied by four people and then by the year, .08. The resulting loading per cottage is 0.25 kg/yr. This number was then multiplied by the total number of cottages, 112 (Land Management Branch, DNR, 1994), giving a total contribution of 28 kg/yr.

One area of concern that requires further study, related to cottage use, is the issue of All Terrain Vehicles (ATV's) that people use for recreation. During field work, ATV's were seen fording rivers and cutting up steep slopes leaving the soil exposed. This damage has not been measured. The potential contribution of TSS and nutrients caused by this damage is probably much higher than the contributions from untreated sewage.

3.3.2.4 Marina

No data are available for the marina at Little Harbour on the north side of Gander Lake. The Town of Gander Parks and Recreation Department operates the marina which harbours about 10 power boats. Recreational boaters questioned by staff, during a field visit, indicated that not many people boat on Gander Lake because it is too windy.

The sampling program indicated that water quality parameters were not elevated at Little Harbour. Indeed, parameters appear to be similar to many other parts of Gander Lake including the pumphouse (see Table 1.3, Part 1).

3.3.2.5 Swimming

Fecal coliforms become elevated in areas where humans swim. Swimming in Gander Lake is limited; a few people swim at the eastern end. The climate of Newfoundland presents a short swimming season (July-August) and local residents consider Gander Lake particularly cold. These factors indicate that swimming will not likely be a high contributor of fecal coliforms to the Lake.

Watershed Management Plan for Gander Lake and its Catchment

TABLE 3.6: EXPECTED SEDIMENT YIELD BY CATCHMENT SIZE

Catchment Area (excluding ponds)	77,250	ha
	298	sq.mi.

U.S. Water Resources Council,
Estimated Sediment Yield from Drainage Areas in the North Atlantic Region

	Sediment Production (non-urbanized catchments) tons/sq.mi./yr	Predicted for Gander	
High value	1210	327,321,253	kg/yr
Average value	250	67,628,358	kg/yr
Low	30	8,115,403	kg/yr

Brune, 1951
Estimated Sediment Yield from Glacial Till Lithologic Type

	Sediment Production (non-urbanized catchments) tons/sq.mi./yr	Predicted for Gander	
high	300	81,154,030	kg/yr
medium	200	54,102,686	kg/yr
low	180	48,692,418	kg/yr

Source: as cited in Dunne and Leopold (1978) and Leopold (1994)

The Gander Lake sampling program, conducted for this study, indicated that, in the eastern part of the Lake, fecal coliforms were not detectable in the Spring and >10/100ml in the late Summer. In many areas of the Lake, where people are not known to swim, readings of this level and higher were found.

3.3.3 Expected Delivery of Sediment and Phosphorous from the Gander Catchment

The total expected export of sediment and phosphorous from the Gander Lake catchment was estimated for use in calibrating the Watershed Decision Model.

3.3.3.1 Total Sediment Delivery

Expected export values for suspended solids from various land uses were derived from Table 3.2 (literature values) and Table 3.3 (as measured in the Gander Airport ditch). These export values were applied to the various land uses. When multiplied by the land use areas, a total amount of suspended solids was obtained. As illustrated in Table 3.5, approximately 7,000,000 kg/yr of suspended solids may be expected to be discharged into the Lake.

From particle size analysis of soil type data (Roberts 1983, Bhure 1971), the approximate percentage of settable solids (sand and most of the silt, given the residence time in the Lake) is about 87%. This means that the suspended solids fraction of the total sediment delivered to the Lake is only about 13%; only about 13% of the total should be suspended or dissolved in the water column. Total sediment loss from the catchment may be calculated by adding the 87% which is assumed to have settled rapidly to the suspended solids. This calculation (equation provided in Section 3.2.4.1) predicts that a total of approximately 54,500,000 kg/yr of sediment is exported from the catchment. See Table 3.5.

As a check for reasonableness, the 7,000,000 kg/yr of suspended solids reaching the Lake, can be translated into a concentration using the total annual catchment flow. To express this loading as a concentration in the water column, the total annual average flows generated from the water balance were used.

The total annual flow contributing to the outlet attributable to the catchment, as calculated in the water balance, is 121,247 ha-m, or 1.212 E^{12} L/yr. Assuming that the concentration measured or expected in the Gander River would be the same for this contribution from the catchment allows the calculation of a simple mass balance relationship.

$$7.07\ E6\ \text{kg/yr} \div 1.212\ E^{12}\ \text{L/yr} = 5.8\ \text{mg/L}$$

As expressed above, this method predicts a concentration of 5.8 mg/L in Gander Lake resulting from this sediment load. This is a reasonable number, considering how clear the Lake water is. (Unfortunately, suspended solids was not a water quality parameter measured in the Rivers).

TABLE 3.5: EXPECTED EXPORT VALUES FROM CATCHMENT LAND USES

Suspended Solid and Sediment Loadings*

Area (ha)	Land Use	Suspended Solids Export in Runoff (kg/ha/yr)	Total for Land Use (kg)
154	Gravel Pits	1200	184,800
49838	Forest	35	1,744,330
3693	Blowdown	200	738,600
7945	Bogs	0	0
1510	Burn	200	302,000
3193	Unvegetated/Bedrock	100	319,300
534	Land Cleared for Development	600	320,400
5424	Recent Clear Cut	400	2,169,600
438	Development	900	394,200
4521	Brush/Regenerating	200	904,200
	In the Water (approx. 13% of total)**		7,077,430
	Remaining 87% assumed lost to sediment		47,364,339
	Total Sediment from the Land (kg/yr)		**54,441,769**

Phosphorous Loadings (literature values)*

Area (ha)	Land Use	Phosphorous Export in Runoff (kg/ha)	Total for Land Use (kg)
154	Gravel Pits	1.500	231
49838	Forest	0.054	2,691
3693	Blowdown	0.300	1,108
7945	Bogs	0.000	0
1510	Burn	0.250	378
3193	Unvegetated/Bedrock	0.100	319
534	Land Cleared for Development	0.900	481
5424	Recent Clearcut	0.550	2,983
438	Development	1.250	548
4521	Brush/Regenerating	0.300	1,356
	Total Phosphorous from the Catchment (kg/yr)		**10,095**

Phosphorous Loadings (Sediment Loadings and %P in Soil)***

Area (ha)	Land Use	Phosphorous Export in Runoff (kg/ha)	Total for Land Use (kg)
154	Gravel Pits	1.32	203
49838	Forest	0.04	1,919
3693	Blowdown	0.22	812
7945	Bogs	0.00	0
1510	Burn	0.20	299
3193	Unvegetated/Bedrock	0.11	351
534	Cleared for Development	0.72	382
5424	Recent Clearcut	0.44	2,387
438	Development	1.00	438
4521	Brush/Regenerating	0.22	995
	Total Phosphorous from the Catchment (kg/yr)		**7,786**

* Loadings from Tables 3.2, 3.3; Areas from Table 3.1.

** 87% of the soil particles (averaged over top soil three horizons) are either sand or silt, and assumed to settle.

***Loadings from assumed sediment export (above) and soil chemistry (Table 3.4).

As a final check for reasonableness the predicted export of sediment was compared to average sediment delivery curves correlated to drainage area, geographic area, land use and lithologic type (Table 3.6, Expected Sediment Yield by Catchment Size). These general values suggest that a yield of between 54 and 67 million kg per year would be considered "average" for the Gander catchment. Again, this number aligns well with the 54,500,000 kg/yr predicted in Table 3.5.

Figure 3.1, Expected Export of Suspended Solids by Land Use, illustrates the application of the export values in Table 3.5 to the land uses catchment.

3.3.3.1 Total Phosphorous Export

As with suspended solids, general phosphorous export values from the literature (Table 3.2) were applied to the catchment land uses, which when multiplied by area, yield the total expected delivery from the catchment. As shown in Table 3.5, this method suggests that approximately 10,000 kg/yr of phosphorous enters the Lake from the catchment. The export values used in the Table were derived by assuming a correlation between the export of suspended solids and phosphorus, and using the relationship between suspended solids and phosphorous for development and forest land uses (those uses for which values are most certain).

Airport ditch data indicated that phosphorous loadings may in fact be lower than literature values for the Gander catchment. Table 3.4: Characteristics of Gander Area Soils, provides average chemical percentages in the top 25 cm of soil. Soil data suggests that, on average, the soils in the Gander Lake catchment are approximately 0.07% phosphorous, and that the phosphorous percentage of the smaller sized particles (e.g., clays) is approximately 0.11%. Using the expected suspended solids export values for different land uses (Table 3.5) number, together with the percentage of phosphorous associated with the smaller particle sizes (those most likely to float) (0.11%), a modified export value of phosphorous for each land use was derived (Table 3.5). Calculated in this manner, approximately 7,800 kg/yr of phosphorous is expected to enter the Lake.

This loading may be expressed as a concentration in Lake water quality, following the equation provided in 3.2.4.2.

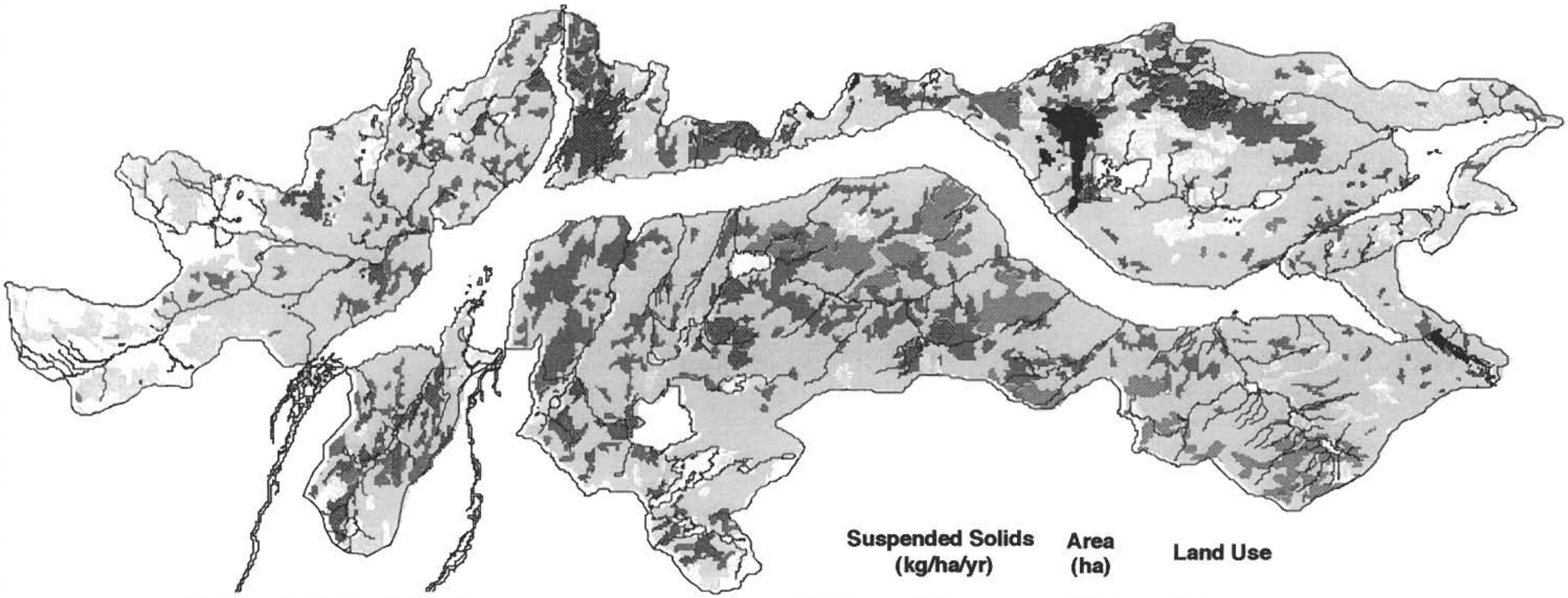
$$Pc = .0011 \text{ kg/kg} \times 7{,}080{,}000 \text{ kg/yr} \approx 7{,}800 \text{ kg/yr}$$

$$Pt \approx 7{,}800 \text{ kg/yr} + 2800 \text{ kg/yr}^{*} + 180 \text{ kg/yr} \approx 10{,}780 \text{ kg/yr}$$

$$[P] \approx (10{,}780 \text{ kg/yr} \times 1{,}000{,}000 \text{ mg/kg} \div 1.212\text{ E12 L/yr}^{**})\,(.65)^{*} \approx 0.006 \text{ mg/L}$$

* values for Pat and %Pd are from the Dillon model, Part 2
** value for catchment flow from the Water Balance, Part 2

This value is very close to actual measured phosphorus concentration in the Lake, conducted in Part 1 (on average Lake concentration was found to be .007 mg/L).



EXPECTED EXPORT OF SUSPENDED SOLIDS BY LAND USE

0 5,000 10,000 Metres

WATERSHED MANAGEMENT STRATEGY FOR GANDER LAKE AND ITS CATCHMENT

Prepared for: Department of Environment, Water Resources Division
Government of Newfoundland and Labrador

Prepared by: EDM Environmental Design and Management Limited, 1996.

Suspended Solids (kg/ha/yr)	Area (ha)	Land Use
0.00	7,945	Bogs
35.00	49,838	Forest
100.00	3,193	Unvegetated
200.00	9,724	Blowdown, Burn and Brush/Regenerating
400.00	5,424	Recent Clear Cut
600.00	534	Land Cleared for Development
900.00	438	Developed
1,200.00	154	Gravel Pits

Figure 3.1

This suggests that a total annual sediment export value of 54,500,000 kg/yr is reasonable to assume for the Gander catchment, and thus the value to be used for calibrating the Watershed Management Decision Model.

3.4 INHERENT SENSITIVITY

The inherent catchment sensitivity is a measure of sensitivity irrespective of land use. It asks - which areas are more sensitive to any land use change, by virtue of their physical attributes? The definition adopted focuses on sediment loss. All land use changes by humans require changes to landscape form and configuration, that can result in sediment loss, be they agriculture, forestry, road construction, cabin development, or urban development. In the Gander catchment, changes in land use that result in changes in soil loss from the land are the primary mechanism for pollutant delivery to the water (refer to 3.3.3.1).

Water quality is also affected by background levels of pollutants (sources from rain, air deposition, etc.), as well as some pollutants that are applied to the land or discharged to the water in conjunction with human activities (e.g., industrial discharges, fertilizer application, etc.). The first set, background levels, are present irrespective of land use, and thus cannot be managed (except at a national or global level). The second set are essentially non-existent in the Gander catchment, and where present are at levels that are generally insignificant when compared to the amount delivered via the soil.

The Universal Soil Loss Equation (USLE) is one of the most widely adopted methods of estimating soil loss or erosion (see Methodology). The first four factors in the USLE were applied to the Gander catchment in order to classify the catchment according to its inherent sensitivity, that is, its inherent sensitivity to soil erosion if the soil is left exposed.

3.4.1 Inherent Sensitivity Model

The first factor in the USLE, the R factor, is a measure of the erosivity of rainfall. R factors vary widely from place to place. An R-factor for Gander has been published by Wall, Dickinson, and Greuel (1983). Rainfall erosivity for Gander is lower than average (for areas of Canada east of the Rocky Mountains) at 870, while at St. John's the R value, higher than average, has been measured at 1700. The highest of the selected locations in Canada is 1960 at Saint John, New Brunswick and the lowest is 495 at Calgary, Alberta. The average for areas of Canada east of the Rocky Mountains is 1200.

The second factor K, soil erodibility, is determined by soil type (percent sand, silt, clay and organic matter), soil structure, and soil permeability. Soil descriptions for most soils in the Gander area were available in the extensive 1972 Soil Survey published by Agriculture Canada. For the western part of the catchment, descriptions from the more general 1992 Soil Survey were used. Descriptions for peat and muck soil types were unavailable and thus estimates for these two types were made. Using these descriptions, K values were determined from tables published in Dunne and Leopold (1978). The K values used are illustrated in Table 3.7: K-Value Approximation.

The third and fourth factors, L and S, are usually defined together. S is the slope and L is the hillslope length. A slope map for the catchment was generated from the DTM provided by the Department of Environment, Water Resources Division. L was defined as the width of the grid cell in the GIS, in this case 100 metres. Again, using tables in Dunne and Leopold (1978), the LS (Length-Slope index) was derived.

Watershed Management Plan for Gander Lake and its Catchment

TABLE 3.7: K-VALUE APPROXIMATION

Soil Types (Newfoundland Soil Survey)	K-Value Approximation*	K-Value Assumed**
Bn, Bu, Wg	0.34	
Ga, Gw	0.37	
Ep	0.065	
Fb, Gb, Sp, Sw	0.27	
Py, Tn	0.12	
Su, Bo, Ho	0.44	
Peat, Muck		0.35

* Soil descriptions and cabability classes described in the 1972 Soil Survey were applied to tables for estimating K values in Dunne and Leopold (for areas on map sheets 2D15 and 2D16). For the 2D14 map sheet (not covered in the 1972 Soil Survey), more general descriptions and values in the 1993 Soil Survey were used. Two methods were applied and averaged.

** Descriptions and values for peat and muck are not available; value was assumed from extrapolation of tables. Confidence in this number is lower.

Sources: Dunne and Leopold 1987; Newfoundland Soil Survey,1978 and 1992

Within the GIS, these four factors (R, K, L, and S) were solved in each 1 ha grid cell in the catchment (C was assumed to be 1, representing no cover or exposed soil conditions). The results are shown in Figure 3.2, Inherent Sensitivity. This map illustrates the erosion potential of the catchment irrespective of land use. Note that in Figure 3.2, the scale is a log scale; this means that the second category is an order of magnitude greater than the first, etc. The Inherent Sensitivity map illustrates the importance of location for any land use change proposed in the catchment.

3.4.2 Model Sensitivity to Slope

The model (A=RKLS) is most sensitive to the slope factor. R and L are constant throughout. Variation in soil type (K), while important, only can explain a change in sediment production of 6 times, given the soil types in the catchment. Thus, it is slope that explains most of the difference between various locations in the catchment.

Slope sensitivity was investigated by dividing the total number of slope values (N) into five equal categories according to area (n1, n2...n5, where each represents approx. 200 km^2 area). Slope values in the catchment range from 0 to 60%; n1 = 0 - 2%; n2 = 3 - 5%; n3 = 6 - 8%; n4 = 9 - 14%; and, n5 = 15 - 60%. Using these slope values, together with the K value for Gander Series soil, and the actual range of C-values (cover) generated in this study (see Section 3.5, below), Table 3.8: Catchment Sensitivity to Slope, was generated. In the Table, the USLE for each slope category is solved. Table 3.8 and accompanying Chart illustrate how sensitive sediment production is to the slope factor. In fact, slope is a good proxy for inherent sensitivity.

3.4.3 Inherent Sensitivity of the Catchment

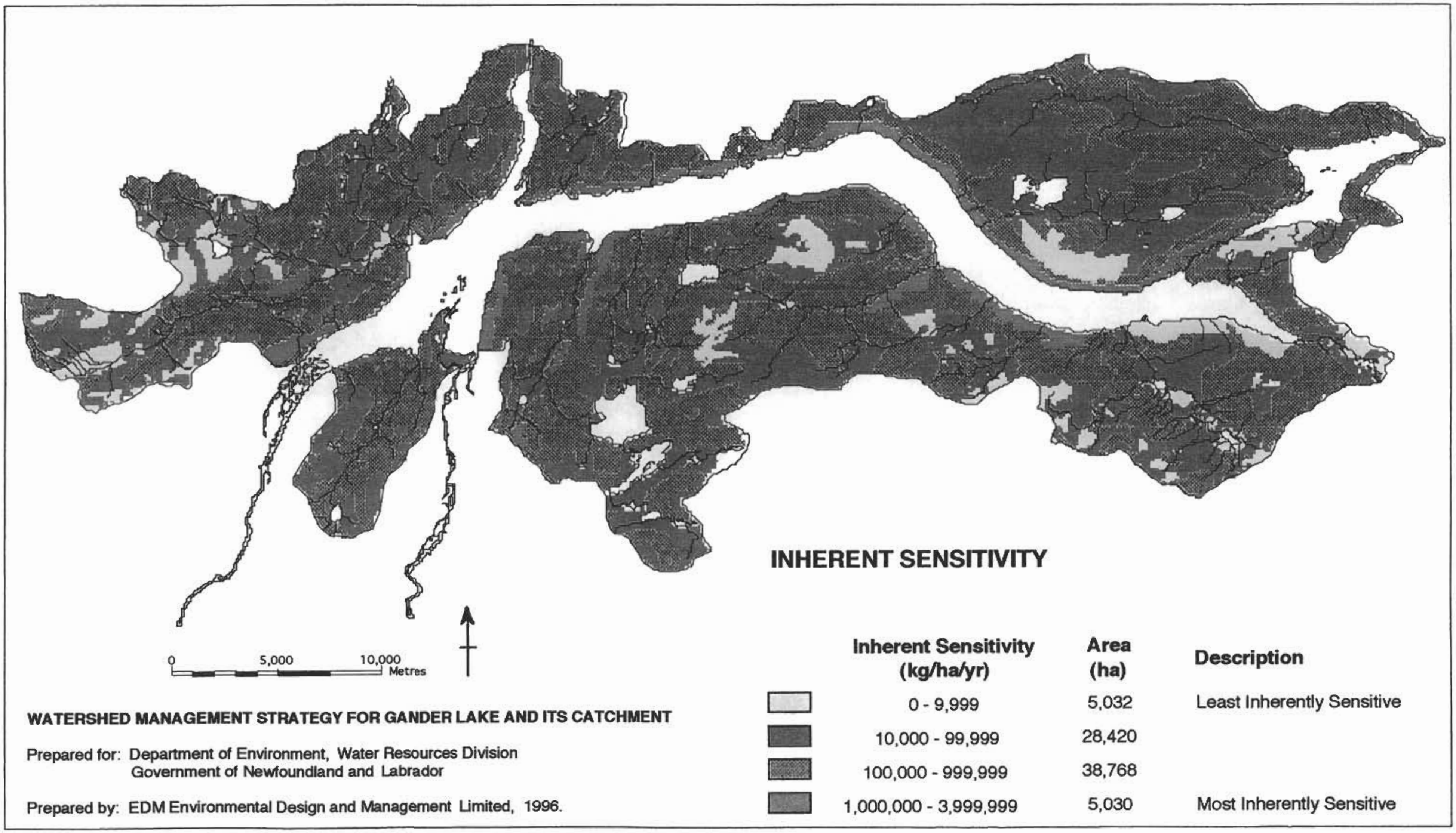
Figure 3.2, Inherent Sensitivity, illustrates those areas which are most sensitive to any land use change. It must be emphasized that the values in the map are the expected export values, in kg/ha/yr, if soil is left exposed, from activities such as agriculture, construction, development, or forest clearing (it is the highest possible value).

In the Figure, note how sensitive the steep slopes along Gander Lake are as opposed to areas on the flat plateau, in particular those slopes adjacent to Gander (in the proposed recreation area), as well as directly across the Lake from Gander. The Figure also illustrates that the Town of Gander itself is very well sited for minimizing sediment delivery to the Lake, i.e., located on the flat plateau.

Also of interest are those areas near a water body which are not sensitive. For example, consider the Town of Benton. Even though Benton is located directly along a water body, it is in a location where development will have the less impact (in terms of sediment production) on water quality. Alternatively, some of the proposed Cottage Management Areas are in locations of very high inherent sensitivity. Note also, that Glenwood is much better located than Appleton in terms of the expected impact on sediment production resulting from intensification of land use.

3.5 SEDIMENT DELIVERY

Sediment Delivery is a combination of Sediment Production (how much soil erodes in the catchment), together with a Sediment Delivery Ratio (what fraction of that which erodes is actually exported to the Lake).



INHERENT SENSITIVITY
0
5,000
10,000
Metres
Inherent Sensitivity (kg/ha/yr)
Area (ha)
Description
0 - 9,999
5,032
Least Inherently Sensitive
10,000 - 99,999
28,420
100,000 - 999,999
38,768
1,000,000 - 3,999,999
5,030
Most Inherently Sensitive
WATERSHED MANAGEMENT STRATEGY FOR GANDER LAKE AND ITS CATCHMENT
Prepared for: Department of Environment, Water Resources Division
Government of Newfoundland and Labrador
Prepared by: EDM Environmental Design and Management Limited, 1996.

Figure 3.2

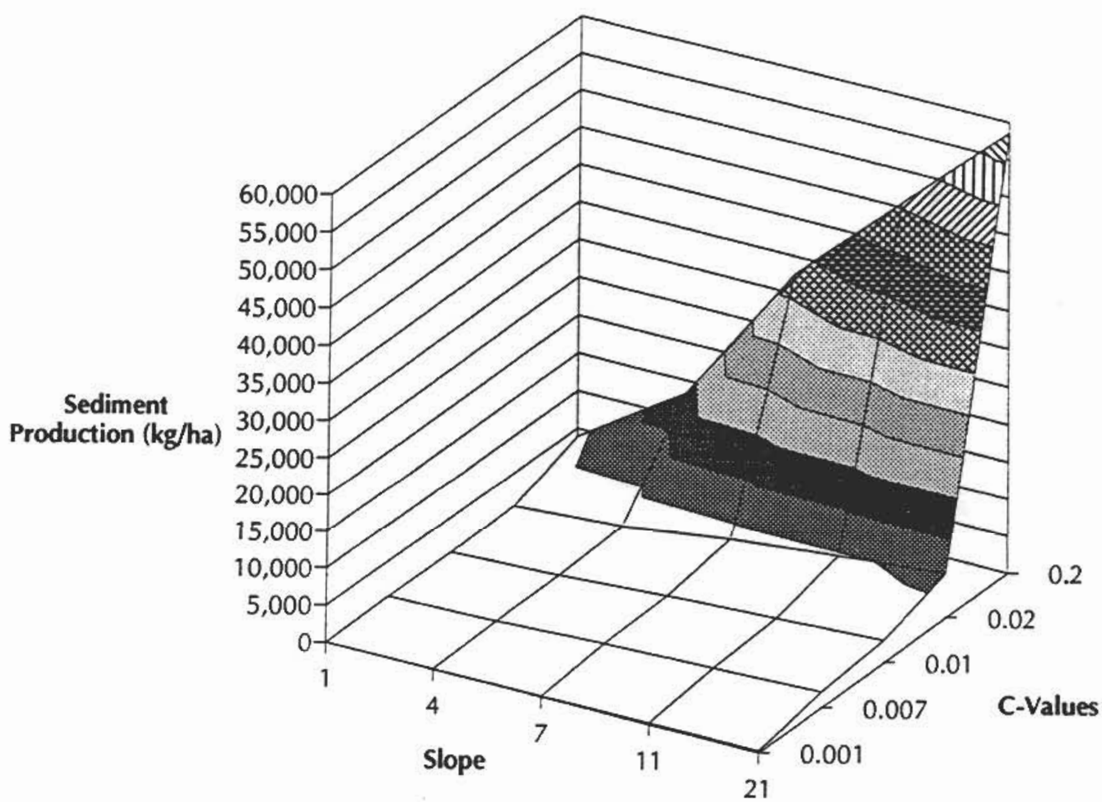
Watershed Management Plan for Gander Lake and its Catchment
TABLE 3.8: CATCHMENT SENSITIVITY TO SLOPE

Sediment Production (kg/ha)

USLE Factors				Cover Values†				
(n1...n5) Slopes	R	K*	LS	Forested 0.001	Burn 0.007	Regenerating 0.01	Clearcut 0.02	Gravel Pit 0.2
1	870	0.34	0.18	20	137	195	391	3,910
4	870	0.34	0.61	66	464	662	1,325	13,249
7	870	0.34	1.50	163	1,140	1,629	3,258	32,580
11	870	0.34	2.10	228	1,596	2,281	4,561	45,612
21	870	0.34	2.70	293	2,053	2,932	5,864	58,644

* Gander Soil Type (Orthic Humo-Ferric Podzol); 67% of watershed in this soil type.
† Actual Range of Cover Values Used In Watershed Management Decision Model.

Gander Catchment Slope Sensitivity



3.5.1 Sediment Production

Actual erosion, or Sediment Production, in the catchment is dependent upon the inherent sensitivity (defined above), and the actual landscape cover, or land use. Most soil research and applications of the USLE are related to agriculture. However, the USLE has been used to estimate sediment production for many land uses other than agriculture, although literature values are not as well developed for these other land uses.

There are no published C values for Newfoundland land uses (A.R. VanKesteren, personal communication). Therefore, C-values were derived from the literature (Table 3.9, C-Values). Final values selected for the Gander catchment align well with literature values, with the following exceptions: the C-value for development was lowered due to the relatively suburban nature of development in the catchment; and, the value for burned areas was lowered because most of these areas are very old burns and it may be assumed that many of these areas have little soil left to erode. In developing the C-values for Gander, the general export values (Table 3.4), and those of the airport ditch (Table 3.5) were also considered. These tables suggest that Gander export values (and thus, likely, C-values) should be similar to those developed in Nova Scotia and New England.

Sediment Production in the catchment was estimated by assigning C values to the different land use types mapped in Figure 1.8, Land Use 1990. The C-value map was then multiplied in the GIS with the other factor maps (R, K, L, and S) to produce an intermediate, Sediment Production Map.

3.5.2 Sediment Delivery Ratios

The Sediment Delivery Ratio map layer in the model assigns a delivery ratio to different areas of the catchment. The delivery ratio is defined as the percentage of the sediment produced in a given cell (USLE) which is actually delivered to the Lake.

The literature on Sediment Delivery Ratios is very sparse, although there is some new research ongoing to better define delivery ratios (Arbour 1996, Binford 1996). In addition, models for routing sediment (and other materials) are being modified for application to other land uses (e.g., AGNIPS, SWERB). For this project, delivery ratios were developed following the method of Snell (1985). Working in an Ontario agriculture landscape, Snell assigned a high delivery ratio to areas that were within 100 metres of a stream or water body; a medium delivery ratio to areas of steep slope (greater than 5%) that were setback from a stream or water body by at least a 100 metre forested buffer; and a low delivery ratio to areas that were tributary to a depression (bog), or had shallow slopes (less than 5%) and were setback from a stream or water body by at least a 100 metre forested buffer. Snell further refined delivery ratios to reflect hydrologic soil properties in the absence of a buffer zone between the disturbed land and the water body. This condition (no buffer) exists so rarely in the Gander catchment that this refinement was not included.

Actual values for Snell's high, medium and low categories were ratios estimated by EDM, based upon literature values reported by Lowrance et al. (1988) and Cooper et al. (1987), and with advice from Arbour (1996). A setback value of 200 metres was used (as opposed to Snell's 100 metres) given recent literature on the effectiveness of various buffer widths (e.g., Lowrance et al. 1988), and considering specific site conditions in the Gander catchment (a more complete discussion of this topic is provided in Section 3.12.1). In addition, the low value areas were split into two categories, Low Value 1 for areas tributary to a bog, and Low Value 2 for other low value areas.

Watershed Management Plan for Gander Lake and its Catchment

TABLE 3.9: C-Values

	C-VALUES		
	Acadia National Park*	Other Values	FINAL Estimated for Gander
Land Cleared for Development	0.1	0.038 - 0.055***	0.05
Development	0.5		0.2
Gravel Pits			0.2
Recent Clear Cut		0.004 - 0.115**	0.02
Brush/Regenerating	0.01	0.01 - 0.04***	0.01
Burn	0.01	0.003 - 0.011***	0.007
Blowdown	0.01		0.01
Forested	0.001	0.001***	0.001
Unvegetated/Exposed Bedrock	0.002		0.002
Bog	N/A	N/A	N/A
Ponds	N/A	N/A	N/A

* Values used by Binford (1989), derived from Kirkby.

**Dissmeyer and Foster 1981

***Dunne and Leopold 1985

This was done to reflect the fact that export from lands draining to a bog will be less than export from other low value areas of the catchment.

The Watershed Management Decision Model was run, applying different Delivery Ratios, until it was calibrated to produce a total sediment export of approximately 54,500,000 kg/yr. The final Sediment Delivery Ratios which resulted in model calibration were as follows:

High Export Value	80%
Medium Export Value	50%
Low 1	20%
Low 2 (bogs)	10%

3.5.3 Present Land Use Sediment Delivery

The Present Land Use Sediment Delivery Map is illustrated as Figure 3.3. The Figure has a logarithmic scale. The Figure illustrates the predicted sediment delivery to the Lake from each 1 ha grid cell in the catchment.

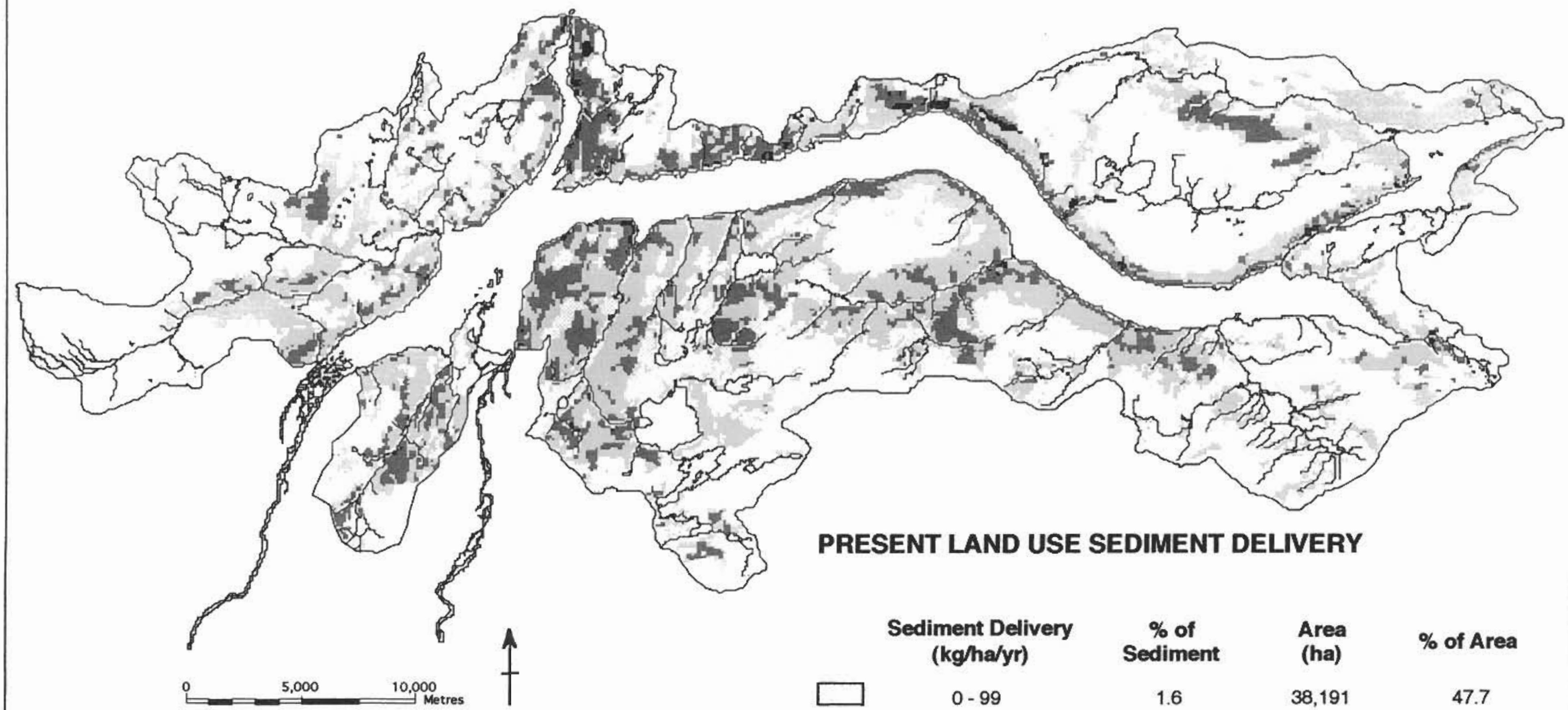
In this Figure, catchment areas in the two darkest categories (values greater than 10,000) cover only approximately 1% of the catchment area, but contribute approximately 40% of the sediment load. Catchment areas in the three darkest categories (values greater than 1000) cover only approximately 16% of the catchment area, and contribute approximately 85% of the sediment. Almost all of the sediment (98%) is delivered to the Lake from only 52% of the catchment area. This result is consistent with other watershed studies which have found that the areas contributing the majority of sediment to a water body typically comprise on a small percentage of the watershed area (Wall et al. 1978).

This Figure (3.3) should be compared to Figure 3.1, Expected Export of Suspended Solids by Land Use. While both Figures are calibrated to deliver the same total amount of sediment to the Lake (approximately 54,500,000 kg/yr), the spatial distribution of that contribution is significantly different. Figure 3.1 considers land use only (i.e., cover type), not the location within the catchment (delivery ratio and the inherent sensitivity). Note, for example, the difference in the Town of Gander's sediment production when location is considered and when it is not. Also, note the importance of location in highlighting the sediment contribution from the steep slopes surrounding the Lake.

The strength of this approach is that location, as seen by comparing the two Figures (3.1 and 3.3) is a critical component of sediment delivery. For physical planning, the Watershed Management Decision Model allows the planner to focus on the actual regions (zones) which are of most concern.

3.5.4 Future Land Use Sediment Delivery

Once calibrated, the cartographic model was used to predict the impact of future land use changes in the catchment. The future land use map predicts forest harvesting at the eastern end of the Lake along the southern shore, and forest clearing for recreation on the slopes below the town of Gander. It also provides for increased cottage development within the Cottage Management Areas. C-values for both the recreation area and cottage development areas were assigned as "development". This is a conservative value for these two land uses. Former clear cut areas (from the Present Land Use Map) were recategorized as "regenerating" in the future land use map.



Sediment Delivery (kg/ha/yr)	% of Sediment	Area (ha)	% of Area
0 - 99	1.6	38,191	47.7
100 - 999	13.3	22,609	36.6
1,000 - 9,999	46.0	8,979	14.5
10,000 - 99,999	26.2	679	1.1
100,000 - 299,999	12.9	44	0.1

Figure 3.3

The Future Land Use Sediment Delivery Map is shown as Figure 3.4. The Figure illustrates the impact of location on sediment export from the future land uses.

For example, in terms of actual land use area, the amount of clear cut land in the future will be less than the current level (Table 3.1: Land Use Areas). However, because of the location of this forest clearing, the Watershed Management Decision Model is predicting a 34% increase in the amount of sediment delivered to the Lake which may be apportioned to this land use type (an increase of approximately 19 million kg/yr). A worst case scenario for forestry would assume a C-value of 0.1, reflecting a siliviculture practice where the soil is disced or poor road construction. In this case, the large clear cut area could delivery an additional 41 million kg/yr (a 74% increase).

The Cottage Management Areas, if modeled as development, are predicted to result in a 25% increase in sediment loading to the Lake (an additional 14 million kg/yr). Gander's recreation area will contribute a further 11 million kg/yr. Together, the cottages and recreation areas are predicted to result in a 46% increase in sediment loading. This combined amount is greater than that predicted for forestry, and is significant. The locations planned for these uses should be carefully rethought.

3.6 LAKE SENSITIVITY

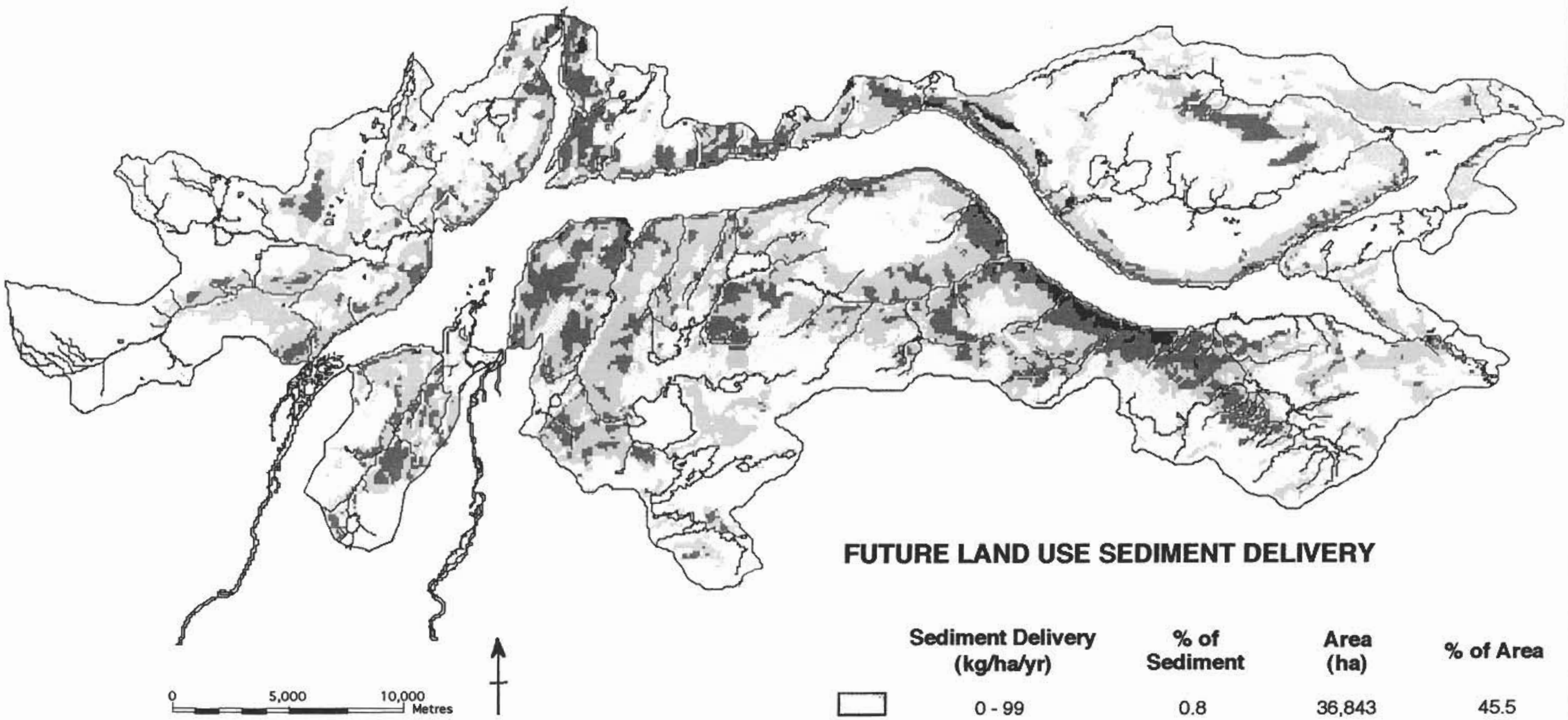
The horizontal circulation model proposed in Part 2 has implications with respect to classifying the Lake in terms of its sensitivity. The circulation model predicted that the Lake is quite sensitive to inputs from outside of the catchment (and beyond the scope of this study). Whether this is a positive thing (increased dilution water and mixing), or a negative thing (increased input of pollutants), depends upon the water quality of the rivers and the management of the water quality in the rivers (most importantly, the NW Gander River).

The water quality data collected in Part 1 may be interpreted to support either complete circulation of the Rivers, or minimal river water circulation. Selecting the most conservative Lake classification scheme, a reasonable way to proceed, depends largely upon the primary water quality management objectives, and the actual circulation pattern of the two Rivers in the Lake.

Lake Sensitivity was considered in three ways: Lake Sensitivity to the Catchment, Lake Sensitivity to a Less Well Mixed East End (Figure 3.6), and Lake Sensitivity to the NW and SW Gander Rivers (Figure 3.7).

3.6.1 Lake Sensitivity to the Catchment

The increased sediment loading predicted by the Watershed Management Model was modeled in terms of predicted phosphorous in the water in the Dillon model. The method are results of phosphorus modelling was described in Part 2. The model predicts that if only the increased forestry occurs (good forestry practice), a Lake concentration of 5.6 mg m-3 is to be expected. This concentration is based on the assumption that if only the direct catchment is considered, the residence time is higher, the fraction of P settling out is higher. The model predicts that the increased sediment will push that Lake closer to a mesotrophic condition than it currently is. However, if the cottage management area and Gander's recreation area become fully developed, an increase in phosphorous loading of approximately 10 mg m-3 is predicted. This concentration is very close to changing the trophic state of the Lake. (Figures 2.13 and 2.14, Part 2). These results suggest that careful management of these activities is essential.



FUTURE LAND USE SEDIMENT DELIVERY

Sediment Delivery (kg/ha/yr)	% of Sediment	Area (ha)	% of Area
0 - 99	0.8	36,843	45.5
100 - 999	7.5	22,622	36.6
1,000 - 9,999	26.8	9,874	16.0
10,000 - 99,999	21.5	929	1.5
100,000 - 499,999	43.4	234	0.4

WATERSHED MANAGEMENT STRATEGY FOR GANDER LAKE AND ITS CATCHMENT

Prepared for: Department of Environment, Water Resources Division
Government of Newfoundland and Labrador

Prepared by: EDM Environmental Design and Management Limited, 1996.

Figure 3.4

A map of the distance (over elevation) from Gander Lake and its tributaries provides a good planning measure for identifying locations within the catchment for potentially polluting land uses (Figure 3.5). Note again, how well sited the Town of Gander is.

3.6.2 Lake Sensitivity to a Less Well Mixed East End

If there is little circulation of water from the NW and SW Gander Rivers, then the Eastern End of the Lake may be considered be less well mixed. Figure 3.6 illustrates the presumed River water circulation pattern for this scenario, as well as the more sensitive east end.

The area tributary to this sensitive east end was delineated and then, within the Watershed Management Decision Model, the total amount of sediment expected to be delivered to this part of the Lake in the future Land Use scenario was calculated. The Model predicted that approximately 34,000,000 kg/yr would be delivered to the sensitive east end; an approximately 180% increase from the previous value (Present Land Use value) of approximately 19,000,000. This increased sediment load was converted to a phosphorous load and modelled in the Dillon model (from Part 2).

The Dillon model predicts that, if the eastern end of the Lake is considered in isolation, then the residence time in this portion of the Lake is higher, and the fraction of P settling out higher. The resulting P concentration of the Lake is predicted to be just 5.7 mg m-3. This value is only slightly higher than that predicted above, but close enough to the mesotrophic line in (Figures 2.13 and 2.14, Part 2) to warrant some concern.

3.6.3 Lake Sensitivity to the NW and SW Gander Rivers

If the NW and SW Gander Rivers circulate more completely, then the water supply intake pipes at Gander, Glenwood and Appleton are sensitive to inputs from the entire watershed (including the River catchments). Lake sensitivity in this case is reversed, as illustrated in Figure 3.7.

If the entire watershed is considered in the Dillon model, the Lake has a relatively low residence time and the fraction of P settling is small, hence the Lake concentration of P is relatively large - 9.9 mg m^{-3}. The average P concentration observed in the upper 60 m of the water column in June and September, 1995, was 6.2 mg m^{-3}, assuming non-detectable concentrations were just below the level of detection. This is taken as a lower bound estimate since P concentrations are expected to be higher at depth. Note that this scenario is the most sensitive scenario of the three described in this section. (Lake water quality is closest to the mesotrophic line, refer to Figures 2.13 and 2.14, in Part 2.)

The Dillon model also predicts that, under this scenario, if phosphorous loadings within the entire watershed were to double, then the Lake would become mesotrophic. A doubling of phosphorous loading is not an unreasonable prediction, given the pressure on the Rivers for recreation. This model suggests that a very close look at the NW and SW Gander Rivers is warranted. It also suggests that full circulation of the Rivers is in fact the worst case scenario for the Lake, and thus the Lake is equally sensitive to contributions, irrespective of the subcatchment discharge location.

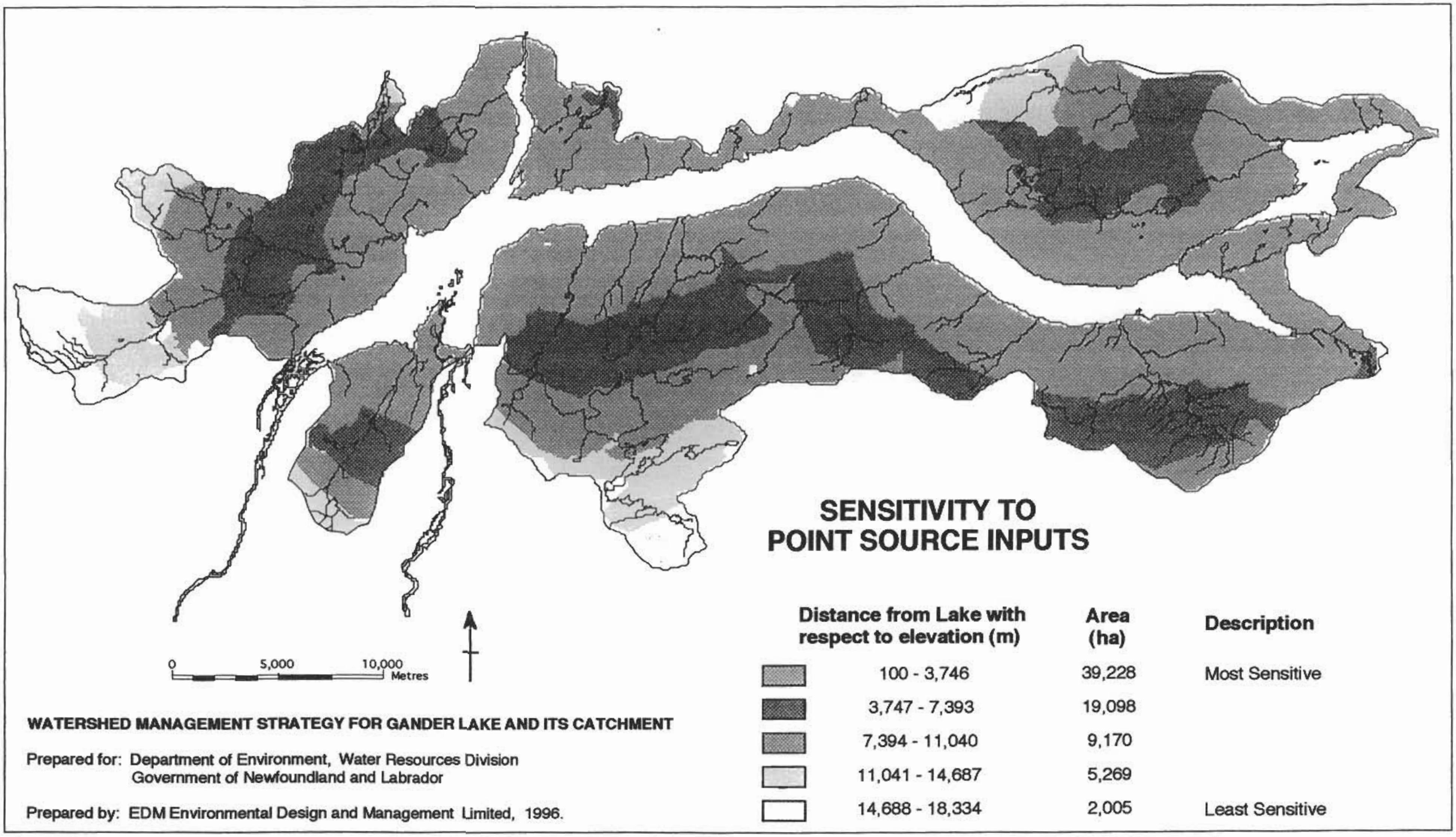

SENSITIVITY TO
POINT SOURCE INPUTS
Distance from Lake with respect to elevation (m)
Area (ha)
Description
100 - 3,746
39,228
Most Sensitive
3,747 - 7,393
19,098
7,394 - 11,040
9,170
11,041 - 14,687
5,269
14,688 - 18,334
2,005
Least Sensitive
0
5,000
10,000
Metres
WATERSHED MANAGEMENT STRATEGY FOR GANDER LAKE AND ITS CATCHMENT
Prepared for: Department of Environment, Water Resources Division
Government of Newfoundland and Labrador
Prepared by: EDM Environmental Design and Management Limited, 1996.

Figure 3.5

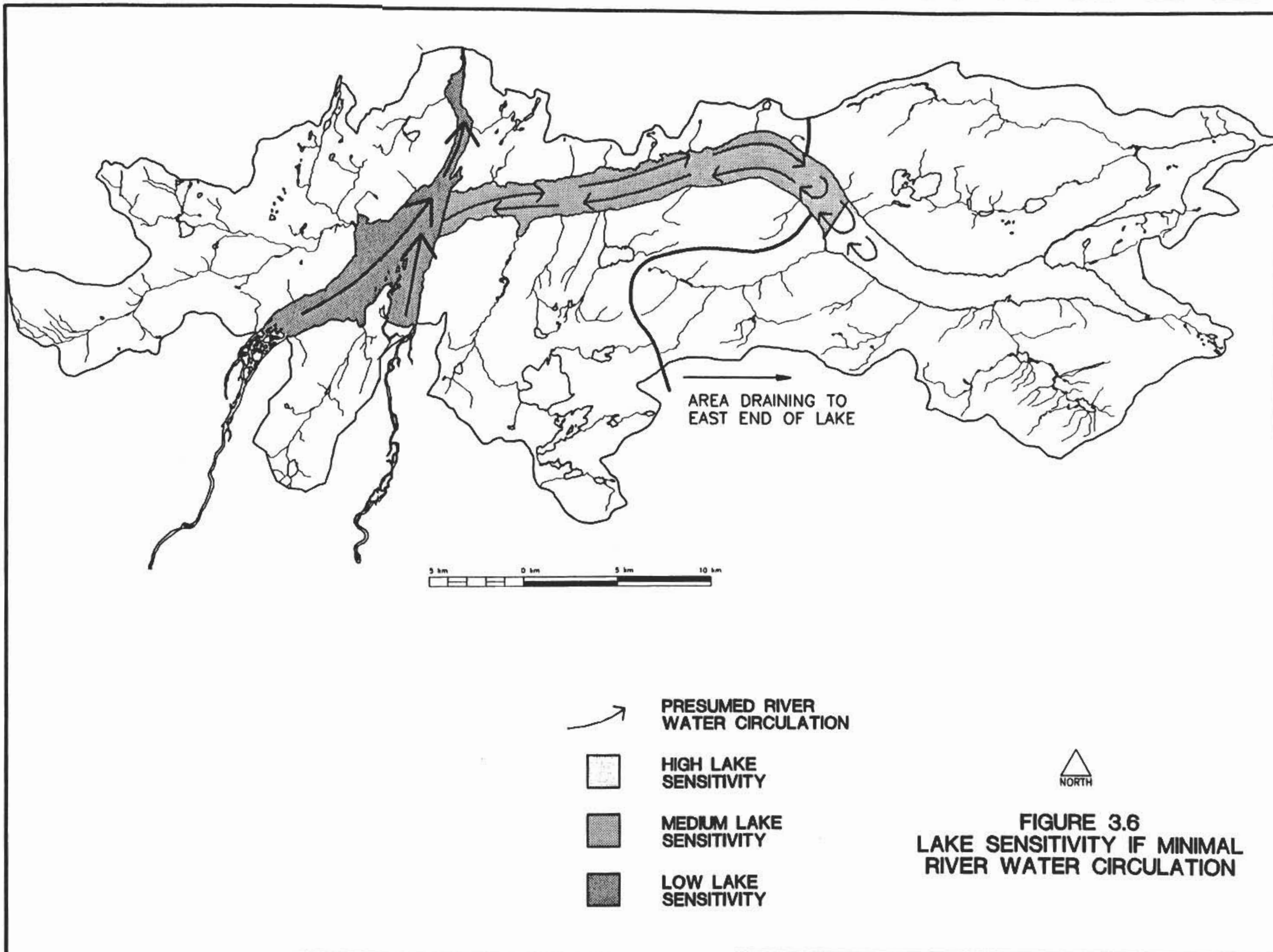


FIGURE 3.6
LAKE SENSITIVITY IF MINIMAL
RIVER WATER CIRCULATION

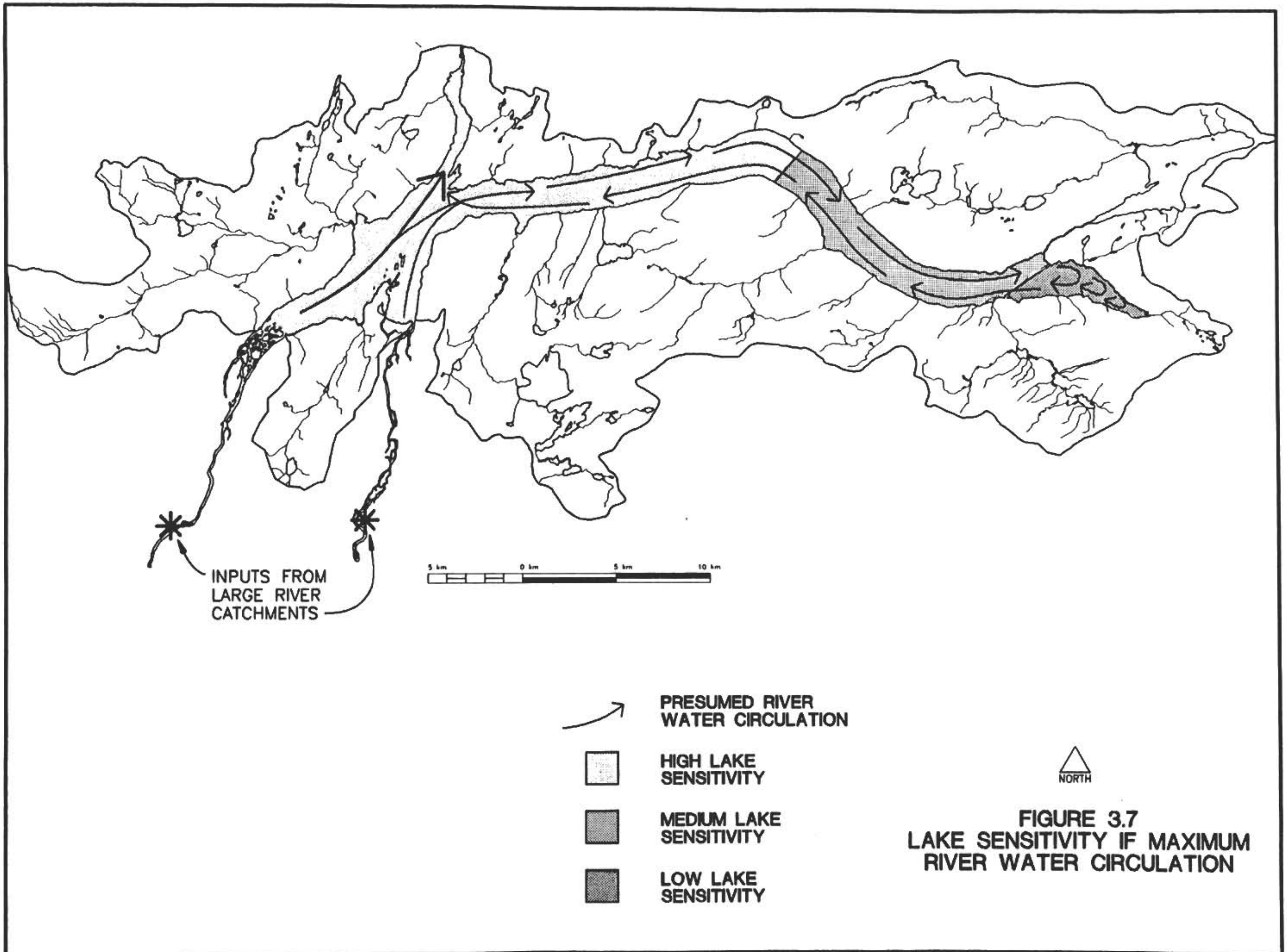
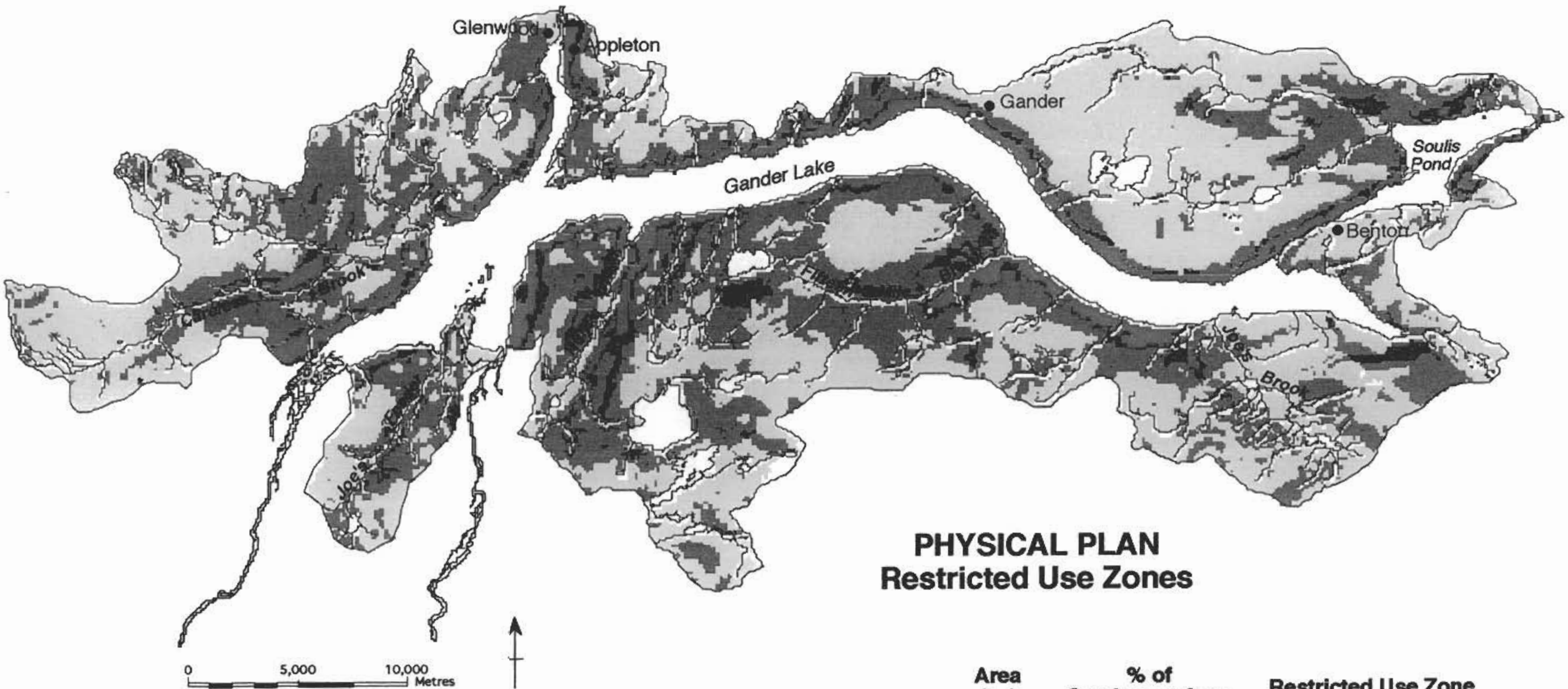


FIGURE 3.7
LAKE SENSITIVITY IF MAXIMUM
RIVER WATER CIRCULATION

3.7 PHYSICAL PLAN

The Physical Plan (Figure 3.8) was created by considering the Inherent Sensitivity Map (Figure 3.2), and the Sediment Delivery Ratio. The physical plan thus classifies the entire catchment in terms of its ability of contribute sediment, and the nutrients associated with soil loss. Consideration of Lake sensitivity was not included in the physical plan. This is because the Lake must be considered to be equally sensitive to inputs throughout the catchment, given that full circulation of the NW and SW Gander Rivers represents the worst case scenario for Lake sensitivity.

The Plan illustrates those areas which require (R) restrictive zoning, (H) high restrictions on land use and activities zoning, (M) medium restrictions on land use and activities zoning, and (L) low restrictions on land use and activities zoning. Approximately 7.6% of the catchment is proposed to receive R level zoning. A further 9% is proposed to be zoned H. The rest of the catchment, (83%) lies within M and L zones, providing plenty of opportunity for future land use change. Activities recommended for these zones are described in Section 3B.



PHYSICAL PLAN
Restricted Use Zones

	Area (ha)	% of Catchment Area	Restricted Use Zone
	33,920	48.1	L - Low
	24,811	35.2	M - Medium
	6,435	9.1	H - High
	5,336	7.6	R - Restricted

WATERSHED MANAGEMENT STRATEGY FOR GANDER LAKE AND ITS CATCHMENT

Prepared for: Department of Environment, Water Resources Division
Government of Newfoundland and Labrador

Prepared by: EDM Environmental Design and Management Limited, 1996.

Figure 3.8

3.8 PART 3A SOURCES

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3B: PLANNING CONTROLS

3.9 REGULATORY BOUNDARIES AND LAND JURISDICTION

Legal jurisdiction within the designated catchment of Gander Lake is distributed between private individuals, municipalities, and several provincial and federal agencies. The various jurisdictions and boundaries are illustrated in Figure 3.9. The Figure illustrates how little of the catchment is actually privately owned. The Figure also illustrates the other key provincial management objectives for the area (in addition to water supply protection) by showing the cottage and agricultural development areas. All areas not otherwise delineated are under lease to forestry companies. Much of the land outlined as private is owned by forestry companies.

The Gander Lake catchment is a protected watershed under Section 26 of the Environment and Lands Act (1990, CD-11). While defined by the Minister, the protection of the water supply is also the responsibility of the Municipal authority or person benefiting from the use of the water (Section 26(1)). Within the designated catchment area a person shall not place, deposit, discharge or allow to remain in the prescribed area material of a kind that might impair the quality of the water; or fish, bathe, swim or wash in, or otherwise impair the quality of the water (Section 26(2)). Section 26(3) allows that the Minister may define and prescribe a section of the public water supply area to be used by persons for fishing, boating, swimming, washing or other activity.

Under Section 33 of the Environment and Lands Act, the Lieutenant-Governor in Council has many regulatory options, which allow for the regulation of discharges to water, control of activities, as well as regulating the method of carrying on of activities (businesses, trades or industries). The description in the Act is relatively broad, giving the Department of Environment and Lands many regulatory options.

A new Policy Directive, P.D. W.R. 95-01, provides further clarification of the Department of Environment's intent under Section 26 of the Department of Environment and Lands Act, and the Waters Protection Act (1990, W-5). The Policy Directive establishes a mechanism for issuing a certificate of environmental approval for all development activities within a designated water supply area. The approval process requires the submission of detailed development plans along with maps, drawings and specifications as required by the Minister. Approval, in the form of a certificate of environmental approval, is granted by the Minister.

While the Department of Environment has no formal powers within its' Acts to legislate land use (i.e., set out zones where specific policy applies to control future development) the Policy Directive (P.D. W.R. 95-01) establishes guidelines for existing and proposed development activities. These guidelines specifically exclude some activities within protected water supply watersheds. The following activities, of relevance to the Gander Lake catchment, are not permitted: the discharge of municipal sewage; residential development (four or more lots) and service stations; extensive land clearing; clear cutting of forest in sensitive areas; resorts, hotels/motels, and golf courses; activities, operations or facilities associated with aggregate extraction and mineral exploration; and the application of herbicides (e.g., along powerline corridors) and use of chemically treated utility poles. Most of these activities are currently occurring, or are proposed within the Gander Lake catchment.

The Policy Directive also seeks to regulate other activities. The following, relevant to the Gander Lake catchment, are regulated activities: expansion and upgrading of existing activities, operations or facilities; construction of residential, commercial, industrial and institutional facilities or any other related activities (including land clearing); development of farm lands; forest logging, resource road construction, stream crossing, skid trails, silvicultural activities, etc.; recreational activities and facilities including cottage development, fishing, swimming, boating, hiking, campgrounds, etc.; mineral exploration and related activities; installation of any pipelines; construction of roads, bridges, culverts and other stream crossings. Finally, the Policy Directive provides for establishing buffer zones around water bodies within designated areas (buffer zone widths are specified, refer to Section 3.12.1).

The new Policy Directive is very broad in its application, and sets up an approval process whereby essentially all activities within a protected water supply watershed require approval from the Minister of the Environment. The guidelines, however, step towards land use regulation in detailing the activities the Department of the Environment seeks to eliminate or minimize within protected watersheds. The guidelines are at odds with the policy of other departments and agencies which have jurisdiction in the Gander Lake catchment. While the Department of Environment has a final review capacity and is able to restrict use, these other departments and agencies set out the rules for what is allowed to happen. Most of these departments and agencies deal directly with project proponents, prior to the proponent seeking approval from the Minister of the Environment. If the policy of these departments and agencies is brought in line with that of the Department of the Environment, conflict may be avoided, and the costs of project review and rejection (both political and monitory costs) are minimized (this approach is in fact encouraged in the Policy Directive, Section 4.9).

The largest land owner in the catchment is the Crown. Crown lands are administered by the Department of Natural Resources, Land Management Branch. The Crown lands in the catchment are largely leased to forestry companies, including Abitibi Price and Corner Brook Pulp and Paper. The Lands Act (1991, C36), provides for leasing and granting of Crown lands. Of interest to watershed management objectives is Section 7(1) of the Lands Act, which allows, in the absence of an express grant, for the reservation of the shoreline not less than 10 metres wide around and adjoining every water body. Maximum shoreline reserves are not specified in the Act. Also, the Minister may grant an easement (Section 5), or a reservation (Section 8) upon Crown lands for the purpose, and for the period, and upon those terms and conditions, that the Minister may set out. This is a very broad definition for easements and reservations, and may be useful for the Department of Natural Resources to use to restrict land use within a defined zone, e.g., a conservation easement.

The Lands Act also allows for the creation of Special Management Areas. These Areas are established by the Lieutenant-Governor in Council. Section 59 (1) of the Lands Act allows that within Special Management Areas regulations may be made to prohibit: conveying, leasing or licensing of lands (even if privately owned); the erection or construction of any thing; and activities (e.g., specific uses, such as agriculture, may be prohibited). As such, within Special Management Areas, the Lands Management Branch has significant regulatory options for aligning with watershed management objectives by establishing the rules for both the type, location and level of development, and the specific land use.

The Gander Lake catchment currently includes a Special Management Area for cottage development (refer to the Northwest/Southwest Gander River Crown Land Plan Boundary in Figure 3.9) This Plan Area was established to address the public demand for recreational cottages and deal with illegal recreational occupation. The Plan proposes 18 cottage development areas, where legal lots will be made available in areas ascertained to be suitable for cottage development. Location selection included, among other considerations, locations not immediately adjacent to the NW and SW Gander Rivers in order to protect the Rivers (50 foot buffer required by the Federal Department of Fisheries and Oceans for Scheduled Salmon Rivers), and the capability to support a waste disposal system.

Cottage development locations which lie within the Gander Lake catchment include: Areas 5 and 6, on Gander Lake, south of Careless Cove; Area 7, between the Seed Farm and Careless Cove; and, Area 18, along the Lake between the NW and SW Gander Rivers (area numbers refer to parcel labels within the Cottage Development Area Plan). Of these areas, only Area 7 includes a buffer zone requirement, along Careless Brook (a Scheduled Salmon River). There are no proposed buffer requirements between cottage development areas and Gander Lake. Thus, while the Special Management Areas legislation allows for the establishment land use and activities in accordance with watershed management objectives, these are not reflected in the current Plan.

Within the catchment there are two Agricultural Development Areas (ADA's), established under the Lands Act. The ADA's indicate the agricultural potential of the land along the NW and SW Gander Rivers. Other areas of provincial ownership in the catchment include the Glenwood Seed Potato Farm, an experimental farm operated by the Department of Fisheries, Food and Agriculture, and Glenwood Provincial Park, owned and operated by the Department of Tourism, Parks Division (the Park is currently for sale). Refer to Figure 3.9.

Federal jurisdiction in the catchment extends to the Northwest and Southwest Gander Rivers and their tributaries. These rivers are Scheduled Salmon rivers under the jurisdiction of the Federal Department of Fisheries and Oceans. No development is permitted along a Scheduled Salmon river unless it is within an area designated for that use. Given that Gander Lake itself is tributary to Gander River, a federally enforced buffer of 50 metres (300 metres around salmon pools) should, in all likelihood, apply.

Federal ownership in the catchment includes the Department of National Defense (CFB Gander) and, Transport Canada (Gander International Airport). All of this land, with the exception of the DND Cadet Camp at Careless Cove, lies within the limits of the Town of Gander's designated planning area. Both of these Federal Departments act autonomously.

The Town of Gander has a large designated planning area which includes Gander International Airport and CFB Gander. Benton is a Local Planning Area controlled by the Department of Municipal Affairs. The Towns of Glenwood and Appleton, partly within the protected catchment area, are incorporated municipalities with planning areas. Refer to Figure 3.9.

The municipal units have regulatory options under the Urban and Rural Planning Act (1990, CU-7). The Act allows for the establishment of plan areas as well as the control of land use within those plan areas, including the establishment of zones for openspace or conservation (i.e., no development), and the establishment of the rules for development within zones (i.e., the level of review required). The zoning within plan areas offers significant regulatory opportunity to control land use such that it occurs in accordance with the Department of Environment's Policy Directive. Of special interest to watershed planning is the ability within the Urban and Rural Planning Act to establish Protected Areas. Established by the Lieutenant-Governor in Council, a Protected Area is an area of natural beauty or amenity to be protected, and to which development control should be applied in order to preserve the natural amenities of the area (Section 58, 59 and 60).

The Town of Gander Municipal Plan 1991-2001, established under the rules of the Urban and Rural Planning Act, allows for multiple land uses within the plan area. In general, industrial uses are proposed to the north of the Airport in areas draining to Gander Lake via the long route through Soulis Pond. The Plan also includes substantial openspace. In general, the Plan is supportive of maintaining Gander Lake water quality. The Plan provides for a 30 metre buffer between the lake shore and any development.

Of greatest concern in the Gander Municipal Plan is the Gander Lake Shore Development Scheme. This comprehensive development area encompasses the land between the Trans Canada Highway and the Lake, directly opposite the Town. The primary development goal for the area is year-round recreation and commercial tourism development. Proposed new land uses include: a retirement complex, camping/trailer park, tourist accommodation facilities, commercial amusement park, golf course expansion, hospital expansion, outdoor amphitheater, openspace areas, and conservation areas. The Municipal Plan states that Gander Lake water quality be maintained, and includes a policy requiring an environmental study to assess the potential impacts of proposed development. In addition, the Municipal Plan requires development review of all proposals and offers numerous opportunities to halt development which is deemed to conflict with water quality protection. This includes a review by the Watershed Monitoring Committee, prior to approval (a description of the Watershed Monitoring Committee is below).

Many of the proposed activities within the Gander Lake Shore Development Scheme are not permitted within a protected water supply watershed, under the guidelines of the Department of Environment's Policy Directive. Municipal Plans set the expectations of individual land owners for property use (and property value). The Plan, as currently drafted, establishes false expectations. The proposed development area could not be in a worse location relative to the intake pipe for the Town, and any problems which occur could have a significant effect on the water supply.

Elsewhere between the Lake and the Trans Canada Highway, the Gander Municipal Plan has zoned the land as RUR or Rural Resource area. Within this area, permitted land uses include: agriculture, forestry, outdoor recreation, and conservation. Uses that may be permitted include wood harvesting and industrial uses associated with the resource base (aggregate extraction is not permitted south of the Trans Canada, within the Municipal Boundary).

The Town of Appleton's Municipal Plan (1982-1992) aims to encourage development infilling, and the maintenance of a compact town around existing municipal servicing (sewer and water). The Future Land Use Plan assigns industrial uses away from the River edge and establishes a large openspace and recreation zone along Gander River. The Plan is generally supportive of the goal of water quality protection (in the Town boundaries defined), although the Plan contains no explicit water quality protection clauses.

The Town of Glenwood's Municipal Plan (1991-2001) is more explicit in environmental protection than Appleton's. Like Appleton, a compact community form in the area of municipal servicing is sought, with development infilling, as opposed to expanding the Town boundaries. The Plan defines a Designated Floodway (Section 2.13) defined by a 1 in 20 year flood along the Gander River, where development is limited to non-building uses. Although defined for building protection, this is also a useful tool for water quality protection. The Plan also includes an Environment Section, where a 15 metre buffer zone along all rivers and streams is called for, together with calling attention to the Federal Fisheries and Oceans review of any development within 30 metres of a water body.

Benton is a Local Planning Area. Again, promoting a tight community form, the future land use plan calls for new residential development to occur behind and adjacent to existing development. In terms of water quality management, a narrow conservation easement along Soulis Pond and Soulis Brook is also delineated; before approving any development within this zone the application will be referred to Fisheries and Oceans for comment. Note that Benton's water supply is Little Pond, and the plan defines a watershed protection zone around the Pond.

In addition to the above legal jurisdictions, a Watershed Monitoring Committee has been appointed for the Gander Lake catchment by the Minister of the Environment. The main purpose of the Monitoring Committee is to provide scientific and technical assistance to developers and concerned parties to minimize the environmental impacts of activities and to ensure that approved undertakings are carried out in an environmentally acceptable manner.

The Monitoring Committee will specifically review legislation and guidelines and recommend protection measures; review development plans; develop and implement surveillance and monitoring programs; specify inspection and impact assessment procedures; prepare reports of information collected; recommend changes to protection measures or inspection and monitoring procedures; and, assess environmental impacts of existing activities and recommend appropriate actions. The Watershed Monitoring Committee, is specifically tasked to uphold the guidelines and recommend projects considering the Department of Environment's Policy Directive (P.D. W.R. 95-01), under Section 26 of the Department of Environment and Lands Act.

The Watershed Monitoring Committee membership consists of representatives of the three Towns, the Provincial Departments of Environment and Lands, Natural Resources, and Tourism and Culture, as well as Abitibi-Price Inc. The Monitoring Committee is chaired by an official from the Town of Gander. With this mandate, the Monitoring Committee is well positioned to oversee the implementation of watershed protection in the Gander Lake catchment.

3.10 WATERSHED MANAGEMENT GOALS AND OBJECTIVES

3.10.1 Goals

The following were established as the primary goals for watershed management in Gander Lake and its catchment:

1) maintaining the integrity of the water supplies of Gander, Glenwood, and Appleton;
2) maintaining the current trophic status of Gander Lake; and
3) maintaining the integrity of the fish (salmon) habitat.

3.10.2 Objectives

The key objectives to achieving these goals are as summarized below. Specific mechanisms for achieving these objectives are listed below each objective. These mechanisms are described in more detail in Sections 3.11 - 3.16. They are listed here to illustrate how the various mechanisms affirm the key objectives in support of the watershed management goals.

A Reduce Erosion and Sedimentation

The primary mechanism of phosphorus and suspended material delivery to Gander Lake is erosion. The study area soils are very thin, and when disturbed by land use activities, extensive erosion may result. Increased phosphorus levels in Gander Lake may lead to changes in trophic state (Section 2.4); increased sediment levels may lead to morphological changes in streams and shallow water areas, changes in the viability of fish habitat, as well as problems with water intake pipes. There are many other materials of concern associated with sediment which may increase in concentration with increased erosion, including silica and certain metals. The following activities or mechanisms can be considered applicable towards meeting the objective of reducing erosion and sedimentation impact on the Lake water quality.

1) Buffer Zones:
The best known mechanism for protecting water quality is the establishment of effective buffer zones, or zones of no cover disturbance (e.g., Toth 1990, Copper et al. 1987). Buffer zones act to protect the Lake by trapping uphill sediment and maintaining shoreline integrity. Effective buffer widths are a contentious issue in the literature, but are generally shown to be correlated to soil conditions and slope (the steeper the slope and more erosive the soil type, the wider the buffer width requirement).

2) Restricted Use Areas
Areas known to be highly prone to erosion should have restrictions placed upon them to reduce the amount of erosion caused by various activities. Restricting both the type of activity (land use), as well as how the activity is carried out should be considered in these sensitive areas.

3) Forestry Practices
The most critical element in forestry leading to erosion is poor road and stream crossing construction techniques (Bonnell, 1995; Scruton, 1995; Celeste, 1996; Douglas, 1996; and Gilbert, 1996). Establishing strict controls on these two elements can significantly reduce erosion. Also, the size of clearcut (smaller clear cuts are preferable) and the amount of remaining cover (e.g., practices such as shelterwood, strip clearing, or thinning as opposed to clearcuts) should be considered. Stricter controls will be required in the most sensitive areas.

4) Development Practices
There are two aspects of development that must be considered. The first is the construction period, when soil is disturbed. Development types that require extensive land manipulation to implement result in extensive erosion. The level and rate at which soil is lost from a construction site can be enormous. The second aspect is the long term pollutant delivery associated with different development types. Many seemingly innocuous developments (e.g., golf courses, ski hills, mountain bike or ATV trails, and cottages) can result in significant long term erosion, as well as the delivery of other undesirable materials. Again, stricter controls will be required in sensitive areas.

5) Stormwater Management
Sediment is delivered to the Lake via stormwater. Stormwater runoff from all development types and land use activities must be carefully planned and designed, and direct discharges avoided.

6) Further Research to Calibrate the Watershed Management Decision Model
Additional research to better calibrate the Watershed Management Decision Model is essential to better informing all of the above.

7) Monitoring of Activities and Land Use in the Lake and Catchment
Monitoring is required in order to determine the effectiveness of and compliance with the programs in place.

8) Water Quality Issues in the Lake and its Catchment
Public awareness and education of the large problems in the watershed, as well as the contributions from activities, such as cottages, boating, ATV's, etc. can help citizens identify problems and learn to be better watershed stewards.

B Determine the Effects of the NW and SW Gander Rivers

The water quality at the intake pipes of the Towns of Gander, Glenwood and Appleton is also a function of the quality of water entering the Lake via the NW and SW Gander Rivers. Initial circulation modelling indicates that the water quality in the rivers is certainly critical to Glenwood and Appleton, and potentially very important to Gander as well.

1) Lake Circulation Modelling and Research
Additional circulation modelling and field work is required to determine the level of influence the rivers water has on the Lake.

2) Water Quality Issues in the Rivers
Given that the quality of the rivers water affects the water quality at the intake pipes of the three Towns, any significant changes in land use, proposed developments, or activity levels in the NW and SW Gander River watersheds should be monitored. In particular, the proposed mine, and the Cottage and Agricultural Development Areas should be monitored closely.

3) Watershed Management Area
Extending watershed management to the rivers watersheds should be considered. If the effect of the rivers is shown to be significant, further study of the river catchments may also be required.

C Control Point Source Inputs

Currently, point source inputs are relatively low (proportionally), when compared to inputs from erosion and sedimentation. There are currently no industrial discharges. The biggest area of concern lies with future development or accidents.

1) Emergency Response
Accidental discharges should be anticipated and a response plan in place for when they do occur.

2) Cottage and Recreation Development
Cottage demand within the catchment itself is relatively low (it is higher on the Northwest and Southwest Gander Rivers), and water recreation use is relatively low given the windy situation on Gander Lake. Nevertheless increased cottage development and recreational use is occurring. These uses can result in point source discharges (beyond erosion and sedimentation). Consideration should be given to the potential point source discharge of these recreation developments.

3) Potential Future Inputs
All land use changes and activity changes should be evaluated for their potential to result in point source discharges (e.g. mines).

3.11 IMPLEMENTATION OPTIONS

This section provides a brief overview of the different implementation options. It is included to provide a background on the various options, and to recommend the most appropriate option for implementing each of the specific mechanisms outlined in Section 3.10, above.

3.11.1 Options for Implementing a Watershed Management Plan

There are many options for achieving watershed management objectives. Options range from strict regulatory requirements (i.e., legal mechanisms such as zoning or other law), to negotiated change or suggestions (i.e., published guidelines, development agreements, etc.), to public education and watershed stewardship programs. Generally, successful implementation requires work at all three levels.

Regulatory options are most useful for strict conservation. For issues where it is clear (both scientifically and socially) that there is only one solution, then a legal mechanism is worth the effort to implement. Regulatory options are least useful where there is ambiguity, or where following a rule (or set of rules) will not necessarily result in the best watershed solution. For example, regulations work well for prohibiting certain development types in certain areas. However, if development is allowed, it is almost impossible to put into effect a set of rules where, if followed, the best development will result. Regulations are very efficient in terms of the amount of effect achieved for the amount of effort expended. They are enforced before an undertaking begins (generally through an application procedure) and typically they require little follow-up monitoring (spot checking is usually sufficient).

Performance standards are a unique regulatory option where, instead of regulating the development type or location, a level of performance is regulated (e.g., the resulting impact on water quality is specified, such as a maximum of 25 mg/l suspended sediment from a construction site). Performance standards work best where there are many possible (and equally good) ways to develop, or carry out an activity. They are most useful where the results of different development practices are predictable (this is difficult in many cases). The biggest drawback with performance standards is that follow-up monitoring is required in order to enforce the regulation, and this can be costly and time consuming.

Options for negotiation can be within or outside of regulations. Regulations often set the framework for the negotiation, for example, regulations can be put in place requiring the negotiation to take place (i.e., development agreement requirements or permit applications). Typically, guidelines are used by the regulating agency to set the tone and expected result of the negotiation. Guidelines are essentially a written document detailing best practices, or how the regulating agency would like to see work proceed. Because they are not law, they allow for negotiation (and thus overcome the shortcoming of regulations which are less flexible when dealing with situations where there are several good ways to proceed).

Because guidelines are written "rules", there is also an element of fairness (every developer, forestry company, etc. is given the same set of "rules" as their peers, and so the negotiation is not seen as being unfair to any specific party). Also, because guidelines are frequently cited in tender document for work performed, they can act like law (e.g., the Town of Gander could require all work performed on Town tenders to be in compliance with a certain set of guidelines). Guidelines work best for activities which occur frequently, such as forestry or development, and where work is carried out by tender or application such that compliance with the guidelines may be included in a final work contract.

Guidelines can also be effective outside of regulations. Guidelines can be implemented simply by being prepared, and being distributed to interested or involved parties. Guidelines are useful to watershed stewardship groups and for public education and awareness. As published documents on how to "best" proceed, guidelines will be used by all groups interested in water stewardship, especially where there is a public input forum requirement prior to a land use activity or development proceeding.

Watershed Stewardship or Watershed Partnership programs are essential for all activities and land uses where there are numerous players and monitoring and enforcement are impractical. These programs typically combine efforts with existing groups and organizations which may already have an environmental program in place. Examples include school groups, hunting and fishing organizations, neighbourhood associations, outdoor recreation groups, boat clubs, tourism operators, and ecological defense clubs or groups. Often, by providing information to these groups and soliciting their support, they become involved in both educating members and monitoring what is going on in the catchment. The benefits of the peer pressure that may be applied to "watershed unfriendly projects" by such partnership programs should never be underestimated. Many of these groups have funding sources, or access to funding, or are able to provide labour, and thus they are often the best and most cost effective way to monitor watershed activities and collect water quality data.

Finally, public education and school education programs should always be considered. In general, if there is no significant cost difference and no significant loss of property enjoyment, individuals will choose to develop or perform activities in an environmentally friendly manner. Frequently, all that is missing is the knowledge. The best time to approach education is prior to the activity being performed (e.g., prior to building the cottage); the best method of approach is typically through a peer organization (as opposed to government). Both the timing and method of education must be carefully considered. Often, public education is best performed through a watershed stewardship program.

3.11.2 Specific Approaches for Gander Lake and its Catchment

There are no hard and fast rules for implementing a watershed management program. All that really matters is that the objectives are achieved. There are many examples where water quality was protected by purely unintentional mechanisms. For example, the water quality in the North River watershed in Massachusetts was protected by a Scenic River bylaw, implemented to preserve the visual character of the river (Steinitz 1991); and, the water quality in the Delavan Lake watershed (Walker 1990) in Wisconsin was better protected by a 15 cent drop in the price of corn, than through a series of expensive engineered treatment systems. Simply stated, if an option works, use it.

All three approaches to implementation, described above (Section 3.11.1), are recommended for Gander Lake and its catchment. Each mechanism outlined in Section 3.10 to achieve a specific watershed management objective is listed below under the most appropriate implementation approach. The approach recommended is based upon the general usefulness and effectiveness of the various options for achieving successful implementation.

<u>Regulatory Approaches:</u>

A1 Buffer Zones
A2 Restricted Use Areas
B3 Watershed Management Area

<u>Negotiated Approaches (Guidelines)</u>

A3 Forestry Practices
A4 Development Practices
A5 Stormwater Management Practices
C2 Cottage and Recreation Development Guidelines

Watershed Stewardship Approaches

A7 Monitoring of Activities and Land Use in the Lake and Catchment
A8 Water Quality Issues in the Lake and its Catchment
B2 Water Quality Issues in the Rivers
C1 Emergency Response Plan
C3 Potential Future Inputs

Achieving the watershed management objectives will also require some further research and monitoring.

The Watershed Monitoring Committee for Gander Lake, briefly described in Section 3.10, is a good choice to play a lead role in implementing the watershed management plan. The Monitoring Committee includes representatives from most of the main stakeholders in the watershed. In almost all cases, water quality will be better protected where the involved parties are able to reach agreement on how to proceed, as opposed to singular (i.e., single agency) approaches. In addition, because the Committee is formed around the goal of watershed management (as opposed to regulation enforcement) it has the opportunity to effectively implement many of the stewardship programs in a manner that need not be punitive.

There is one key stakeholder missing from the Committee, the Federal Department of Fisheries and Oceans. In addition, the Committee should consider including several citizen members, members that are connected with one or more local stewardship partnership groups (e.g., school groups, hunting and fishing organizations, neighbourhood associations, outdoor recreation groups, boat clubs, tourism operators, etc.), and at least one citizen member representing the local emergency response (e.g., firefighters).

The Department of Environment is in the best position to technically administer the Watershed Management Plan, in consultation with the Watershed Monitoring Committee. An ideal relationship would be where the Monitoring Committee utilized the Department of Environment as both the "big stick" in the event of punitive issues, and as the technical advisor on all scientific aspects of plan implementation.

3.12 REGULATORY APPROACH

3.12.1 Buffer Zones (A1)

The single most important mechanism for protecting the water quality in Gander Lake is the establishment of wide buffer zones. Buffer zones are always the most effective means of protecting water quality. In the case of Gander Lake, buffer zones are even more significant in that the Lake is surrounded by extremely steep, highly erosive banks. The geomorphology of Gander Lake is such that, essentially, if the steep slopes adjacent to the Lake were never disturbed, there would be little else required in the watershed to protect the Lake from sedimentation. Adequate buffer zones are the single most important protection mechanism.

The Department of Environment's Policy Directive (P.D. W.R. 95-01) establishes guidelines for buffer zone widths (these are currently not legislated). Staff at the Water Resources Management Division are conducting studies into appropriate buffer widths for forestry in Newfoundland. The results of such studies, when available, should be considered as well. The current guidelines are as follows:

Water Body	Width of Buffer Zone
intake pond or lake	minimum 150 metres
river intake	minimum 150 metres upstream
	minimum 100 metres
downstream	
main river channel	minimum 75 metres
major tributaries, lakes or ponds	minimum 50 metres
other water bodies	minimum 30 metres

Buffer widths, set by other jurisdictions are as follows:

Shoreline Reserve (Crown Lands)	minimum 10 metres
Federal Fisheries and Oceans (recommended)	
Scheduled Salmon River	30-50 metres
Salmon Pool	300 metres
Nova Scotia, forestry buffer, all water courses	30 metres
New Brunswick, forestry buffer, all water courses	65 metres
along all access roads	100 metres

Literature Values, include:

Chesapeake Bay Area Commission	
Critical Area Requiring Intensive Review	300 metres
R. E. Toth (1990), recommended width	150 metres
Washington State Shorelines Management Act	
No Development Zone	60 metres or the 100 yr
floodplain	

Ideally, the buffer zone for Gander Lake and its catchment should be based on the landscape sensitivity (Figure 3.2). All lands bordering the Lake and within the two highest levels of inherent sensitivity should be included in a Lake buffer. The level of the sediment delivery associated with this zone around the lake suggests that this buffer is critical (Figures 3.3 and 3.4). Refer also to the Physical Plan, Figure 3.8.

The buffer illustrated in the Figures significant. One option to consider is legislating a relatively wide protection buffer, where essentially no development or activities may occur, and then implementing very strict negotiated controls over other land uses and activities within the rest of the sensitive zone delineated. For example, a buffer of 500 metres which must be left in a forested state could be legislated around the Lake. Then, a strict control zone could be established in the adjacent sensitive areas.

Determining the most appropriate buffer width for no development or land use change is not an exact science. Recent research suggests that a minimum 100 metre buffer zone is required to protect a stream channel from uphill sediment. This comes from studies of sediment deposition which show that this width is required to trap uphill sediment where the objective is to reduce sediment load by 50 to 70 percent (e.g., Lowrance et al. 1988, Snell 1985, Cooper et al. 1987). The width of the buffer, however, should increase in direct proportion to (1) the size of the area contributing runoff and sediment; (2) the steepness of both the adjacent slope and the riparian zone; and (3) the intensity of cultural activities and disturbances in the uplands, such as agriculture, forestry or suburban or urban development (Cooper et al. 1987).

The fact that the shoreline of Gander Lake and many of its tributary rivers has most of the above characteristics, and that the Lake is protected for drinking water supply, suggests that a wide buffer zone is warranted. A zone of between 300 and 500 metres is recommended around Gander Lake; a buffer zone of 100 metres is recommended along the larger Brooks with high sensitivity ratings (refer to Figure 3.2) discharging into the Lake (Careless Brook, Joe's Feeder, Hunts Brook, Fifteen Mile Brook, and Soulis Brook); and, a zone of 30-50 metres is recommended around all other streams and lakes tributary to Gander Lake. Any ditches created by land use changes (e.g., development, forestry) will also deliver sediment to Gander Lake. Wherever possible, ditches should have a buffer zone established adjacent to them.

The buffer zones should be established under the Policy Directive, under Section 26 of the of the Environment and Lands Act. These buffer zone lands, among the most sensitive areas in the catchment, should be excluded from any land use change, as provided under the Policy Directive for sensitive lands. The regulation of activities within buffer zones (i.e., no forest clearing activities may carried out in buffer zones), may be implemented under Section 33 of the Environment and Lands Act.

Some of the buffer zone area lies within overlapping jurisdiction. The following are of concern: the special management area for cottage development, located along the eastern side of Gander Lake, currently does not require any buffer zone along the Lake (only along the rivers feeding to the Lake); the Town Plans for Gander (especially the Gander Lake Shore Development Scheme), Glenwood, Appleton and Benton, do not reflect these buffer zone widths; the Department of Natural Resources policy and leases for forest clearing are also not aligned with these buffer zones. The Watershed Monitoring Committee should encourage these department and agencies to revise their policy relative to their overlapping jurisdiction to reflect the new buffer widths.

While the Department of Environment has the jurisdiction to prevent development within buffer zones under the new Policy Directive (requirement of a certificate of environmental approval), encouraging alignment in other agencies development plans will serve to educate those policy makers about the Department of Environment's goals in the Gander catchment. In addition, this will make individuals in these agencies who deal more directly with project proponents, aware of the Department of Environment's role in the watershed and hopefully responsive to it. Finally, policy alignment should avoid confusion for the general public.

Finally, it should be noted that buffer zones are often visually unappealing when the forest has been cut to the line. A green fringe along the lake or waterbody serves to highlight, not diminish the effect of the cut behind. The visual appeal of the shoreline of Gander Lake is important to the local tourism industry. An alternative which the Town, together with the Watershed Monitoring Committee may wish to investigate is the establishment of the entire visible slope area adjacent to Gander Lake as a Protected *Area under the* Urban and Rural Planning Act. This designation would recognize the natural beauty and tourism benefits derived from these slopes, while simultaneously protecting water quality.

3.12.2 Restricted Use Zones (A2)

The catchment has been delineated into a series of zones. The zones were determined, primarily by the Inherent Sensitivity of the land (Figure 3.2) and the delivery ratio of erosion to Gander Lake. The Inherent Sensitivity describes those land units which are most likely to produce erosion and sedimentation if their land use is changed to a more intensive use. When considered in conjunction with a delivery ratio (the percentage of sediment likely to be delivered to the Lake), areas in need of protection are clear (refer to Physical Plan, Figure 3.8).

Within each zone, only compatible land use types should be allowed, and in the strictest zones, the method by which activities are carried out (level of use) should also be controlled. There are many options to implement the zones. A regulatory approach (described above) is certainly recommended for at least the first two zones (R and H). The other zones might not be established in regulation, but administered by encouragement or negotiation.

The zones delineated in the Physical Plan (Figure 3.8) are as follows:

Zone Restricted (R)
Area restricted to development. These areas are must remain forested. The Physical Plan assigns only 7.6% of the catchment into this category.

Zone High (H)
Zone H is the highest activity restriction zone. Only forestry land use should be allowed within this zone. Forest cutting should be required to follow the strictest guidelines (see below) in terms of the number of roads, road construction technique, and stream crossing technique. The forestry practice should be required to leave a minimum 40% canopy, and the sites must not be disked. A Zone H category is recommended for 9.1% of the catchment area.

Zone Medium (M)
Zone M has medium restrictions associated with it. Land Use activities include: forestry, outdoor recreation, and low impact development types (e.g., cottage, tourist accommodation, very low density residential). The development impact should be defined, primarily, by the amount of land clearing and grading associated with the proposal as well as the amount of vegetative cover that will remain after implementation (refer to Negotiated Approach, Section 3.13, below). Of the total catchment area, 35.2% has been assigned an M Zone.

Zone Low (L)
Zone L has low restrictions. Development and intensive land uses should be encouraged in these areas. All land use types, including forestry, agriculture, residential, recreation, commercial, tourist uses, etc. should be allowed in this area. However, because this is a protected catchment, the guidelines (below) should still be encouraged. This is the largest land use zone, covering 48.1% of the catchment area.

Controlling the land uses types and activities within the catchment is the responsibility of the Watershed Monitoring Committee. The Committee is encouraged to take a proactive approach to this task, by encouraging other departments and agencies to align their land use policy and activities to reflect the zones described above. This will allow project proponents to be aware of the sensitivity of the various areas of the catchment, and the Department of Environment's level of concern, prior to even envisioning a project. While the Committee and the Department of Environment have the authority to halt an activity, they will have more public support and cause less hardship to project proponents if their objectives are clearly understood at the time of project development. Project development is typically handled by other departments or agencies; these departments should not be encouraging proponents by granting land leases or building permits which are in accordance with their own legislation but unable to achieve a certificate of environmental approval under the Policy Directive, under Section 26 of the Environment and Lands Act.

The zones established above conflict with land uses allowed in the Appleton Municipal Plan, the Gander Municipal Plan, the Crown Lands forestry leases, and the Cottage Management Areas (established under Section 59 of the Lands Act).

3.12.3 Watershed Management Area (B3)

The water intake pipes for the three Towns are vulnerable to pollutants resulting from activities in the Northwest and Southwest Gander Rivers. Determining more precisely the extent of the Rivers influence on the Lake requires further study (see 3.15.2, below). There are essentially two options, either the water from the Rivers circulates through the Lake, making the Gander intake pipe vulnerable, or the Rivers bypass the Lake, making the intake pipes at Glenwood and Appleton vulnerable. Under either scenario (the actual circulation probably lies somewhere between these two extremes), water supplies are vulnerable to activities in the catchments of the Northwest and Southwest Gander Rivers.

Activities on the Northwest and Southwest Gander Rivers may have greater potential than originally anticipated to jeopardize water quality in Gander Lake. This is true, not only because there may be some level of mixing between the River and Lake water, but also because of potential future development within the River catchments. The Northwest Gander River is especially vulnerable to development. The River, near Gander Lake, has numerous cottages, is a popular hunting, fishing and boating area, has land suitable for agriculture, and has had a recent discovery of a commercially viable antimony deposit. Many of these land uses and activities are occurring in areas which appear to have relatively high inherent sensitivities. Southwest Gander River is also subject to cottage development pressure.

The designated watershed management area should be extended (by regulation) to include the Northwest and Southwest Gander Rivers. This may be established under Section 26 of the Department of Environment and Lands Act. This extension recognizes the influence the Rivers have on the drinking water quality in the three communities, and the need to consider potential impacts that might occur in the river catchments. This would also allow the Department of Environment to review development decisions and permit activities within the entire watershed.

3.13 NEGOTIATED APPROACH (Guidelines)

A negotiated approach is most effective for controlling land use and activities in areas where there are several equally good ways to proceed. In this case, guidelines are a useful mechanism for establishing the intent of the watershed management plan, or the best practice desired by the Water Resources Division. The following guidelines are recommended for the Gander Lake catchment.

3.13.1 Forestry Practices

There are existing forestry practice guidelines used by the Department of Natural Resources, Newfoundland and Labrador Forest Service. These guidelines should be revised to include the results of new research showing that road construction is a primary source of erosion and sedimentation, and several silviculture practices can lead to increased erosion (e.g. disking).

New research in forestry indicates that resource roads are the main cause of erosion and sedimentation in areas where forestry is practiced. Several members of the Western Newfoundland Model Forest team who were contacted during this study, related that field observations indicate that forestry roads generate much more sediment than clear cutting (Bonnell, 1995; Scruton, 1995). Employees of J. D. Irving Limited, Woodland Division of Sussex New Brunswick (Celeste, 1996; Gilbert, 1996) stated that roads, road construction and culvert installation techniques are the principle sources of sediment in their forest operations.

Douglas, 1996, stated that r[illegible]s, road construction and culvert installation techniques, as well as skidders, are the r[illegible] problems in his experience. This is also the experience of Agriculture Canada (Rees, [illegible]95).

J.D. Irving staff (Celeste, 1996) noted that installing culverts with an excavator or using a bulldozer and an excavator as a team greatly reduced siltation. Pile driven bridges also reduce erosion. Celeste also recommends careful planning of roads in the usual five year planning stage. Roads are a large cost of the business of conducting forestry, as well as being the main source of silt. For these two reasons, it is best to determine maximum spacing for road location. Forwarders are also recommended over skidders; a forwarder is efficient to operate up to a distance of 2000 feet from a resource road where a skidder becomes less than cost effective at 1200 feet. Irving also uses trucks with self inflating tires. Drivers can deflate tires to about half pressure when off the pavement and inflate when they leave the resource road to return to the highway. This greatly reduces rutting and siltation (Gilbert, 1996).

University of New Brunswick staff (Douglas, 1996) recommend not having low areas in forestry roads. These collect silt in dry weather and contribute it to nearby water bodies during rain storms. Douglas also recommends settling ponds.

None of these recommendations preclude the effectiveness of maintaining a healthy buffer zone, nor the importance of appropriate forest cutting techniques. Canadian provincial and federal departments have generated guidelines for logging road construction, logging around fish habitat, and other publications about how forestry can impact the natural environment. In addition, silviculture practices which expose mineral soil to improve seedling establishment (e.g., disking) can lead to a significant increase in erosion and sedimentation.

The following is a useful list of available guidelines that reflect the goal of reducing erosion in forestry practice, that may be useful for adoption in Newfoundland and Labrador:

- Brathwaite, Glen C. 1992. Woodlot Roads Stream Crossings. Canada - Nova Scotia Cooperation Agreement for Forestry Development.
- Department of Fisheries and Oceans. A Guide to Trout and Salmon Habitat for Loggers.
- Department of Fisheries and Oceans. Fish Habitat and Forestry.
- Department of Fisheries and Oceans, Newfoundland Region. 1994. Factsheet Series.
- J. D. Irving Limited, Woodlands Division. 1991. Environmental Guidelines for Watercourse Crossings.
- McNubbin, R.N. et al. 1990 (Revised). Resource Road Construction - Fish Habitat Protection Guidelines. Fisheries and Oceans Canada.
- Newfoundland and Labrador Department of Environment and Lands. Water Resources Division, Water Investigations Section. 1992. Environmental Guidelines for Watercourse Crossings.
- Newfoundland and Labrador Department of Natural Resources. Newfoundland and Labrador Forest Service. Environmental Protection Plan for Ecologically Based Forest Resource Management.
- Nova Scotia Department of the Environment. 1983. Environmental Standards for the Construction of Forest Roads and Fire Ponds in Nova Scotia.
- Ontario Ministry of Natural Resources. 1990. Environmental Guidelines for Access Roads and Water Crossings.

In addition, it is possible to quickly determine, using a GIS database, the areas of land which are most suitable for road construction. Correctly sited roads will require less cut and fill, and generate less sediment than their counterpart. This might be a subject for further study and use of the database created for this study.

3.13.2 Development Practices Guidelines

The Department of Environment should promote best management practices (BMP's) for sediment and erosion control. The Town of Gander, Engineering Department experienced a problem with sediment clogging the water intake at the pump house. Upon investigation, Town staff discovered the source of silt was a bulldozer in the Airport ditch. This example illustrates how much erosion can result from a single instance of poor development practice.

Development Practices Guidelines should address the issue of construction site management to avoid erosion and sedimentation. Examples include:

- Maryland Department of the Environment Standards and Specifications for Soil Erosion and Sediment Control, 1991.
- Nova Scotia Department of the Environment, 1988. Erosion and Sediment Control - Handbook for Construction Sites.

In addition, the Guidelines should rank land uses according to their potential to contribute erosion and sedimentation (e.g., according to their C Values in the USLE). This would give an ordering to the various land uses that would be useful in evaluating future proposals for land use change. Many seemingly benign land use types are actually notable sediment contributors, as well as sources of nutrients, e.g., agriculture, golf courses, amusement parks, and ski hills.

Another approach might be to provide guidelines, or criteria for rating future development according to its potential to contribute to erosion and sedimentation. These criteria might require development to include: minimum disturbance of tree canopy, minimum land clearing and grubbing, minimum soil exposure, minimum amount of grading (volume of earth moved), and a minimum amount of hard surfaced area (buildings, parking lots, etc.). These criteria suggest both appropriate development types and patterns, but are not prescriptive of actual land use. In terms of water quality protection, applying these criteria to any proposed development might be much more useful than zoning by land use type. This is because a given development type (land use), such as a retirement complex, can contribute either significant amounts of sediment (e.g., site leveled, large flat parking lot, grading performed to shape the site, a high percentage of lawn, sprawling building footprint, etc.) or very little sediment (e.g., forest canopy maintained, small building footprint nestled into contours, parking lots scattered to fit with the land form, etc.). The criteria allow for the evaluation of a land use change or development proposal based upon its actual anticipated impact (high, medium or low), irrespective the development type itself.

Of most concern in the catchment, in terms of development, is the proposed Gander Lake Shore Development Scheme to the west of the pump house in Gander. Expansion of the golf course, ski hill, and other recreation facilities near the pump house, and especially to the west of the pump house, threaten the integrity of the Gander water supply. The development types proposed are examples of development types which are highly variable in terms of their impact, and where the impact will largely depend upon the actual facility design (not its type). These developments include: a retirement complex, a camping/trailer park, tourist accommodation facilities, a commercial amusement park, the golf course expansion, and an outdoor amphitheater.

Evaluating these developments according to the criteria described above would be of more benefit to protecting the water supply than zoning by type or level of use.

In addition to recreation area, the RUR zone in Gander, which extends to the steep slopes adjacent to the Lake outside of the recreation area, allows for agricultural land use. Agriculture would not easily meet the criteria described above.

The development guidelines should also address road construction. There is often confusion about the amount of disturbance caused by road construction. The Gander Municipal Plan calls for road construction in the new recreation area to be perpendicular to slopes in order to minimize cut and fill and landscape disruption (Section 3.10.2 (5) II). This is the correct approach. Roads should be constructed parallel to the contours wherever possible, and when they must cross contours, do so where the contour interval (land slope) is similar to the road slope.

In addition to Municipal roads, the Provincial Department of Works, Services and Transportation hopes to twin the TransCanada Highway across Newfoundland. One route alignment option is in the area of the power line corridor between Gander Lake and the Town. This area has a very high inherent sensitivity (sensitive to erosion). In addition, stormwater from the new highway would need to be directed towards the Lake (any spill, road salt, etc. would be directed towards the Lake). A much better route, from a water quality perspective, would be closer to the existing highway, or to the North of the Town of Gander. If this expansion occurs, caution must be exercised during construction. Highway construction can result in significant erosion and sedimentation. Careful layout must be assured and very stringent construction guidelines applied. The development guidelines should address this concern.

Through the use of sediment and erosion control methods in construction and land management practices, land developers and managers can ensure that their activities present minimum impact on water quality of Gander Lake.

3.13.3 Stormwater Management Practices

The stormwater guidelines yet to be developed for the Gander catchment are anticipated to be much different from typical stormwater management guidelines. Most stormwater guidelines are written to address the problem of downstream flooding, where stormwater from a new development must not be released in greater volumes than occurred pre-development in order that a downstream drainage system is not overwhelmed. As a result, the typical approach is to model the post-development runoff likely to occur from a given development during a large storm event (e.g., a 100 year storm). This runoff volume is then compared to the runoff volume in the pre-developed condition. The landscape is then configured with ditches and ponds sized to convey and to store this increased runoff volume, such that the resulting peak flow leaving the development is kept the same as under the pre-development condition. The resulting landscape appears similar to that shown in the photographs in Appendix F.

Flooding is not a development issue in the catchment. Certainly flooding occurs, however, the amount of increased flooding (over natural levels) that might be correlated to increased human development is negligible. In addition, when there is a substantial forested buffer zone around the receiving water, the pollutant delivery via stormwater is lessened. This is reflected in the Gander Municipal Plan, which notes that there is little problem with releasing storm water from proposed developments in the new recreation area into existing ditches or onto lower slopes, as long as the development remains at a distance from the Lake (Section 3.10.8 (2) c).

There is, however, another serious issue which is often overlooked, and yet is associated with increased volumes of stormwater runoff - increased stream bank erosion. It is this issue, stream bank erosion, which should be the focus of the stormwater management guidelines for the Gander catchment.

In a natural situation, there is a storm (typically with a return interval between 1 to 1.5 years, which defines the morphology of a natural channel (Leopold 1994, Newbury and Gaboury 1993). The runoff from this rainfall event has sufficient energy, and occurs frequently enough to define the stream bank and establish a dynamic equilibrium. Larger, infrequent storms cause the stream to flood its banks, but do not seriously affect the channel itself. When development occurs, both the runoff volume and peak flow from any given storm increase over the pre-development condition. This causes significant stream bank erosion, as the stream cuts deeper or wider (depending upon geomorphology) to reestablish equilibrium. This effect can be accelerated by steep slopes.

In addition, where there are no defined channels, surface runoff flowing as sheet flow over the landscape will increase in both volume and velocity of flow in a developed (versus predevelopment) condition. This also results in increased erosion.

Stormwater management guidelines to reduce erosion would require absolute minimum disturbance of the landscape, maximum retention of tree canopy and vegetation (trees are large stormwater consumers), protection of natural areas where stormwater infiltration occurs, minimum increase in hard surface area, and development patterns and types which encouraged stormwater infiltration as opposed to increased runoff. As opposed to modelling a 1 in 100 year storm, the channel defining storm would be modelled, and post-development would be required to match both the flow volume and frequency of that storm. A 2-year storm is often a good choice because it is often available from Environment Canada. The development resulting from these guidelines would be much different in appearance than that shown in the photographs in Appendix F.

Stormwater management guidelines also must recognize that a ditch is equivalent to a stream in its delivery of sediment and erosion to Gander Lake. All ditches, tributary to Gander Lake, should have a buffer zone established adjacent to them, equivalent to that required for a stream (e.g., 30 metres).

3.13.4 Cottage and Recreation Development Guidelines

Cottage development within the Cottage Development Areas established by the Lands Branch are predicted to result in more sediment deposition in Gander Lake than any other development activity, and nearly as much as proposed forestry activity. The Watershed Monitoring Committee should play a lead role in working with the Lands Branch to find better cottage development areas within the catchment. In addition, cottage development guidelines should be created to encourage owners to develop their cottage land in an environmentally appropriate manner.

Legal cottage dwellers represent an appropriate place to begin educating wilderness users about environmental stewardship. Those who come to enjoy what nature has to offer are likely to be good stewards of the water and land if they are given the information they need to make the right decisions. Cottagers come to hunt, fish, pick berries, boat, and for other reasons related to the natural resources of the area. If the level of use exceeds the carrying capacity of the land and water, they may lose the enjoyment of these resources, but the users may not realize this.

A legal permit for a cottage should be accompanied by a cottage lot "manual". (It will be difficult to change existing cottages because of the expense involved.) Such a manual should contain guidelines related to the following areas of cottage development and recreation use:

- lot layout (where building should be located, avoiding steep slopes, etc.);
- maintaining tree cover (erosion);
- ATV use (danger as well as soil erosion);
- driveways (steep slopes, stream crossings);
- on-site systems (nutrient contribution and lake environments);
- location of docks and waterfront access; and
- garbage disposal.

These and other topics could be included in the package. Also, new owners should be informed, in the information package, about how these techniques protect the resources, i.e., how silt affects salmon and trout. Once some cottagers are practicing stewardship on their land, peer pressure should help to make the reluctant comply with better management practices. Having youth and school groups involved in the Watershed Management Committee will also help foster good stewardship. Children are usually open to ideas about resource protection, and parents often support their children in such endeavours. Even if adults do not comply, the next generation of cottagers will be well informed at the start.

A further step would be to require cottagers to submit a plan of their proposed lot development, including the location of the access road, cottage, on-site sewage disposal system, and any forest clearing, to the Watershed Monitoring Committee. The Committee could then evaluate the proposal, referring to the development guidelines (described above, Section 3.13.2), and work with cottage owners to improve their plan.

3.14 WATERSHED STEWARDSHIP APPROACH

3.14.1 Monitoring of Activities and Land Use in the Lake and Catchment (A7)

Monitoring of activities and land use in the Lake and its catchment is essential to ensuring the effectiveness of the programs and controls implemented. Regulatory monitoring, where an enforcement officer ensures compliance, is typically a very expensive. If it is the only approach, the chances of getting "caught" are often so slim that proponents may not follow the regulations.

An alternative approach empowers citizen stakeholders who are already present in the catchment to take on a monitoring role. Citizens can be trained to observe and report on actual infractions; they may also be trained to collect water samples and perform simple water chemistry. In this way, many individuals who are on the ground in the catchment can be utilized to help ensure compliance.

Citizen volunteers could be coordinated by a representative from the Town of Gander, and report to the Watershed Monitoring Committee. An office (a room) and a phone number (with an answering machine) in Gander would also be required (the Watershed Stewardship Office). This might be located in a school or other public facility. Citizen volunteers must then be trained to recognize erosion problems and other issues in the catchment, report on them, and collect water samples. The office could also distribute guidelines to the public, and accept phone calls from the public reporting problems observed in the catchment.

The Watershed Stewardship Office need not have any official enforcement capacity. Most very successful water stewardship groups have actually little if any legal enforcement capacity. These groups are successful because they have public support, and because peer pressure works. It is much harder to break the law if someone is watching you, even if that person has no mechanism to make you stop.

Two successful Nova Scotia examples of watershed stewardship offices are the Dartmouth Lakes Advisory Board, and the Clean Annapolis River Project (CARP). Both of these groups monitor water quality issues. The Dartmouth Board advises developers and City Council on any development in the Dartmouth Lakes region. The Board has no actual legal mechanism, however, it is well known that a smooth passage through Council requires a "stamp of approval" from the Board. CARP is a much larger organization involving many citizen volunteers. CARP actively monitors water quality issues, collects water samples, maintains a watershed management GIS database, and directs funding to projects which clean up the river. CARP volunteers are successful at all technical monitoring tasks.

A local example of a successful watershed stewardship program is the Indian Bay Ecosystem Management Process. The Indian Bay Ecosystem Corporation's watershed management proposal was the first community based recreational fishery management project to receive official Pilot Project status from the Provincial Government in 1994. In doing so, the government entered into a five-year evolving process with the Corporation with the objective of defining a management strategy that would protect and enhance the fishery resource, but equally important, would generate economic wealth, preferably from out of province sources. This management strategy would be designed to incorporate communities in the decision making, planning, management, enforcement and development control processes.

There have been a variety of significant players involved in the process ranging from community leaders and volunteers, the Economic Recovery Commission, businessmen, academics, scientists, federal and provincial government planners and biologists. Much of their work has been assisted by the funding made available through the Canada Agreement on Salmonid Enhancement and Conservation. The emphasis of the work to date has been on habitat restoration and fish stock, primarily trout, rehabilitation. The results have shown that with strict management, the stocks have the potential to return to their historic trophy size and legendary abundance. However, more collaboration is required with other agencies to truly have an integrated planning approach. Agencies such as Water Resources and Forestry whose activities and research have much to contribute towards habitat management need to be incorporated into the planning scheme.

The Corporation is managed by a Board of Directors elected from the member communities participating in the project in accordance with the bylaws of the corporation. These directors represent the interests of their communities in the decisions being made in terms of the research and recreational fishery management regulations for the watershed. In 1996, a management plan will be developed to formalize the framework for continuation of the project beyond the five year pilot project timeframe.

A good information source for establishing watershed stewardship programs is The United States Environmental Protection Agency publication, "Nonpoint Source Watershed Workshop", Washington DC, September 1991 (EPA/625/4-91/027). This publication includes many case studies and "lessons learned" from other jurisdiction which have implemented similar programs. In addition, Stephen Hawboldt of CARP is an excellent source of information on establishing watershed stewardship groups and Canadian funding sources.

3.14.2 Water Quality Issues in the Lake, its Catchment, the Rivers and River Catchments (A8, B2)

Citizens are frequently the first observers of a water quality issue or problem in the catchment. The best way to harness these observations is to educate citizens, so that they recognize a problem and know where to report it.

There are many organizations who may be active in the catchment. These include, among others: school groups, hunting and fishing organizations, neighbourhood associations, outdoor recreation groups, boat clubs, tourism operators, and ecological clubs. All of these groups have a stake in ensuring that a high quality environment is maintained within the catchment.

These groups should be the focus of outreach programs initiated by the Watershed Stewardship Office. Through distribution of the guidelines developed, presentations which might be made to the groups, and effective follow-up on the issues reported, the Watershed Stewardship Office can take advantage of the presence of all of these individuals in the catchment. These groups in turn will include individuals trained in biology, engineering or other sciences, as well as "old timers" who remember what conditions were like in the past. All of these individuals will be able to make a substantial informed contribution to the Watershed Stewardship Office.

By working through existing groups, an organization structure is achieved at little overhead cost. The existing groups can undertake to educate their members, and further distribute information as required.

3.14.3 Emergency Response Plan (C1)

Spills of hazardous material within the watershed area threaten public health, natural resources and economic activity based on them, as well as fish and wildlife habitat. Potential hazards were discussed in detail in Section 1.7. Gander Lake is vulnerable to environmental emergencies. The volume of traffic and materials transported on the TransCanada Highway, underground fuel storage, the existence of an International Airport, as well as the Airforce Base present opportunities for accidental spills.

An emergency response plan requires many different players, at many different levels. Government agencies have a technical role to play in assessing the problem and determining the most appropriate clean up plan. Local groups are necessary to implement the plan in a rapid and coordinated manner. In many cases, rapid response is essential to containing the problem and protecting the environment. For this reason, it is important that an emergency response plan is in place.

The emergency response concept for Gander Lake and its catchment is to have people and equipment, in the Gander area, ready to respond to, and capable of dealing with, environmental emergencies. The provincial Department of Environment, Water Resources Division, as well as the Watershed Monitoring Committee, should play a lead role in the development the emergency response plan. Actual emergency response and direction of the emergency response team should be coordinated in Gander.

An emergency response team for Gander Lake and its catchment should include representatives of the Towns, the relevant provincial and federal departments (especially those with offices in Central Newfoundland), Canadian Forces Base Gander, the Search and Rescue Unit at the Base, Gander International Airport, the Gander and Glenwood Fire Departments and the Atlantic Canada Regional Environmental Emergency Team Contingency Plan (REET) agencies that can provide assistance with training and existing contingency plans, as well as expert advise on technical issues.

The Atlantic Provinces, in conjunction with Environment Canada, Environmental Protection Branch, have developed the REET. The "team" is comprised of technical experts in various government agencies who are available to provide advice and assistance in developing emergency response plans and in the event of an actual emergency. In emergency situations, technical advice is required at the assessment stage of the problem and during clean up and remediation activities. More detailed information on REET is found in an Environmental Protection Branch publication called Atlantic Regional Environmental Emergency Team Contingency Plan, published by Environment Canada in December 1994.

The following paragraphs describe REET agencies in Newfoundland and particularly those in Central Newfoundland.

Atlantic Canada Regional Environmental Emergency Team (REET) determines the chain of command in a major event. The Newfoundland and Labrador Department of Environment, Environmental Management Division and Government Service Centre, in cooperation with the Government Service Centre, is the lead agency where spills occur under their jurisdiction (i.e., not on federal property). The Department of Environment is responsible for investigating spills that originate from land based sources or sewers, and spills that affect water supplies. They may also be the agency to which the incident is first reported. The Environmental Investigations Division is located in St. John's.

In the event of an emergency, the Environmental Management Division and Government Service Centre is responsible for determining disposal sites, disposal procedures, and cleanup. To perform this role, they may solicit advice from other REET agencies. Environment Canada, Environmental Protection Branch, provides advice on oil spills and their containment. Environment Canada Atmospheric Environment Branch has a climate station at Gander Airport. In the event of an emergency, Branch staff can assist by providing weather information that is helpful in determining how materials will behave as a result of wind and precipitation. Environment Canada, Canadian Wildlife Conservation has an office in Lewisporte and in St. John's. This agency can provide advice on wildlife and wildlife habitat related to hazardous material spills. Finally, Fisheries and Oceans Canada have staff who are knowledgeable about the Gander Rivers and Gander Lake. They are located in St. John's and at a field station on the Lower Gander River. Staff would be valuable in an incident that threatens aquatic life in these habitats.

If the spill originates from a federal facility (e.g., the Airport or DND lands within the Gander catchment), where the source of the spill is unknown, or where the spill affects waters frequented by fish (e.g., a spill on the TransCanada at Soulis Brook or the Gander Outflow), Environment Canada, Environment Protection Branch would be the lead agency under the REET scheme. The role and responsibilities of Environment Canada in this situation is similar to that described above for the Environmental Investigations Division in their jurisdiction. Environment Protection Branch staff are also located in St. John's.

The lead agency is also responsible for organizing the cleanup and disposal at the spill site. In order to accomplish this, an on site response team is required. The response team is essentially a body of workers with competent intermediaries to disseminate information and control the response effort. Because a timely response is frequently essential, it is important to have workers and suitable supplies located in the immediate area. This greatly reduces the cost of clean up operations and the time it takes to respond. For instance, workers who live in the area will not require housing, and materials will not have to be transported in at the time of the incident.

Establishing the on site response team will be the most important aspect of an emergency response plan for the Gander Lake catchment. There is currently no response team in the Gander catchment, although there are several existing elements in place. These include the environmental contingency plan for the Gander Airport, the existence of CFB Gander, and the local fire departments.

Gander International, like all Canadian Airports, has an environmental contingency plan. The plan outlines a communication and response procedure for the individuals and agencies involved. Airports maintain a supply of products and materials for cleanup. The contingency plan also holds a list of local contractors and agencies who are able to provide materials and services should they be required. Gander Airport should be asked to demonstrate their response capability to the Department of Environment and share their knowledge about emergency response in the Gander area. They can also define their area of responsibility in respect to response. The Airport may also be able to offer materials and equipment in the event of a spill outside of their jurisdiction as part of the complete response team for the catchment.

CFB Gander is located at Gander Airport. The base has a workforce of almost 500 including military personnel and civilian employees. CFB Gander is also home to 103 Search and Rescue Unit, with a staff of almost 100 people. The Unit and the Base are potential sources of staff and equipment in case of emergency. The Base should demonstrate, to the Department of the Environment, its emergency plan for its areas of jurisdiction. The Base should also be solicited for advice, materials and labour as part of the complete response team for the catchment.

Another potential source of workers in the event of an environmental emergency are the Town of Gander and the Town of Glenwood Fire Departments. These individuals are trained to operate under emergency situations and prepared to respond quickly in times of need. The Fire Stations may be good locations for materials storage, and emergency coordination.

Once the structure and mechanism for on site response has been established, information and training may be required. Emergency Preparedness Canada, with a representative in St. John's, can provide emergency training courses in conjunction with the federal and provincial governments. In addition, Environment Canada, Environmental Emergencies Section in Dartmouth, Nova Scotia, is represented on the REET team. This agency can provide information on contingency plans, resource sensitivities, environmental impacts and emergency counter measures. The Environmental Emergencies Section is a good source of information for groups formulating a contingency plan.

Representatives of all the agencies described above need to meet in order to formulate a coordinated approach to emergency response. They must decide who is responsible for what, what is required to protect the resources, what equipment and support systems are presently available in the area, and what other equipment and resources are needed. Once a plan is in place, the agencies need to meet on a regular basis (e.g., annually) to review the plan and make certain that it is still viable.

In addition, to describing roles and responsibilities, the Plan should identify the most vulnerable areas in the catchment from the perspective of water supply protection. Refer to Figure 1.12, Hazardous Materials. For particularly vulnerable areas, like the Soulis Brook Bridge where a spill on the TransCanada could result in a direct discharge to the Lake, the plan should recommend emergency response practice sessions. Finally, a goal of the response plan should be to contain the spill on land. Containing spills on land will require a plan with a high level of local preparedness and a rapid response time.

3.14.4 Potential Future Inputs (C3)

Protecting the water quality of Gander Lake will require that all future land use and activity changes within the Lake and River catchments are evaluated for their potential to generate point source pollution. While there are no currently significant point source concerns in the catchment, this may not always be the case. Keeping abreast of potential future inputs will require an ongoing involvement and interest in the watershed, as well as a local source of information on what is actually occurring in the catchment.

Responsibility for keeping abreast of potential future inputs should rest with the Watershed Monitoring Committee. The Monitoring Committee itself should monitor large scale developments and provincial and federal government issues which might affect water quality in the area. In order to fully achieve this objective, the Monitoring Committee should again make use of citizen observers who are already in the Gander catchment (many members of the Watershed Monitoring Committee are not Gander residents). Similar to Section 3.14.2 above, citizen observers should be established by outreach programs to existing groups from the Water Stewardship Office in Gander.

3.15 LONG-TERM WATER QUALITY MONITORING AND MODELLING RECOMMENDATIONS

There are several areas of concern, that were beyond the scope of this study, that require further research. These are briefly summarized below.

3.15.1 Further Research to Calibrate the Watershed Management Decision Model (A6)

Additional research to better calibrate the Watershed Management Decision Model is essential to better informing the watershed plan.

As noted in Section 1.7, runoff (in Newfoundland) has not been monitored for pollutant contributions. This is true for all types of land use, including forestry, the most commonly monitored activity in other areas. Therefore, the study team determined likely pollutant contributions, for specific types of land use, based on research in the New England States and in the Maritime Provinces. While the resulting numbers are useful, they are not specific to the climate and soil conditions of Newfoundland.

Land to the south of Gander Lake, at the east end, is scheduled for logging operations that will last for the next 10 to 15 years. The logging road enters off the Trans Canada Highway, opposite Denty's Pit (the asphalt plant area). The first major sub-catchment in the cutting area is Joe's Brook. This would make a good location for a stream flow and water quality monitoring station.

Water Resources Division should require that the forestry company operating in this area establish a monitoring station near a forestry road (apparently more deleterious to water quality than cutting). To provide good base data, the watershed needs to be monitored for one year before any cutting takes place. The watershed then needs to be monitored for the period of cutting and for several years afterward to show how forests in the Gander area recover from clear cutting. This would help to determine how detrimental forestry activity, in the designated catchment, is and to generate actual numbers to further refine the GIS model.

3.15.2 Lake Circulation Modelling and Research (B1)

Additional circulation modelling and field work is required to determine to the level of influence the Northwest and Southwest Rivers have on the Lake. This work has bearing on all of the decisions related to the influence of the Rivers on lake water quality and the importance of protecting the River's catchments.

If this work determines that there is indeed a significant effect on the Lake, then more detailed study of the River's catchments, and the implementation of land use controls, would be essential.

3.15.3 Lake Water Quality Sampling and Monitoring

This study has determined that Gander Lake does in fact turn over twice a year, has determined that the current Lake water quality is excellent, and has refined the bathymetric shape of the Lake. Further, Lake water quality sampling is probably not warranted at this time. The volume of the Lake is such that the majority of parameters are non-detectable in the water column. This, together with the Lake's size and wind conditions, make further research oriented water quality sampling very expensive for little return.

Instead of focusing on sampling Lake water quality, further water sampling conducted by the Department of the Environment, should be focused on the contributing streams and perhaps the sheltered cove areas, where results are detectable and can be extrapolated to predict resulting Lake conditions (Section 3.15.1 above). This is the most important sampling work. Water sampling in the Lake itself should be limited to investigations of direct environmental problems.

In addition to undertaking water sampling in contributing streams, the Watershed Monitoring Committee should assemble and organize water quality sampling by other groups, and support others in their water sampling efforts. Water quality samples taken at the intake pipes of the three Towns should be assembled and monitored. The Federal (Fisheries and Oceans) sampling efforts should be supported, as well as any sampling by Universities. The Gander Rivers are a focus of Fisheries and Oceans due to the excellent salmon population, and the Lakes unique morphology offers many interesting research opportunities for University students and others. All of these efforts should be supported by the Watershed Monitoring Committee, and wherever possible, the Committee should barter for the data these studies collect.

3.16 ADDITIONAL DATA COLLECTION

3.16.1 Model Forest Research Update

The Department of Environment is involved in research in the Western Newfoundland Model Forest (WNMF), near Corner Brook, on the effects of forest activity on water quality. WNMF has not yet generated any published data for pollutant contributions resulting from forestry activity. When data is available, the Water Resources Division should compare the Newfoundland data with that from New England and the other Maritime Provinces which used in this study. If necessary, the study results should be adjusted to better reflect Newfoundland conditions.

3.16.2 Old Land Fills

Several landfills have been closed in the Gander area. It is unlikely that closure measures, such as those currently required, were instituted. Contents of the landfills are also unknown. As was common practice in the 1930's and 1940's, the U.S. Airforce may have deposited a variety of material or equipment in its landfills.

It may be impossible to trace the deposit of materials, because it is unlikely that records were kept. Also, due to the nature of military service, regular and constant turnover of staff, it would be extremely difficult to find anyone who might know what was placed in Gander's landfills. However, studies of leachate may be able to disclose what types of pollutants are leaving the landfill areas and what measures should be taken.

3.16.3 All Terrain Vehicles

In Newfoundland, all terrain vehicles (ATV's) have made large areas of land, previously protected by their remoteness and inaccessibility, available for those who hunt, fish, and pick berries. All over the island, trails are obvious and numerous. The use of ATV's in wetland and stream habitats is commonly considered deleterious. Where people ride ATV's across peatlands, ruts develop. When driven through streams, the vehicles disturb stream beds.

The extent of damage is largely unknown, but the Department of Natural Resources, Land Management Branch is investigating environmental effects. The Department is attempting to regulate use of the vehicles by establishing legal trails to keep the traffic on a smaller number of paths. Obviously, the Department's policing power is incapable of patrolling the numerous trails. More investigation is needed to determine the extent of damage and to find an effective mechanism to prevent abuse of the wetland and stream resources.

3.16.4 Industrial Areas

There are no major industrial areas in the Town of Gander, but small industries in the catchment area may contribute undesirable substances to the Lake. Sawmills at Benton, Glenwood, and Appleton stock pile sawdust and wood chips, that upon decomposition, may produce leachate. The golf course, farms, gravel pits and the asphalt plant (Dente's Pit in the east end) may produce sediment and contribute elements that are associated with poor water quality.

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PART 4: CONCLUSIONS AND RECOMMENDATIONS

4.1 INTRODUCTION

This section provides a summary of conclusions from Parts 1, 2 and 3 of this study. The conclusions are presented in the order that they are found in the report. Recommendations are, primarily, from Chapter 3.

4.2. PART 1 – CONCLUSIONS

Part 1 of the study involved the collection of background information on the Gander Lake and its catchment, including the compilation of slope information, past, present and future land use information, and information on water quality and quantity.

- The valleys of Northwest Gander River, Southwest Gander River, Hunts Brook, and Careless Brook exhibit glaciofluvial material which is some of the most fertile soil in the Province, relative to Newfoundland agriculture conditions. Soils contribute sediment and nutrients to the Lake when eroded.

- The steepest slopes in the catchment area are on the sides of Gander Lake, which rise sharply to a flat plateau on the north side of the Lake where the Town of Gander is built. South of Gander Lake, the Lake shore rises to topography that is hilly and higher in elevation in many areas. Steep slopes are more prone to erosion than flatter slopes. The most significant areas of concern in terms of development are steep shoreline slopes. These are particularly sensitive when roads are built, trees are cut, or the soil is exposed through development.

- Gander has a temperate climate with an average annual precipitation of 1181 mm. The maximum temperatures are experienced in July at 21.66° C (average) and the minimum in February at -11.8° C (average). Westerly winds are most common at Gander. These are strongest in the west end and middle of the Lake, and are somewhat dissipated by the hills before they reach the east end.

- While scientific survey of this area dates back as far as 1874, there were gaps in the information needed to understand how deep the Lake is and to what extent this large lake environment is capable of assimilating pollution and still provide clean drinking water to the Towns of Gander, Glenwood and Appleton.

- Bathymetric information was collected to supplement that surveyed by Memorial University's Physics Department in 1962. The deepest point of the Lake was confirmed *to be 290 m east of the Town of Gander.*

- Prior to water quality data collection, the MinLake model was tested to determine the particular water quality parameters, to which the model was sensitive. Ortho-phosphorous, total dissolved phosphorous and chlorophyll were added to the sampling program to support the model's input requirements.

- In June, 1995, samples were taken at locations where some influence from the catchment was anticipated; others were located near the confluences of incoming and outflowing rivers. Because the Lake shore drops off rapidly in many areas (facilitating fast assimilation in deep water), and because many parameters were not detectable, sampling sites were moved closer to shore for the September program.

- Low levels of fecal coliform bacteria were noted in one location in the June program and nine locations in the September program. The increased presence (not at levels of concern) are attributed to locating sampling sites nearer to shore, as well as the presence of cottagers throughout the summer months.

- Gander Lake is an oligotrophic lake, which means that it has low biological productivity due to low organic input. It is also a dimictic lake which means that it mixes, or turns over, twice a year and exhibits thermal stratification. The lake environment is resilient to the pressures of land development.

- Forestry is the primary land use in the catchment of Gander Lake and will continue to be an important economic activity in the area. When the area was largely inaccessible, dams were used to drive logs to Gander Lake and on to Glenwood where they were loaded on trains for transport. Cutting became more extensive following construction of the Trans Canada Highway in 1965. A large cut will be operational for the next ten to fifteen years at the southeast end of Gander Lake. Forestry is known for causing erosion and sedimentation problems, and forestry resource road construction is a primary source.

- Urban areas within the catchment include the community of Benton, the Towns of Glenwood and Appleton, and the Town of Gander including Canadian Forces Base Gander and Gander International Airport. The entire area was rural in character until the airport was built in 1936 and the Town of Gander was built in 1952. During its most significant development period, Gander's population went from 603 in 1941 to 7183 in 1966. Gander's population continues to increase at a slow rate. Presently, it is about 10,000 and the population for the whole watershed is about 12,000. Urban areas, which can contribute nutrients, organic matter, heavy metals, as well as oil and grease, are not extensive.

- The golf course and ski hill west of the Gander pumphouse are potentially major sources of sediment at the water supply intake pipe. Development and management practices need to be applied in these and other developments on the steep slope adjacent to the pumphouse area.

- While runoff control measures have been implemented at the construction site of the hospital expansion, erosion and sediment control measures have not. The measures implemented appear to be designed to control flooding (large storm incidents), and have required significant land grading and grubbing. They may result in a net detrimental effect. Sediment and erosion control measures, such as maintaining vegetation, minimizing grading, and maximizing infiltration should be the goal on these sites.

- Agriculture has never been a significant activity in the catchment area, though the agriculture potential has been recognized. The Department of Fisheries, Food, and Agriculture maintains an experimental potato seed farm near Glenwood and had set aside several areas on the Northwest and Southwest Gander Rivers as agricultural development areas. Siltation, increased nutrients, herbicide and pesticide input due to agriculture should not be a problem in Gander Lake.

- Mining has not been a significant activity in the catchment, except for regular extraction of gravel for construction. A recent discovery of antimony on the Northwest Gander River (outside of the direct catchment area, but within the watershed), is commercially viable. Mine development can jeopardize long-term sustainable resource uses like the Atlantic Salmon fishery in the Gander River because acid runoff often decreases the pH of water.

- Many people use the rivers, lakes and ponds of the catchment and watershed of Gander River for recreation. Some of the areas used were the former logging camps operated by forestry companies prior to the 1960's. The main area of demand for cottage development is the Northwest and Southwest Gander River areas where the Department of Natural Resources, Land Management Division has set aside a cottage development area.

- The effect of sewage discharges from cottage development areas appear to be insignificant when compared to the overall catchment land use contributions. However, sediment and nutrient inputs resulting from cottage construction, and associated vehicle use may be very substantial. The all terrain vehicles (ATV's) associated with many recreation uses may have an even larger effect than the cottages.

- The water supply provided by Gander Lake meets or exceeds Canadian drinking water quality guidelines. The Airport drainage ditch is near the pumphouse intake and, on at least one occasion, has been the source of silt that clogged the intake pipe.

- Gander River is considered one of the best rivers in North America for Atlantic Salmon. The fish population in the rest of the catchment does not compete with the Gander River, but people also fish on the Northwest and Southwest Gander Rivers, as well as on Soulis Brook and in the west end of Gander Lake.

- Boating is not popular on Gander Lake because of rough water conditions and strong winds. There is one small marina west of the Town of Gander on the north side of the Lake. Boaters are most active in the Northwest and Southwest Gander Rivers and there is a larger marina at Glenwood, outside of the watershed area.

- Swimming is insignificant in Gander Lake, as the water is cold. The east end where there is a small beach has some swimming activity, but this is only in the months of July and August.

- Two sewage treatment systems discharge indirectly into Gander Lake. The Town of Gander discharges treated sewage in a series of wetlands that eventually drain into Soulis Pond and Soulis Brook which runs into Gander Lake. Benton's large on-site system also drains into the area around Soulis Brook.

- The Airport drainage ditch discharges directly into Gander Lake. The Airport ditch monitoring data shows that the runoff water quality from the Airport drainage area is similar to that of other semi-urban areas.

4.3 PART 2 – CONCLUSIONS

- A water balance for the catchment utilized monthly runoff coefficients, rather than the annual estimate of 6.8 or 68%. This was done because some months (winter) exhibit little or no runoff, and some months have high rainfall, or rainfall combined with a large volume of runoff due to spring melt.

- The model simulations of Lake water circulation (using the DYNHYD component of WASP) predict that a substantial fraction of runoff from the Northwest and Southwest Gander Rivers circulates through the upper layer of the central and eastern regions of the Lake. Thus, the quality of Gander Lake, even in the central and eastern portions, is not entirely independent of the water quality of the Northwest and Southwest Gander Rivers. This means that activities in the headwaters and watersheds of both of these branches of the Gander River may affect the drinking water supply and the environment of Gander Lake.

However, water quality data collected in Part 1 does not conclusively support this claim. Information and data available at this time is insufficient to determine exactly how far, to the east, river water circulates in Gander Lake. A conservative approach suggests that both limited and complete circulation should be planned for.

- For central and eastern regions of the Lake, the residence time is shorter than might otherwise have been anticipated in the absence of winds, the aerial water loading is higher, and the assimilative capacity is greater than if the runoff from the large Rivers was confined to the western region of the Lake.

- Phosphorous is expected to be the limiting nutrient in Gander Lake. Phosphorous flux in this catchment is associated with eroding sediments. Quantitative assessments of assimilative capacity for phosphorous indicate that there is reserve capacity at present.

4.4 PART 3 – CONCLUSIONS

- The disturbance of soil, its mobilization, and subsequent deposition in surface waters is the primary delivery mechanism of phosphorous and other non-point source pollutants into Gander Lake. This assumption, which held true for Gander, is typical of non-urbanized catchments, and is the basis of the Watershed Management Decision Model created for this project.

- The Watershed Management Decision Model is a straight forward, but powerful means of quantifying the impact of various land uses. The method implicitly considers the range of impacts resulting from different land uses, how the impacts change with respect to variations in landscape units, and how these factors combine to affect water quality in Gander Lake.

- The inherent sensitivity of the catchment is a measure of erosion sensitivity irrespective of land use. The inherent sensitivity map shows those areas most sensitive to any land use change. Generally, the most sensitive areas are the steep slopes along the sides of Gander Lake. The Town of Gander is actually situated in an area of the catchment that is well suited to development.

- Actual sediment delivery from the catchment to the Lake was estimated by the Watershed Management Decision Model. The model was calibrated using expected export values for sediment and phosphorous. These values were determined from the literature, water quality data collected in Part 1, water sampling results collected by others, and from team members' experience in other watersheds. The total expected sediment export from the Gander Lake catchment is estimated at 54,500,000 kg/yr. The total amount of phosphorous delivered to Gander Lake was calculated by summing that delivered from the catchment (in sediment), the atmosphere (in precipitation), and from anthropogenic sources (like sewage). Approximately 7,800 kg/yr of phosphorous is expected to enter Gander Lake.

- The model was run using the expected future land use coverage to predict future inputs. The model results indicate that future forestry will result in approximately a 34% increase in the sediment load from the catchment (the worst case scenario, if the area is clear cut and the soil is disked, is approximately a 74% increase).

- The model is also predicting a further 46% increase in sediment loading to Gander Lake resultant of future recreation and cottage development. These proposed uses are located in areas of high inherent sensitivity.

- The Lake and its shoreline were considered for sensitivity in three ways: lake sensitivity to the catchment; lake sensitivity to a less well mixed east end; and lake sensitivity to the NW and SW Gander Rivers. The expected future sediment delivery predicted by the Watershed Management Decision Model was correlated to expected increases in phosphorous as a result of this increased sediment delivery for all three scenarios. The results indicate that the Lake is sensitive to increased inputs. In particular, to the scenario where circulation of both Rivers throughout the Lake is assumed.

- The catchment was also modelled for sensitivity to point source inputs. A map illustrating the best (and worst) locations for a points source discharge was created. The Town of Gander is well situated for future point source loadings.

- The Physical Plan prepared for the Gander Lake catchment considered, primarily, the inherent sensitivity of each landscape unit in the catchment, as well as the potential for that landscape unit to deliver sediment (and other nutrients) to the Lake.

4.5 RECOMMENDATIONS

Following are the key recommendations from the Study. The majority of these recommendations are found in Part 3.

- The following goals, ranked in order of priority, are recommended for the watershed management plan:
  1) maintaining the integrity of the water supplies of Gander, Glenwood and Appleton;
  2) maintaining the current trophic status of Gander Lake; and
  3) maintaining the integrity of the fish habitat (Atlantic Salmon).

- The following key objectives should be the focus of the watershed management plan in order to achieve the above goals:
  1) reduce sediment and erosion;
  2) determine the effects of the Northwest and Southwest Gander Rivers on the Lake; and
  3) control point source inputs.

- The plan recommends a variety of approaches to achieving these objectives. Regulatory approaches are recommended for establishing zones, including buffer zones, restricted use areas, and changes to the designated watershed management area. Negotiated approaches are recommended for controlling land use activities, including forestry guidelines, development guidelines, stormwater management guidelines, cottage and recreation development guidelines. Finally, watershed stewardship approaches are recommended for monitoring activities and land use in the Lake and catchment; understanding and resolving water quality issues in the Lake, the Lake catchment, the Rivers and the River's catchments; maintaining an effective emergency response plan; and, educating to mitigate potential future inputs.

- Buffer zones, areas of no cover disturbance, serve to protect the water body by trapping uphill sediment and maintaining shoreline integrity. A buffer zone of 300-500 metres is recommended for Gander Lake. A buffer zone of 100 metres is recommended for major brooks tributary to the Lake, and a buffer zone of between 30 and 50 metres is recommended for all other waterbodies in the catchment.

- Restricted use areas are locations where both the type of activity and how the activity is carried out are controlled. The most sensitive areas of the catchment are recommended for restricted use zoning. Other areas are recommended for high, medium and low zoning restrictions.

- The designated watershed area should be expanded to include the catchment areas of the Northwest and Southwest Gander Rivers. This is due to the potential influence of water from these Rivers on Gander Lake. Water from Northwest and Southwest Gander Rivers circulates in Gander Lake.

- New Provincial guidelines for forestry practice in sensitive areas are recommended. These guidelines should make use of recent research, and be focused on reducing erosion and sedimentation. Road construction and silviculture techniques should be a focus of the guidelines.

- Guidelines for development in sensitive areas should be developed. These guidelines should focus on sediment and erosion control. The guidelines should consider both the construction period and long-term inputs of different development types. They should also consider the actual impact of development, which may vary significantly depending on project design. Techniques to avoid disturbance of the soil (e.g., extensive grading, tree cutting, etc.) should be the focus of the guidelines.

- Stormwater management guidelines should be developed describing techniques for minimizing erosion and sedimentation, and preserving channel morphology (as opposed to avoiding flooding).

- Cottage and recreation development guidelines can help users to limit soil disturbance, as well as pollutants from garbage and sewage. Cottage development is potentially a significant impact on the Lake water quality. The focus of the guidelines should be on the proper location of buildings, sewage disposal system, roads, appropriate setbacks, and rules about forest clearing and other activities, such as use of all terrain vehicles, which might disturb the soil. Guidelines should be made available to all new cottage lot recipients. Building inspectors should also be made aware of the guidelines.

- Some of the best agricultural land in Newfoundland is located in the deltas of the Northwest and Southwest Gander Rivers. In a Province with such minimal soil cover, it might be better to protect these areas from cottage development in order to provide local growing areas.

- Citizen volunteers should be organized to collect water samples, perform simple water chemistry analysis, and report actual infractions, in order to monitor activities on land in the catchment, in the Lake, in the Rivers and on land in their catchments. Peer role models may have a greater effect on good stewardship that regulatory measures.

- Government agencies located in the Gander area should take lead roles in organizing an emergency response plan. The Gander Lake Watershed Monitoring Committee should monitor large scale developments, as well as provincial and federal government issues which might affect water quality in the area.

- Extensive modelling exercises were conducted and a comprehensive field program was executed for Gander Lake. As is typical of scientific investigation, new questions have arisen. These questions should be investigated by collecting new information to use in the models. The long-term water quality monitoring and modelling program should include the following:

    1) further research to calibrate the watershed management decision model;
    2) further lake circulation modelling and research; and
    3) lake water quality monitoring;

- Subsequent sampling for chemical parameters in the Lake should focus on major inflows to Gander Lake; in particular, those areas identified as probable contaminant sources. The analytical parameters should be targeted for the suspect parameter only, as many of the general chemical parameters and analyses included in this program do not occur at a level that is high enough to be of concern.

- Issues beyond the scope of this study arose during the course of investigation. We have identified, according to the data available at present, the most likely causes of potential pollutants for Gander Lake. We have also identified several suspect problems. Additional data collection should include the following:

  1) comparison of values used in this study with results from the Western Newfoundland Model Forest;
  2) old landfills in the catchment;
  3) the effects of all terrain vehicles on soil erosion; and,
  4) industrial areas.

- Regulation of land and water use activities is considered to be a key to the protection of natural or background water quality of drinking water sources and accomplishment of watershed management objectives. Review of present government statues indicate that Section 26 of the Department of Environment and Lands Act is the only legislative authority relating to the administration of public water supply areas which appears to be very general in nature with no specific provisions to deal with present and future land and water use activities. In order to protect the integrity of drinking water sources, it is essential that government takes appropriate steps to introduce regulations relating to the control of present and future development activities within public water supply areas.

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APPENDIX A
INSTRUMENT SPECIFICATIONS

VIDEO SOUNDER

AVS-7

OPERATION MANUAL

SI-TEX®

DOC. NO. AVS-7 09-89

TransPak II GPS

6-Channel Receiver with NMEA Interface

Features

3D Position:	Latitude, Longitude, and Altitude
Multiple Modes:	Sea; Land; Air
Waypoint Library:	999 Waypoints; 12 Character Name
Navigation Data:	COG: Course Over Ground SOG: Speed Over Ground RNG: Range to Waypoint BRG: Bearing to Waypoint XTE: Cross Track Error ETA: Estimated Time of Arrival TTG: Time to Go VMG: Velocity Made Good
Interfacing:	
Serial Output:	One RS-422 channel; ASCII or NMEA-0183
Serial Input:	One RS-422 channel; ASCII
NMEA 0183 Library:	Selectable Output
Sentences:	APB, BWC, GGA, GLL, VTG, XTE
Other Features:	Waypoint Uploading and Downloading Multiple Datums Coordinate Systems: UTM, OSGB External 12 Volt Power Adapter

Options

- Rechargeable NiCad Battery Pack with Charger (120V or 220V)
- Remote GPS Antenna with Cable and Mounting Bracket
- Receiver Mounting Bracket
- RS-422 to RS-232 Converter
- I/O Cable (TransPak II to 25-pin D-shell connector)
- Waterproof Remote Display

Interfacing Capabilities

Autopilots **Plotters** **Depth Sounders** **Fish Finders** **Radars** **ARPAs** **Instrumentation**	The TransPak II is designed to interface with a broad range of marine navigation equipment. It has been successfully interfaced with equipment in the categories listed to the left. If your equipment accepts the NMEA-0183 interface protocol, the TransPak II is probably compatible with your equipment. Consult your equipment manuals for information on interfacing.
Computers*:	When connected to a computer, the TransPak II can upload waypoints to the computer and receive waypoints downloaded from the computer using a proprietary ASCII protocol. Contact Trimble Navigation for more information.
Protocols:	NMEA-0183 @ 4800 baud ASCII @ 9600 baud
NMEA-0183 Output:	APB, BWC, GGA, GLL, VTG, XTE

Physical Characteristics

Receiver

Dimensions:	6.5" W x 7.0" D x 2.0" H (16.5 cm x 17.8 cm x 5.1 cm)
Weight:	3.5 lbs. 4.5 lbs. (with NiCad battery pack)
Battery Life:	
Alkaline Batteries:	4 hours (continuous usage)
NiCad Battery:	6 hours (continuous usage) (Battery life exceeds 50 hours @ 4 fixes per hour)
Power Options:	
Alkaline Batteries:	8 alkaline AA batteries (standard)
Ext. DC Power:	External 12 volt power adapter (standard)
NiCad Battery:	8.4 volt rechargeable NiCad battery (option)
Display:	4 line x 20 character, backlit LCD
Operating Temp:	0° to +60°C (Storage: -40° to +70°C)
Humidity:	95% non-condensing

Remote GPS Antenna (optional)

Dimensions:	6.0" diameter x 7.0" high (15.2 cm x 17.8 cm)
Weight:	1 lb.
Operating Temp:	-40°C to +70°C
Cable Length:	75 feet (22 meters)

GPS Performance Characteristics

General:	Six-channel digital GPS receiver Tracks up to 8 satellites
Update Rate:	1 second
Acquisition Time:	<1 minute (typical)
Accuracy (typical):**	Position: 50 feet (15 meters) RMS Velocity: 0.1 knots (0.1 m/sec) RMS steady-state
Dynamic Tracking:	Velocity: 0-650 mph (0-300 m/sec) Acceleration: 2g

* Note: The TransPak II includes an IBM-compatible diskette containing sample programs for waypoint management and position logging. A connector for the TransPak II I/O port is also included. This connector can be used for fabricating a custom I/O cable. Alternatively, an optional I/O cable is available from Trimble Navigation. Attaching the TransPak II to the communication port on the computer may require an RS-422 to RS-232 converter (available as an option). Consult the computer manufacturer for details on RS-422 compatibility.

** Note: All GPS receivers are subject to degradation of position and velocity accuracies under Department of Defense imposed S/A (Selective Availability). Position accuracy may be degraded up to 328 feet (100 meters) 2D RMS. The effect on velocity accuracy is yet to be determined.

Specifications subject to change without prior notice.

TrimbleNavigation

Marine Division
645 North Mary Avenue
Post Office Box 3642
Sunnyvale, CA 94088-3642

1-800-TRIMBLE
44-732-366201 (Trimble Europe)
81-472-74-7070 (Trimble Japan)
FAX: (408) 730-2997

Specifications

Display	6-inch amber screen
Presentation	4 shades
Resolution	256 x 256 dots
Output	100 watts RMS (800 watts peak to peak)
Frequency	120kHz or 50kHz
Beam Angle	15°×15° (120KHz) or 50°×50° (50KHz)
Range	40, 80, 160, 320, 640 feet 10, 20, 40, 80, 160, 320 meter 10, 20, 40, 80, 160 fathom
Auto Range	Automatically switches basic range to keep bottom displayed within the range from 35% to 90% of the screen.
Zoom Function	1/4, 1/2, 3/4 of Range Selection
Noise Rejection	Internal
Image Speed	Fixed speed: 5 speeds plus STOP
Alarm	Upper and lower limits alarm
Digital Readout	Bottom depth, boat speed (KT/MPH), water temperature, measuring unit, range in use, zoom range in use, screen top depth, screen bottom depth, upper and lower alarm limits.
Pulse Repetition Rate (times/min)	Range: 40 / 80 / 160 / 320 / 640 PPR: 1061 / 827 / 571 / 350 / 200
Marker	Upper and lower alarm marks
Power Requirement	11 to 16 VDC less than 10 watts

Specifications subject to change without notice.

MDS
Environmental Services Limited

Client: Jacques Whitford Environment Ltd.
607 Torbay Road
St. Johns, NFD, CANADA
A1A 4Y6

Fax: 709-576-2126

Attn: Narcissus Walsh

Date Submitted:	September 21/95
Date Reported:	September 26/95
MDS Ref#:	954756
MDS Quote#:	95-041-VG
Client PO#:	775
Client Ref#:	775
Sampled By:	Bruce Bennett

Certificate of Analysis

Analysis Performed: Trihalomethanes

Methodology: 1) Analysis of Trihalomethanes in water by Purge and Trap capillary GC-PID. External std quantitation with surrogate standards.
U.S. EPA Method No. 5030
U.S. EPA Method No. 502.2

Instrumentation: 1) PT-GC/ELCD,PID, Hewlett Packard 5890II GC, O.I. 4460A P&T, A/S

Sample Description: Water

QA/QC: Refer to CERTIFICATE OF QUALITY CONTROL report.

Results: Refer to REPORT of ANALYSIS attached.

Certified By
V. Geldart, B.Sc.
Service Manager

Certified By
T. Munshaw, M.Sc.,C.Chem
Director, Laboratory Operations

SEABIRD CTD WITH DO_2 SENSOR

MEASUREMENT RANGE	
Temperature	-5 to +35°C
Conductivity	0 to 7 S/m (0 to 70 mmho/cm)
Pressure	300 psia
Dissolved Oxygen	0 to 15 ml/l
ACCURACY	
Temperature	0.01°C/6 months
Conductivity	0.001 S/m/month
Pressure	0.25% of full scale range (50 to 300 psia)
Dissolved Oxygen	0.1 ml/l (achievable with frequent field calibrations)
RESOLUTION	
Temperature	0.001°C
Conductivity	0.0001 S/m
Pressure	0.015% of full scale range
Dissolved Oxygen	0.01 ml/l
SENSOR CALIBRATION (measurements outside range may be at slightly reduced accuracy due to extrapolation errors)	
Temperature	-1 to +31°C
Conductivity	0 to 7 S/m, physical calibration over the range 1.4 to 6 S/m
OTHER	
Pressure	0 to full scale in 20% steps
Counter time-base	Quartz TCXO, ±2 ppm per year aging; ±2 ppm vs. temperature (-5 to +30 °C)
Memory	128K CMOS static RAM; battery backed for minimum 2 years data retention.
Real-time clock	Watch-crystal type 32,768 Hz; battery backed for minimum of 1 year operation irrespective of condition of main battery. Corrected for drift and aging by comparison to *SEACAT counter time-base.*
Batteries	6 alkaline 'D' cells provide 48 hours continuous operation and 2 year data retention reserve
Materials	600 Meter Pressure Case, acetal copolymer (plastic)
DO Sensor Time Response	2 sec @ 25°C; 5 sec @ 0°C (time to reach 63% of final value following a step change in oxygen concentration)
Pump standard V. input range	12 to 18 VDC
Pump low V. input range	6 to 13.5 VDC
Power Required	6 to 24 VDC, 4 ma.
Outputs	0 to +5 V.
Operating Depth	600 meters
Weight	34 Kg (shipping weight) in air, 15 Kg (operational)

MDS
Environmental Services Limited

Client:	Jacques Whitford Environment Ltd. 607 Torbay Road St. Johns, NFD, CANADA A1A 4Y6	Date Submitted:	September 21/95
		Date Reported:	October 3/95
		MDS Ref#:	954756
		MDS Quote#:	95-041-VG
		Client PO#:	775
Fax:	709-576-2126	Client Ref#:	775
Attn:	Narcissus Walsh	Sampled By:	Narcissus Walsh

Certificate of Analysis

Analysis Performed:

SPECIFIC WATER ANALYSIS(SWA)
Reactive Silica
Colour
Total Kjeldahl Nitrogen, Digestion Required
Total Phosphorous, Autoanalyzer

:ethodology:

1) Analysis of anions in water by Ion Chromatography.
   U.S. EPA Method No. 300.0
   Standard Methods(1985) No. 429.0
2) Analysis of alkaline metals in water by Inductively Coupled Plasma Spectrophotometry.
   U.S. EPA Method No. 200.7
   (Ministry of Environment ELSCAN)
3) Analysis of trace metals in water by Inductively Coupled Plasma Spectrophotometry.
   U.S. EPA Method No. 200.7
   (Ministry of Environment ELSCAN)
4) Analysis of reactive silica in water by Inductively Coupled Plasma.
   Standard Methods(17th.ed.)No. 4500-Si G

MDS
Environmental Services Limited

Client: Jacques Whitford Environment Ltd.
607 Torbay Road
St. Johns, NFD, CANADA
A1A 4Y6

Fax: 709-576-2126

Attn: Narcissus Walsh

Date Submitted:	September 21/95
Date Reported:	October 3/95
MDS Ref#:	954756
MDS Quote#:	95-041-VG
Client PO#:	775
Client Ref#:	775
Sampled By:	Narcissus Walsh

Certificate of Analysis

Methodology: (Cont'd)

5) Analysis of water for pH(by electrode), conductivity(by measuring resistance in micro siemens/cm), turbidity(by nephelometry) and alkalinity(by titration to pH 4.5).
U.S. EPA Method No. 150.1, 120.1, 180.1
Standard Methods(17th ed.) No. 2320
6) Determination of theoretical SWA parameters by calculation.
EPL Internal Reference Method
7) Determination of colour in water by UV-Visible Spectrophotometry following pretreatment(filtration with 0.45 um membrane).
U.S. EPA Method No. 110.2
8) Analysis of total Kjeldahl Nitrogen in water by colourimetric determination in a continuous liquid flow.
ASTM Method No. D3590-84AFD
Refer - Method No. 1100106 Issue 122289
9) Analysis of total phosphorus in water by colourimetry in a continuous liquid flow.
U.S. EPA Method No. 365.1
Refer - Method No. 1100205 Issue 122289

MDS
Environmental Services Limited

Client: Jacques Whitford Environment Ltd.
607 Torbay Road
St. Johns, NFD, CANADA
A1A 4Y6

Fax: 709-576-2126

Attn: Narcissus Walsh

Date Submitted:	September 21/95
Date Reported:	October 3/95
MDS Ref#:	954756
MDS Quote#:	95-041-VG
Client PO#:	775
Client Ref#:	775
Sampled By:	Narcissus Walsh

Certificate of Analysis

Instrumentation:

1) Dionex Ion Chromatograph, Series 4500i
2, 3, 4) Thermo Jarrell Ash ICAP 61E Plasma Spectrophotometer
5) pH Meter/MetroOhm Conductometer/Titrator/UV - Visible Spectrometer
6) Calculation from existing results; no instrumentation required.
7) Hach UV - Visible Spectrophotometer, Model DR/3000
8) Skalar Segmented Flow Analyzer, Model SA 20/40
9) Technicon Autoanalyzer

Sample Description: Water

QA/QC: Refer to CERTIFICATE OF QUALITY CONTROL report.

Results: Refer to REPORT of ANALYSIS attached.

for
Certified By
V. Geldart, B.Sc.
Service Manager

Certified By
T. Munshaw, M.Sc.,C.Chem
Director, Laboratory Operations

APPENDIX B
WATER SAMPLING RESULTS

SEATECH LTD.
Chemists & Environmental Scientists
1127 Barrington Street
Halifax, Nova Scotia, Canada
B3H 2P8
email seatech@seatech.nstn.ca
Telephone: (902) 423-5296 Fax: (902) 422-0581
24 HOUR EMERGENCY SERVICE (902) 422-2763

File No.: SP6
Lab No.: LP274
PO No.: 775

Chlorophyll A Analysis Data

Location: Gander, NF

Sampled By: JWA - St. John's

Date Received: June 12, 1995

Sample ID	Pigment (mg/m^3)
1.1 GL-001	4.2
1.2 GL-001	3.6
1.3 GL-001	1.1
2.1 GL-001	3.8
2.2 GL-001	3.8
2.3 GL-001	1.7
3.1 GL-001	1.7
3.2 GL-001	4.5
3.3 GL-001	1.9
4.1 GL-001	3.5
4.2 GL-001	4.9
4.3 GL-001	2.0
5.1 GL-001	1.0
5.2 GL-001	2.0
5.3 GL-001	2.4
6.1 GL-001	0.8
6.2 GL-001	9.2
6.3 GL-001	0.7
A GL-001	3.1
B GL-001	0.9
C GL-001	3.6

Steven Devitt, BSc.

August 8/95

Gander Lake
Sampling Location Air Temperature
June 24, 1995

LOCATION	AIR TEMPERATURE °C	NOTES
A	19.0	
1.1	19.0	No profile; water too shallow.
1.2	19.0	
1.3	20.0	
EXTRA	23.7	
2.1	23.0	
2.2	23.0	
2.3	23.7	
B	23.0	
3.1	20.9	
3.2	22.8	
3.3	19.3	
4.1	17.5	
4.2	17.5	
4.3	18.4	
5.1	17.0	
5.2	16.7	
5.3	16.7	
6.1	13.3	
6.2	13.0	
6.3	13.0	
C	n/a	No profile: water too shallow. No temperature recorded.

SEATECH LTD.
Chemists & Environmental Scientists
1127 Barrington Street
Halifax, Nova Scotia, Canada
B3H 2P8
email seatech@seatech.nstn.ca
Telephone: (902) 423-5296 Fax: (902) 422-0581
24 HOUR EMERGENCY SERVICE (902) 422-2763

File No.: SP6
Lab No.: LP274
PO No.: 775

Chlorophyll C Analysis Data

Location: Gander, NF

Sampled By: JWA - St. John's

Date Received: June 12, 1995

Sample ID	Pigment (m-SPU/L)[1]
1.1 GL-001	4.2
1.2 GL-001	3.1
1.3 GL-001	<0.1
2.1 GL-001	2.1
2.2 GL-001	4.5
2.3 GL-001	<0.1
3.1 GL-001	<0.1
3.2 GL-001	5.2
3.3 GL-001	<0.1
4.1 GL-001	2.4
4.2 GL-001	5.6
4.3 GL-001	15.5
5.1 GL-001	<0.1
5.2 GL-001	<0.1
5.3 GL-001	<0.1
6.1 GL-001	<0.1
6.2 GL-001	37
6.3 GL-001	<0.1
A GL-001	<0.1
B GL-001	<0.1
C GL-001	<0.1

1 m-SPU - Specific Plant Units

Steven Devitt, BSc.

August 8/95

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File No.: SP6
Lab No.: LP274
PO No.: 775

Chlorophyll B Analysis Data

Location: Gander, NF

Sampled By: JWA - St. John's

Date Received: June 12, 1995

Sample ID	Pigment (mg/m^3)
1.1 GL-001	6.1
1.2 GL-001	6.1
1.3 GL-001	3.5
2.1 GL-001	6.4
2.2 GL-001	6.2
2.3 GL-001	4.0
3.1 GL-001	4.3
3.2 GL-001	7.1
3.3 GL-001	5.0
4.1 GL-001	6.5
4.2 GL-001	7.6
4.3 GL-001	7.3
5.1 GL-001	5.1
5.2 GL-001	4.3
5.3 GL-001	5.0
6.1 GL-001	3.7
6.2 GL-001	11.4
6.3 GL-001	4.0
A GL-001	5.4
B GL-001	3.6
C GL-001	6.2

Steven Devitt, BSc.

August 8/95

D.O. Readings From 95/06/23 and 95/06/24 Samplin

DO Bottle #	Location	Depth	DO (mg/L)
100	2.1	60m	11.2
158	2.2	45m	11.4
008	2.3	30m	11.4
78	4.1	120 m	11.5
104	6.2 (Surf)	0m	11.2
57	6.2 (60m)	60m	11.3.

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File No.: SP6
Lab No.: LP274
PO No.: 775

Carotenoids Analysis Data

Location: Gander, NF

Sampled By: JWA - NF

Date Received: June 12, 1995

Sample ID	Pigment (m-SPU/L)[1]
1.1 GL-001	<0.1
1.2 GL-001	<0.1
1.3 GL-001	<0.1
2.1 GL-001	<0.1
2.2 GL-001	<0.1
2.3 GL-001	<0.1
3.1 GL-001	<0.1
3.2 GL-001	<0.1
3.3 GL-001	<0.1
4.1 GL-001	<0.1
4.2 GL-001	0.2
4.3 GL-001	<0.1
5.1 GL-001	<0.1
5.2 GL-001	<0.1
5.3 GL-001	<0.1
6.1 GL-001	<0.1
6.2 GL-001	<0.1
6.3 GL-001	<0.1
A GL-001	<0.1
B GL-001	1.5
C GL-001	<0.1

1 m-SPU - Specific Plant Units

Steven Devitt, BSc.

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August 8/95

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Chemists & Environmental Scientists
1127 Barrington Street
Halifax, Nova Scotia, Canada
B3H 2P8
email seatech@seatech.nstn.ca
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File No.: SP6
Lab No.: LP409
PO No.: 775

CHEMICAL DATA FOR SEAWATER
CHLOROPHYLL a

Sampled By: Jacques Whitford

Samples Received: September 11, 1995

Sample ID	Volume (L)	Chlorophyll a (mg/m^3)
A-GL-001	0.53	1.6
B-GL-001	0.56	1.5
C-GL-001	0.53	1.3
1.1-GL-001	0.56	1.5
1.2-GL-001	0.56	1.1
1.3-GL-001	0.56	1.3
2.1-GL-001	0.56	1.2
2.2-GL-001	0.54	1.0
2.3-GL-001	0.53	0.5
3.1-GL-001	0.54	<0.1
3.2-GL-001	0.53	1.9
3.3-GL-001	0.55	1.0
4.1-GL-001	0.54	2.6
4.2-GL-001	0.53	0.1
4.3-GL-001	0.54	0.7
5.1-GL-001	0.52	0.2
5.2-GL-001	0.54	<0.1
5.3-GL-001	0.55	<0.1
6.1-GL-001	0.54	<0.1
6.2-GL-001	0.55	<0.1
6.3-GL-001	0.53	<0.1

Tim Kruger, BSc

Sept 15/95

Gander Lake : Secchi Disk Depths and Air Temperatures. Se tember 07, 1995		
Location	**Secchi Depth (m)**	**Air Temperature °C**
A	3.0	15.0
1.1	2.5	15.8
1.2	3.0	16.1
1.3	2.0	15.8
B	3.0	17.0
2.1	3.0	16.8
2.2	3.0	18.7
2.3	3.0	17.6
3.1	3.5	16.7
3.2	3.0	19.3
3.3	3.0	19.0
4.1	3.0	17.8
4.2	2.8	17.6
4.3	3.0	18.5
5.1	3.5	15.4
5.2	3.5	15.0
5.3	3.5	17.2
6.1	2.75	12.4
6.2	2.5	12.2
6.3	2.5	13.0

RESULTS OF CHEMICAL ANALYSES

Client: JWE
Mr.Narcissus Walsh
File No.: LL-126 (L-775)

Sample: Water Samples
Type: Surface
Source: Gander Lake

Date Received: September 09, 1995
Date Analysed: September 11, 1995
Date Reported: September 18, 1995

NO.	BOTTLE #	DESCRIPTION	DATE COLLECTED	DISSOLVED OXYGEN (mg/L)
1		1.2-GL-001		10.80
2		1.2-GL-002		10.56
3		2.2-GL-001		9.68
4		2.2-GL-002		11.36
5		3.2-GL-001		10.08
6		3.2-GL-002		11.28
7		4.1-GL-001		9.76
8		4.1-GL-002		11.12
9		5.2-GL-001		9.60
10		5.2-GL-002		11.68
11		6.1-GL-001		10.48
12		6.1-GL-002		12.00

Performed by:______________________
(Kimberly Burke)

Approved by:______________________
(Sandra Whiteway)

Date:______________________

Temperature and Conductivity Probes - June 1995
(Note: Dissolved oxygen results do not correlate with Winkler dissolved oxygen samples and are considered invalid.)

Location B	Depth(m)	Temp (°C)	Conductivity (S/M)	Oxygen (D/O)
	3	5.17	.0017	12.92
	6	5.03	.0017	11.88
	9	4.86	.0017	11.41
	12	4.79	.0017	10.90
	15	4.79	.0017	10.66
	18	4.68	.0017	10.38
	21	4.59	.0017	9.73
	24	4.51	.0016	9.25
	27	4.39	.0016	8.72
	30	4.33	.0016	8.18
	33	4.32	.0016	7.82
	36	4.32	.0016	7.47
	39	4.32	.0016	7.11
	42	4.32	.0016	6.79
	45	4.32	.0016	6.49
	48	4.32	.0016	6.17
	51	4.31	.0016	5.80
	54	4.31	.0016	5.45
	57	4.31	.0016	5.15
	60	4.32	.0016	4.88
	63	4.42	.0016	4.64
	63	4.47	.0016	4.00
	66	4.49	.0016	4.37
Location 1.1	Depth(m)	Temp (°C)	Conductivity (S/M)	Oxygen (D/O)
	3	7.61	.0020	9.93
	6	7.18	.0020	8.08
	9	6.99	.0020	8.32
	12	6.88	.0019	8.82
	15	6.85	.0019	9.12
	18	6.80	.0019	9.23
	21	6.67	.0019	9.13
	24	6.47	.0019	8.68
	27	6.38	.0019	7.90
	30	6.15	.0018	7.16
	33	5.86	.0018	6.17
	36	5.79	.0018	5.19
	39	5.63	.0018	4.43
	42	5.26	.0017	3.51
	45	5.21	.0017	2.52
	48	5.16	.0017	2.00
	51	5.08	.0017	1.47
	54	5.06	.0017	1.00
	57	5.04	.0017	0.57
	60	5.02	.0017	0.18
	63	5.01	.0017	-0.05
	66	4.98	.0017	-0.03

Location 1.2	Depth(m)	Temp (°C)	Conductivity (S/M)	Oxygen (D/O)
	3	5.74	.0018	12.06
	6	5.70	.0018	11.58
	9	5.75	.0018	10.88
	12	5.71	.0018	10.40
	15	5.56	.0018	9.85
	18	5.43	.0018	8.90
	21	5.39	.0017	8.07
	24	5.36	.0018	7.41
	27	5.36	.0017	6.83
	30	5.31	.0017	6.28
	33	5.20	.0017	5.57
	36	5.20	.0017	4.67
	39	5.19	.0017	3.99
	42	5.18	.0017	3.38
	45	5.11	.0017	2.85
	48	5.05	.0017	2.26
	51	5.04	.0017	1.74
	54	4.98	.0017	1.31
	57	4.97	.0017	0.86
	60	4.88	.0017	0.46
	63	4.74	.0017	0.05
	66	4.72	.0017	-0.04
Location 1.3	Depth(m)	Temp (°C)	Conductivity (S/M)	Oxygen (D/O)
	3	5.96	.0017	13.31
	6	5.75	.0018	11.86
	9	5.71	.0018	10.85
	12	5.63	.0018	10.19
	15	5.53	.0018	9.43
	18	5.46	.0018	8.68
	21	5.42	.0017	7.98
	24	5.39	.0017	7.40
	27	5.33	.0017	6.81
	30	5.31	.0017	6.18
	33	5.30	.0017	5.58
	36	5.29	.0017	4.91
	39	5.29	.0017	4.31
	42	5.27	.0017	3.71
	45	5.27	.0017	3.09
	48	5.26	.0017	2.46
	51	5.21	.0017	1.83
	54	5.18	.0017	1.22
	57	5.15	.0017	0.74
	60	5.12	.0017	0.28
	63	5.07	.0017	-0.03
	66	5.01	.0017	-0.03
	69	4.94	.0017	-0.03
	72	4.88	.0017	-0.03
	75	4.79	.0017	-0.03
	78	4.75	.0017	-0.03
	81	4.74	.0017	-0.03
	84	4.72	.0017	-0.03

	87	4.71	.0017	-0.03
	90	4.71	.0017	-0.03
	93	4.70	.0017	-0.03
	96	4.70	.0017	-0.03
	99	4.69	.0017	-0.03
	102	4.68	.0017	-0.03
	105	4.67	.0017	-0.03
	108	4.64	.0017	-0.03
	111	4.60	.0017	-0.03
	114	4.58	.0017	-0.03
	117	4.57	.0016	-0.03
	120	4.57	.0016	-0.03
	123	4.57	.0016	-0.03
Location 2.1	Depth(m)	Temp (°C)	Conductivity (S/M)	Oxygen (D/O)
	3	4.46	.0016	11.37
	6	4.46	.0016	10.93
	9	4.47	.0016	10.58
	12	4.50	.0016	10.40
	15	4.51	.0016	10.26
	18	4.51	.0016	10.00
	21	4.50	.0016	9.69
	24	4.47	.0016	9.29
	27	4.47	.0016	8.98
	30	4.48	.0016	8.71
	33	4.48	.0016	8.46
	36	4.46	.0016	8.16
	39	4.45	.0016	7.83
	42	4.44	.0016	7.51
	45	4.46	.0016	7.29
	48	4.35	.0016	6.99
	51	4.28	.0016	6.58
	54	4.21	.0016	6.09
	57	4.21	.0016	5.74
	60	4.21	.0016	5.41
	63	4.21	.0016	5.05
	66	4.21	.0016	4.68
	69	4.19	.0016	4.39
	72	4.19	.0016	4.12
	75	4.18	.0016	3.90
	78	4.18	.0016	3.72
	81	4.18	.0016	3.54
	84	4.18	.0016	3.39
	87	4.18	.0016	3.07
Location 2.2	Depth(m)	Temp (°C)	Conductivity (S/M)	Oxygen (D/O)
	3	5.16	.0017	13.51
	6	5.10	.0017	12.16
	9	5.05	.0017	11.64
	12	5.01	.0017	11.18
	15	4.97	.0017	10.76
	18	4.94	.0017	10.23
	21	4.88	.0017	9.73

	24	4.78	.0017	9.25
	27	4.73	.0017	8.80
	30	4.67	.0017	8.38
	33	4.52	.0016	7.90
	36	4.35	.0016	7.29
	39	4.22	.0016	6.67
	42	4.15	.0016	6.08
	45	4.11	.0016	5.55
	48	4.10	.0016	5.12
	51	4.07	.0016	4.73
	54	4.08	.0016	4.34
	57	4.08	.0016	4.00
	60	4.08	.0016	3.65
	63	4.08	.0016	3.36
	66	4.08	.0016	3.07
	69	4.06	.0016	2.84
	72	4.05	.0016	2.67
	75	4.03	.0016	2.48
	78	4.02	.0016	2.35
	81	4.00	.0016	2.22
	84	4.00	.0016	2.08
	87	4.00	.0016	2.02
	90	4.00	.0016	1.96
	93	3.99	.0016	1.81
	96	3.99	.0016	1.73
	99	3.99	.0016	1.60
	102	3.98	.0016	1.50
	105	3.98	.0016	1.37
	108	3.98	.0016	1.24
	111	3.98	.0016	1.10
	114	3.97	.0016	0.95
	117	3.97	.0016	0.80
	120	3.96	.0016	0.64
	123	3.96	.0016	0.49
	126	3.96	.0016	0.36
	129	3.95	.0016	0.24
	132	3.95	.0016	0.13
	135	3.95	.0016	-0.02
	138	3.95	.0016	-0.04
	141	3.95	.0016	-0.04
	144	3.94	.0016	-0.04
	147	3.94	.0016	-0.04
	150	3.93	.0016	-0.04
	153	3.92	.0016	-0.04
	156	3.92	.0016	-0.04
	159	3.91	.0016	-0.04
	162	3.91	.0016	-0.04
	165	3.91	.0016	-0.04
	168	3.90	.0016	-0.04
	171	3.91	.0016	-0.04
	174	3.90	.0016	-0.04
	177	3.90	.0016	-0.04
	180	3.90	.0016	-0.04

	183	3.90	.0016	-0.04
	186	3.89	.0016	-0.04
	189	3.89	.0016	-0.04
Location 2.3	Depth(m)	Temp (°C)	Conductivity (S/M)	Oxygen (D/O)
	3	5.66	.0017	12.94
	6	5.30	.0017	12.03
	9	5.19	.0017	11.43
	12	5.13	.0017	10.94
	15	5.09	.0017	10.56
	18	5.06	.0017	10.22
	21	5.00	.0017	9.87
	24	4.98	.0017	9.39
	27	4.95	.0017	9.04
	30	4.93	.0017	8.76
	33	4.90	.0017	8.51
	36	4.88	.0017	8.18
	39	4.86	.0017	7.89
	42	4.83	.0017	7.62
	45	4.79	.0017	7.31
	48	4.78	.0017	6.98
	51	4.76	.0017	6.64
	54	4.72	.0017	6.29
	57	4.71	.0017	5.97
	60	4.71	.0017	5.72
	63	4.71	.0017	5.48
	66	4.69	.0017	5.21
	69	4.61	.0016	4.87
	72	4.47	.0016	4.01
Location 3.1	Depth(m)	Temp (°C)	Conductivity (S/M)	Oxygen (D/O)
	3	4.25	.0016	13.07
	6	4.01	.0016	9.93
	9	4.03	.0016	9.09
	12	3.99	.0016	8.58
	15	3.97	.0016	8.13
	18	3.97	.0016	7.81
	21	3.97	.0016	7.52
	24	3.96	.0016	7.21
	27	3.92	.0016	6.86
	30	3.95	.0016	5.98
Location 3.2	Depth	Temp (°C)	Conductivity (S/M)	Oxygen (D/O)
	3	4.57	.0016	16.98
	6	4.42	.0016	12.29
	9	4.38	.0016	10.97
	12	4.36	.0016	10.24
	15	4.36	.0016	9.86
	18	4.31	.0016	9.40
	21	4.31	.0016	8.79
	24	4.29	.0016	8.28

	27	4.27	.0016	7.88
	30	4.26	.0016	7.56
	33	4.22	.0016	7.27
	36	4.20	.0016	6.91
	39	4.20	.0016	6.58
	42	4.19	.0016	6.31
	45	4.22	.0016	6.02
	48	4.25	.0016	5.78
	51	4.24	.0016	5.57
	54	4.23	.0016	5.27
	57	4.21	.0016	5.02
	60	4.19	.0016	4.71
	63	4.19	.0016	4.44
	66	4.19	.0016	4.19
	69	4.19	.0016	3.91
	72	4.19	.0016	3.65
	75	4.18	.0016	3.36
	78	4.16	.0016	3.09
	81	4.16	.0016	2.86
	84	4.14	.0016	2.67
	87	4.13	.0016	2.50
	90	4.12	.0016	2.34
	93	4.11	.0016	2.21
	96	4.08	.0016	2.05
	99	4.07	.0016	1.92
	102	4.03	.0016	1.78
	105	4.01	.0016	1.59
	108	4.02	.0016	1.48
	111	3.99	.0016	1.38
	114	3.96	.0016	1.22
	117	3.92	.0016	1.04
	120	3.91	.0016	0.86
	123	3.91	.0016	0.72
	126	3.92	.0016	0.63
	129	3.91	.0016	0.54
	132	3.88	.0016	0.38
	135	3.87	.0016	0.26
	138	3.86	.0016	0.13
	141	3.85	.0016	0.01
	144	3.84	.0016	-0.04
	147	3.83	.0016	-0.04
	150	3.83	.0016	-0.04
	153	3.83	.0016	-0.04
	156	3.83	.0016	-0.04
	159	3.83	.0016	-0.04
	162	3.81	.0016	-0.04
	165	3.80	.0016	-0.04
	168	3.80	.0016	-0.04
Location 3.3	Depth(m)	Temp (°C)	Conductivity (S/M)	Oxygen (D/O)
	3	5.93	.0020	16.35
	6	5.77	.0018	13.73
	9	5.70	.0018	13.04

	12	5.43	.0017	12.66
	15	5.29	.0017	11.83
	18	5.24	.0017	11.34
	21	5.14	.0017	10.96
	24	5.07	.0017	10.48
	27	5.01	.0017	9.97
	30	4.95	.0017	9.53
	33	4.93	.0017	9.15
	36	4.96	.0017	8.87
	39	4.96	.0017	8.67
	42	4.95	.0017	8.39
	45	4.93	.0017	8.04
	48	4.92	.0017	7.69
	51	4.88	.0017	7.34
	54	4.78	.0016	7.07
	57	4.71	.0017	6.63
	60	4.70	.0016	6.29
	63	4.69	.0016	5.99
	66	4.66	.0016	5.71
	69	4.60	.0016	5.34
	72	4.56	.0016	5.03
	75	4.51	.0016	4.63
	78	4.50	.0016	4.29
	81	4.46	.0016	4.01
	84	4.40	.0016	3.74
	87	4.30	.0016	3.37
	90	4.28	.0016	3.05
	93	4.28	.0016	2.88
	96	4.27	.0016	2.74
	99	4.26	.0016	2.60
	102	4.25	.0016	2.49
	105	4.25	.0016	2.34
	108	4.23	.0016	2.20
	111	4.20	.0016	2.05
	114	4.19	.0016	1.90
	117	4.18	.0016	1.76
	120	4.18	.0016	1.64
	123	4.18	.0016	1.48
	126	4.17	.0016	1.36
	129	4.16	.0016	1.10
	126	4.17	.0016	0.83
	123	4.18	.0016	0.78
	120	4.18	.0016	0.70
	117	4.18	.0016	0.62
	114	4.19	.0016	0.52
	111	4.20	.0016	0.46
Location 4.1	Depth(m)	Temp (°C)	Conductivity (S/M)	Oxygen (D/O)
	3	5.20	.0017	11.39
	6	4.56	.0016	10.68
	9	4.39	.0016	9.53
	12	4.34	.0016	8.86
	15	4.32	.0016	8.53

	18	4.30	.0016	8.22
	21	4.28	.0016	7.89
	24	4.26	.0016	7.50
	27	4.25	.0016	7.15
	30	4.22	.0016	6.85
	33	4.18	.0016	6.51
	36	4.14	.0016	6.19
	39	4.09	.0016	5.84
	42	4.09	.0016	5.50
	45	4.08	.0016	5.21
	48	4.06	.0016	4.90
	51	4.06	.0016	4.58
	54	4.06	.0016	4.31
	57	4.05	.0016	4.08
	60	4.04	.0016	3.83
	63	4.03	.0016	3.55
	66	4.02	.0016	3.20
	69	4.02	.0016	2.87
	72	4.01	.0016	2.51
	75	4.01	.0016	2.11
	78	4.00	.0016	1.83
	81	3.99	.0016	1.60
	84	3.98	.0016	1.40
	87	3.98	.0016	1.21
	90	3.97	.0016	1.09
	93	3.97	.0016	0.91
	96	3.95	.0016	0.80
	99	3.95	.0016	0.67
	102	3.94	.0016	0.59
	105	3.94	.0016	0.48
	108	3.93	.0016	0.38
	111	3.91	.0016	0.03
Location 4.2	Depth(m)	Temp (°C)	Conductivity (S/M)	Oxygen (D/O)
	3	6.28	.0018	12.15
	6	5.83	.0018	9.68
	9	5.75	.0018	7.83
	12	5.70	.0018	6.59
	15	5.53	.0017	5.73
	18	5.17	.0017	4.64
	21	5.11	.0017	3.42
	24	5.11	.0017	2.67
	27	5.06	.0017	2.04
	30	4.91	.0017	1.36
	33	4.78	.0017	0.55
	36	4.75	.0017	0.01
	39	4.72	.0017	-0.03
	42	4.72	.0017	-0.03
	45	4.70	.0016	-0.03
	48	4.60	.0016	-0.03
	51	4.50	.0016	-0.03
	54	4.48	.0016	-0.03
	57	4.46	.0016	-0.03

	60	4.44	.0016	-0.03
	63	4.37	.0016	-0.03
	66	4.29	.0016	-0.03
	69	4.19	.0016	-0.03
	72	4.11	.0016	-0.03
	75	4.10	.0016	-0.03
	78	4.10	.0016	-0.03
	81	4.07	.0016	-0.03
	84	4.04	.0016	-0.04
	87	4.03	.0016	-0.04
	90	4.02	.0016	-0.04
	93	4.01	.0016	-0.04
	96	4.01	.0016	-0.04
	99	4.01	.0016	-0.04
	102	4.00	.0016	-0.04
	105	3.99	.0016	-0.04
	108	3.97	.0016	-0.04
	111	3.97	.0016	-0.04
	114	3.97	.0016	-0.04
	117	3.97	.0016	-0.04
	120	3.95	.0016	-0.04
	123	3.95	.0016	-0.04
	126	3.92	.0016	-0.04
	129	3.87	.0016	-0.04
	132	3.85	.0016	-0.04
	135	3.84	.0016	-0.04
	138	3.83	.0016	-0.04
	141	3.82	.0016	-0.04
	144	3.81	.0015	-0.04
	147	3.80	.0015	-0.04
	150	3.81	.0015	-0.04
	153	3.81	.0015	-0.04
	156	3.80	.0016	-0.04
	159	3.79	.0016	-0.04
	162	3.78	.0015	-0.04
	165	3.78	.0015	-0.04
Location 4.3	Depth(m)	Temp (°C)	Conductivity (S/M)	Oxygen (D/O)
	3	7.01	.0018	15.07
	6	6.30	.0018	11.90
	9	6.28	.0018	10.23
	12	6.15	.0018	9.41
	15	6.05	.0018	8.60
	18	5.84	.0018	7.90
	21	5.62	.0018	7.00
	24	5.47	.0017	6.19
	27	5.31	.0017	5.45
	30	5.18	.0017	3.95
Location 5.1	Depth(m)	Temp (°C)	Conductivity (S/M)	Oxygen (D/O)
	3	5.37	.0018	12.26
	6	4.54	.0016	11.61

	9	4.27	.0016	9.79
	12	4.22	.0016	9.02
	15	4.19	.0016	8.70
	18	4.10	.0016	8.37
	21	4.05	.0016	7.98
	24	4.02	.0016	7.51
	27	3.97	.0016	7.03
	30	3.98	.0016	6.64
	33	3.99	.0016	6.33
	36	3.99	.0016	6.11
	39	3.95	.0016	5.87
	42	3.93	.0016	5.57
	45	3.92	.0016	5.25
	48	3.93	.0016	4.93
	51	3.91	.0016	4.36
Location 5.2	Depth(m)	Temp (°C)	Conductivity (S/M)	Oxygen (D/O)
	3	5.20	.0017	11.20
	6	4.50	.0016	10.59
	9	4.41	.0016	9.12
	12	4.40	.0016	8.64
	15	4.40	.0016	8.38
	18	4.38	.0016	8.12
	21	4.35	.0016	7.77
	24	4.35	.0016	7.40
	27	4.35	.0016	7.01
	30	4.34	.0016	6.70
	33	4.31	.0016	6.33
	36	4.29	.0016	6.01
	39	4.28	.0016	5.70
	42	4.25	.0016	5.41
	45	4.22	.0016	5.09
	48	4.19	.0016	4.75
	51	4.17	.0016	4.42
	54	4.12	.0016	4.11
	57	4.09	.0016	3.76
	60	4.07	.0016	3.48
	63	4.05	.0016	3.15
	66	4.05	.0016	2.81
	69	4.02	.0016	2.54
	72	4.01	.0016	2.20
	75	3.97	.0016	1.90
	78	3.93	.0016	1.59
	81	3.91	.0016	1.33
	84	3.88	.0016	1.11
	87	3.88	.0016	0.88
	90	3.86	.0015	0.70
	93	3.86	.0016	0.55
	96	3.87	.0015	0.44
	99	3.87	.0015	0.34
	102	3.86	.0015	0.23
Location 5.3	Depth(m)	Temp (°C)	Conductivity (S/M)	Oxygen (D/O)

	3	7.09	.0019	15.42
	6	6.53	.0019	14.55
	9	5.73	.0018	13.53
	12	5.40	.0017	11.99
	15	5.28	.0017	11.15
	18	5.09	.0017	10.66
	21	5.04	.0017	10.01
	24	5.00	.0017	9.60
	27	4.91	.0017	9.19
	30	4.88	.0017	8.72
	33	4.82	.0017	8.43
	36	4.71	.0017	7.94
	39	4.67	.0016	7.53
	42	4.67	.0016	7.22
	45	4.61	.0016	6.96
	48	4.55	.0016	6.53
	51	4.52	.0016	6.22
	54	4.48	.0016	5.92
	57	4.47	.0016	5.65
	60	4.43	.0016	5.38
	63	4.41	.0016	5.06
	66	4.38	.0016	4.56
Location 6.1	Depth(m)	Temp (°C)	Conductivity (S/M)	Oxygen (D/O)
	3	5.89	.0018	12.65
	6	5.49	.0017	12.52
	9	4.92	.0017	11.68
	12	4.68	.0016	10.42
	15	4.66	.0016	9.73
	18	4.61	.0016	9.28
	21	4.51	.0016	8.77
	24	4.46	.0016	8.20
	27	4.45	.0016	7.85
	30	4.43	.0016	7.53
	33	4.41	.0016	7.21
	36	4.39	.0016	6.90
	39	4.39	.0016	6.63
	42	4.39	.0016	6.37
	45	4.37	.0016	6.11
	48	4.36	.0016	5.79
	51	4.35	.0016	5.50
	54	4.34	.0016	5.21
	57	4.30	.0016	4.94
	60	4.19	.0016	4.52
	63	4.14	.0016	4.08
	66	4.09	.0016	3.67
	69	4.06	.0016	3.24
	72	4.01	.0016	2.78
	75	3.96	.0016	2.35
	78	3.95	.0016	1.98
	81	3.94	.0016	1.41

Location 6.2	Depth(m)	Temp (C)	Conductivity (S/M)	Oxygen (D/O)
	3	6.22	.0018	14.05
	6	5.44	.0017	13.42
	9	4.82	.0017	11.89
	12	4.79	.0017	10.61
	15	4.78	.0016	10.23
	18	4.75	.0017	9.89
	21	4.70	.0016	9.50
	24	4.67	.0016	9.07
	27	4.64	.0016	8.75
	30	4.61	.0016	8.42
	33	4.62	.0016	8.07
	36	4.61	.0016	7.88
	39	4.52	.0016	7.59
	42	4.40	.0016	7.15
	45	4.40	.0016	6.73
	48	4.40	.0016	6.45
	51	4.38	.0016	6.15
	54	4.38	.0016	5.88
	57	4.38	.0016	5.65
	60	4.38	.0016	5.46
	63	4.35	.0016	5.19
	66	4.32	.0016	4.69
Location 6.3	Depth(m)	Temp (C)	Conductivity (S/M)	Oxygen (D/O)
	6	5.73	.0018	12.84
	9	5.35	.0017	12.37
	12	5.10	.0017	11.29
	15	5.04	.0017	10.66
	18	4.99	.0017	10.27
	21	4.93	.0017	9.87
	24	4.83	.0017	9.48
	27	4.80	.0017	8.93
	30	4.78	.0017	8.52
	33	4.78	.0017	8.10
	36	4.77	.0017	7.85
	39	4.77	.0017	7.66
	42	4.73	.0016	7.44
	45	4.69	.0016	7.11
	48	4.68	.0016	6.81
	51	4.65	.0016	6.50
	54	4.57	.0016	6.17
	57	4.44	.0016	5.57

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(Note: Dissolved oxygen results do not correlate with Winkler dissolved oxygen samples and are considered invalid.)

Location A	Depth (m)	Temperature (deg. C)	Oxygen (mg/L)	Conductivity (S/m)
	1	14.57	6.22	0.0047
	2	14.48	6.38	0.0028
	3	14.41	6.38	0.0028
	4	14.35	6.39	0.0028
	5	14.29	6.37	0.0028
	6	14.25	6.36	0.0028
	7	14.22	6.34	0.0028
	8	14.20	6.30	0.0028
	9	14.17	6.27	0.0028
	10	14.10	6.25	0.0028
	11	14.03	6.23	0.0028
	12	13.99	6.19	0.0028
	13	13.94	6.17	0.0028
	14	13.88	6.16	0.0027
	15	13.85	6.15	0.0027
	16	13.76	6.16	0.0027
	17	13.71	6.15	0.0027
	18	13.70	6.12	0.0027
	19	13.69	6.08	0.0027
	20	13.68	6.07	0.0027
	21	13.62	6.08	0.0027
	22	13.61	6.07	0.0027
	23	13.60	6.05	0.0027
	24	13.60	6.03	0.0027
	25	13.60	6.02	0.0027
	26	13.59	6.03	0.0027
	27	13.55	6.03	0.0027
	28	13.54	6.02	0.0027
	29	13.53	6.00	0.0027
	30	13.53	5.99	0.0027
	31	13.52	6.00	0.0027
	32	13.46	6.00	0.0027
	33	13.32	6.04	0.0027
	34	12.62	6.23	0.0026
	35	12.38	6.17	0.0026
	36	12.30	5.92	0.0025
	37	12.11	5.87	0.0025
	38	11.43	6.05	0.0024
	39	11.10	5.86	0.0024
	40	10.86	5.13	0.0024
Location 1.1	Depth (m)	Temperature (deg. C)	Oxygen (mg/L)	Conductivity (S/m)
	1	14.12	6.37	0.0014
	2	14.00	6.32	0.0028
	3	13.93	6.33	0.0028
	4	13.91	6.28	0.0027
	5	13.86	6.29	0.0027
	6	13.64	6.35	0.0027
	7	13.52	6.35	0.0027

	8	13.47	6.27	0.0027
	9	13.44	6.23	0.0027
	10	13.39	6.22	0.0027
	11	13.34	6.22	0.0027
	12	13.29	6.20	0.0027
	13	13.26	6.20	0.0026
	14	13.25	6.17	0.0027
	15	13.20	6.17	0.0026
	16	13.16	6.18	0.0026
	17	13.15	6.16	0.0026
	18	13.14	6.15	0.0026
	19	13.12	6.15	0.0026
	20	13.10	6.15	0.0026
	21	13.08	6.16	0.0026
	22	13.06	6.15	0.0026
	23	13.04	6.16	0.0026
	24	12.99	6.17	0.0026
	25	12.96	6.17	0.0026
	26	12.90	6.17	0.0026
	27	12.85	6.16	0.0026
	28	12.85	6.15	0.0026
	29	12.84	6.14	0.0026
	30	12.84	6.13	0.0026
	31	12.76	6.17	0.0026
	32	12.69	6.18	0.0026
	33	12.65	6.16	0.0026
	34	12.61	6.12	0.0026
Location 1.2	Depth (m)	Temperature (deg. C)	Oxygen (mg/L)	Conductivity (S/m)
	1	13.97	6.77	-0.0045
	2	13.94	6.25	0.0028
	3	13.91	6.26	0.0027
	4	13.79	6.31	0.0027
	5	13.59	6.39	0.0027
	6	13.51	6.41	0.0027
	7	13.49	6.35	0.0027
	8	13.40	6.29	0.0027
	9	13.26	6.31	0.0027
	10	13.21	6.31	0.0026
	11	13.18	6.22	0.0027
	12	13.15	6.19	0.0026
	13	13.11	6.19	0.0026
	14	13.08	6.16	0.0026
	15	13.07	6.13	0.0026
	16	13.03	6.11	0.0026
	17	12.97	6.12	0.0026
	18	12.93	6.11	0.0026
	19	12.90	6.09	0.0026
	20	12.89	6.07	0.0026
	21	12.87	6.05	0.0026
	22	12.86	6.03	0.0026
	23	12.86	6.02	0.0026
	24	12.86	6.01	0.0026
	25	12.86	6.00	0.0026

	26	12.86	6.00	0.0026
	27	12.86	5.99	0.0026
	28	12.86	5.99	0.0026
	29	12.86	5.99	0.0026
	30	12.86	5.98	0.0026
	31	12.85	5.98	0.0026
	32	12.84	5.98	0.0026
	33	12.80	5.98	0.0026
	34	12.69	6.01	0.0026
	35	12.48	6.04	0.0026
	36	12.16	6.10	0.0025
	37	11.85	6.10	0.0025
	38	11.50	6.06	0.0024
	39	11.40	5.92	0.0024
	40	11.11	5.87	0.0024
	41	10.81	5.90	0.0023
	42	10.61	5.82	0.0023
	43	10.44	5.73	0.0023
	44	10.33	5.69	0.0023
	45	10.12	5.69	0.0023
	46	9.96	5.69	0.0022
	47	9.63	5.72	0.0022
	48	9.19	5.79	0.0021
	49	8.77	5.75	0.0021
	50	8.48	5.64	0.0021
	51	8.06	5.56	0.0020
	52	7.70	5.53	0.0019
	53	7.38	5.43	0.0019
	54	6.75	5.46	0.0018
	55	6.46	5.33	0.0018
	56	6.39	5.07	0.0018
	57	6.34	4.93	0.0018
	58	6.33	4.89	0.0018
	59	6.30	4.90	0.0018
	60	6.27	4.89	0.0018
	61	6.12	4.94	0.0017
	62	5.88	5.00	0.0017
	63	5.69	5.00	0.0017
	64	5.55	4.90	0.0017
	65	5.37	4.84	0.0017
	66	5.28	4.77	0.0017
	67	5.23	4.67	0.0016
	68	5.17	4.62	0.0016
	69	5.11	4.59	0.0016
	70	5.05	4.57	0.0016
	71	4.97	4.56	0.0016
	72	4.91	4.54	0.0016
	73	4.87	4.49	0.0016
Location 1.3	Depth (m)	Temperature (deg. C)	Oxygen (mg/L)	Conductivity (S/m)
	1	13.73	6.34	0.0019
	2	13.72	6.05	0.0027
	3	13.65	6.09	0.0027
	4	13.39	6.21	0.0027

	5	13.28	6.24	0.0027
	6	13.24	6.16	0.0027
	7	13.21	6.11	0.0027
	8	13.18	6.08	0.0026
	9	13.15	6.08	0.0026
	10	13.14	6.07	0.0026
	11	13.12	6.07	0.0026
	12	13.09	6.08	0.0026
	13	13.02	6.09	0.0026
	14	12.98	6.10	0.0026
	15	12.96	6.08	0.0026
	16	12.93	6.08	0.0026
	17	12.92	6.07	0.0026
	18	12.92	6.05	0.0026
	19	12.92	6.05	0.0026
	20	12.91	6.05	0.0026
	21	12.91	6.05	0.0026
	22	12.91	6.05	0.0026
	23	12.90	6.04	0.0026
	24	12.90	6.04	0.0026
	25	12.90	6.03	0.0026
	26	12.90	6.04	0.0026
	27	12.90	6.03	0.0026
	28	12.90	6.03	0.0026
	29	12.89	6.03	0.0026
	30	12.89	6.03	0.0026
	31	12.88	6.03	0.0026
	32	12.72	6.07	0.0026
	33	12.54	6.12	0.0026
	34	12.33	6.09	0.0025
	35	12.15	6.07	0.0025
	36	11.99	6.01	0.0025
	37	11.70	6.02	0.0025
	38	11.46	6.01	0.0024
	39	11.34	5.90	0.0024
	40	11.21	5.82	0.0024
	41	10.93	5.87	0.0024
	42	10.73	5.88	0.0023
	43	10.64	5.78	0.0023
	44	10.59	5.72	0.0023
	45	10.26	5.79	0.0023
	46	9.95	5.86	0.0022
	47	9.45	5.88	0.0022
	48	9.00	5.87	0.0021
	49	8.63	5.72	0.0021
	50	8.17	5.66	0.0020
	51	7.77	5.62	0.0020
	52	7.62	5.43	0.0019
	53	7.41	5.30	0.0019
	54	7.15	5.30	0.0019
	55	6.92	5.29	0.0019
	56	6.78	5.21	0.0018
	57	6.71	5.13	0.0018
	58	6.68	5.07	0.0018

	59	6.65	5.05	0.0018
	60	6.62	5.04	0.0018
Location B	Depth (m)	Temperature (deg. C)	Oxygen (mg/L)	Conductivity (S/m)
	1	13.78	6.17	0.0070
	2	13.49	6.55	0.0027
	3	13.44	6.49	0.0027
	4	13.39	6.38	0.0027
	5	13.35	6.34	0.0027
	6	13.31	6.31	0.0027
	7	13.27	6.31	0.0027
	8	13.22	6.30	0.0026
	9	13.08	6.30	0.0026
	10	12.83	6.37	0.0026
	11	12.68	6.31	0.0026
	12	12.51	6.28	0.0026
	13	12.33	6.24	0.0026
	14	12.29	6.18	0.0025
	15	12.28	6.09	0.0025
	16	12.23	6.08	0.0025
	17	12.19	6.07	0.0025
	18	12.16	6.04	0.0025
	19	12.11	6.03	0.0025
	20	12.03	6.02	0.0025
	21	11.90	6.04	0.0025
	22	11.81	6.02	0.0025
	23	11.68	6.00	0.0024
	24	11.37	6.07	0.0024
	25	11.00	6.14	0.0024
	26	10.36	6.19	0.0023
	27	9.47	6.33	0.0022
	28	9.03	6.17	0.0021
	29	8.66	5.87	0.0021
	30	8.45	5.67	0.0020
	31	8.22	5.59	0.0020
	32	8.11	5.55	0.0020
	33	8.03	5.50	0.0020
	34	7.82	5.55	0.0020
	35	7.67	5.57	0.0019
	36	7.60	5.51	0.0019
	37	7.50	5.48	0.0019
	38	7.15	5.56	0.0019
	39	6.91	5.59	0.0019
	40	6.78	5.44	0.0018
	41	6.64	5.35	0.0018
	42	6.51	5.31	0.0018
	43	6.42	5.26	0.0018
	44	6.34	5.22	0.0018
	45	6.28	5.18	0.0018
	46	6.18	5.16	0.0018
	47	6.04	5.16	0.0017
	48	5.88	5.16	0.0017
	49	5.74	5.12	0.0017
	50	5.63	5.05	0.0017

	51	5.50	5.00	0.0017
	52	5.34	4.96	0.0016
	53	5.23	4.91	0.0016
	54	5.18	4.84	0.0016
	55	5.16	4.78	0.0016
	56	5.08	4.76	0.0016
	57	4.94	4.77	0.0016
	58	4.91	4.73	0.0016
	59	4.90	4.66	0.0016
	60	4.89	4.63	0.0016
	61	4.88	4.61	0.0016
	62	4.87	4.60	0.0016
	63	4.86	4.59	0.0016
	64	4.84	4.58	0.0016
	65	4.81	4.58	0.0016
	66	4.80	4.56	0.0016
	67	4.79	4.54	0.0016
	68	4.78	4.53	0.0016
	69	4.77	4.51	0.0016
	70	4.76	4.49	0.0016
Location 2.1	Depth (m)	Temperature (deg. C)	Oxygen (mg/L)	Conductivity (S/m)
	1	13.99	7.04	-0.0046
	2	13.75	6.55	0.0027
	3	13.43	6.63	0.0027
	4	13.28	6.61	0.0026
	5	13.14	6.51	0.0026
	6	12.99	6.47	0.0026
	7	12.90	6.41	0.0026
	8	12.88	6.33	0.0026
	9	12.83	6.29	0.0026
	10	12.79	6.26	0.0026
	11	12.75	6.23	0.0026
	12	12.69	6.22	0.0026
	13	12.59	6.22	0.0026
	14	12.54	6.20	0.0026
	15	12.48	6.16	0.0025
	16	12.41	6.15	0.0025
	17	12.37	6.13	0.0025
	18	12.35	6.08	0.0025
	19	12.30	6.06	0.0025
	20	12.19	6.07	0.0025
	21	12.10	6.06	0.0025
	22	12.04	6.01	0.0025
	23	11.94	6.00	0.0025
	24	11.91	5.97	0.0025
	25	11.81	5.95	0.0025
	26	11.77	5.94	0.0025
	27	11.73	5.91	0.0025
	28	11.64	5.91	0.0024
	29	11.60	5.89	0.0024
	30	11.57	5.87	0.0024
	31	11.50	5.87	0.0024
	32	11.39	5.89	0.0024

	33	11.29	5.89	0.0024
	34	11.24	5.85	0.0024
	35	11.11	5.85	0.0024
	36	10.52	6.02	0.0023
	37	9.22	6.41	0.0021
	38	8.43	6.35	0.0020
	39	8.23	5.79	0.0020
	40	8.23	5.37	0.0020
	41	8.23	5.26	0.0020
	42	8.24	5.28	0.0020
	43	8.25	5.32	0.0020
	44	8.23	5.36	0.0020
	45	8.17	5.42	0.0020
	46	8.13	5.44	0.0020
	47	8.14	5.43	0.0020
	48	7.92	5.48	0.0020
	49	7.65	5.56	0.0019
	50	7.39	5.58	0.0019
	51	7.17	5.32	0.0019
	50	7.22	5.19	0.0019
Location 2.2	Depth (m)	Temperature (deg. C)	Oxygen (mg/L)	Conductivity (S/m)
	1	14.24	7.57	-0.0131
	2	13.85	6.62	0.0027
	3	13.60	6.68	0.0027
	4	13.42	6.62	0.0027
	5	13.32	6.51	0.0027
	6	13.25	6.42	0.0026
	7	13.14	6.38	0.0026
	8	13.08	6.33	0.0026
	9	13.07	6.26	0.0026
	10	13.06	6.21	0.0026
	11	13.04	6.20	0.0026
	12	13.01	6.18	0.0026
	13	12.99	6.15	0.0026
	14	12.98	6.13	0.0026
	15	12.97	6.11	0.0026
	16	12.95	6.11	0.0026
	17	12.93	6.10	0.0026
	18	12.90	6.10	0.0026
	19	12.85	6.10	0.0026
	20	12.77	6.09	0.0026
	21	12.63	6.12	0.0026
	22	12.42	6.15	0.0025
	23	12.18	6.16	0.0025
	24	12.06	6.09	0.0025
	25	12.02	5.99	0.0025
	26	11.99	5.94	0.0025
	27	11.97	5.91	0.0025
	28	11.93	5.91	0.0025
	29	11.87	5.91	0.0025
	30	11.74	5.92	0.0024
	31	11.56	5.94	0.0024
	32	11.24	5.98	0.0024

	33	10.72	6.05	0.0023
	34	10.08	6.11	0.0022
	35	9.69	5.97	0.0022
	36	9.43	5.73	0.0022
	37	9.09	5.65	0.0021
	38	8.94	5.58	0.0021
	39	8.78	5.52	0.0021
	40	8.71	5.48	0.0021
	41	8.56	5.48	0.0021
	42	8.11	5.62	0.0020
	43	7.72	5.63	0.0019
	44	7.50	5.51	0.0019
	45	7.44	5.36	0.0019
	46	7.34	5.26	0.0019
	47	7.18	5.28	0.0019
	48	6.94	5.32	0.0018
	49	6.71	5.32	0.0018
	50	6.53	5.25	0.0018
	51	6.41	5.16	0.0018
	52	6.29	5.10	0.0018
	53	6.18	5.06	0.0018
	54	6.09	5.01	0.0018
	55	5.98	4.99	0.0017
	56	5.85	4.99	0.0017
	57	5.78	4.95	0.0017
	58	5.69	4.91	0.0017
	59	5.65	4.87	0.0017
	60	5.60	4.84	0.0017
	61	5.56	4.82	0.0017
	62	5.49	4.79	0.0017
	63	5.43	4.79	0.0017
	64	5.38	4.75	0.0017
	65	5.35	4.72	0.0016
	66	5.32	4.69	0.0017
	67	5.28	4.68	0.0016
	68	5.23	4.69	0.0016
	69	5.18	4.65	0.0016
	70	5.14	4.65	0.0016
	71	5.09	4.62	0.0016
	72	5.06	4.61	0.0016
	73	5.05	4.57	0.0016
	74	5.04	4.56	0.0016
	75	4.99	4.57	0.0016
	76	4.95	4.55	0.0016
	77	4.93	4.52	0.0016
	78	4.92	4.51	0.0016
	79	4.91	4.49	0.0016
	80	4.90	4.47	0.0016
	81	4.90	4.46	0.0016
	82	4.88	4.46	0.0016
	83	4.86	4.46	0.0016
	84	4.84	4.43	0.0016
	85	4.81	4.41	0.0016

Location 2.3	Depth (m)	Temperature (deg. C)	Oxygen (mg/L)	Conductivity (S/m)
	1	14.01	6.28	-0.4613
	2	13.99	6.81	0.0027
	3	13.96	6.31	0.0027
	4	13.87	6.34	0.0027
	5	13.72	6.41	0.0027
	6	13.56	6.44	0.0027
	7	13.45	6.43	0.0027
	8	13.39	6.39	0.0027
	9	13.36	6.36	0.0027
	10	13.36	6.34	0.0027
	11	13.34	6.35	0.0027
	12	13.33	6.35	0.0027
	13	13.33	6.36	0.0027
	14	13.32	6.36	0.0027
	15	13.32	6.37	0.0027
	16	13.31	6.37	0.0026
	17	13.31	6.38	0.0027
	18	13.31	6.38	0.0027
	19	13.30	6.38	0.0027
	20	13.30	6.38	0.0027
	21	13.30	6.38	0.0027
	22	13.30	6.38	0.0027
	23	13.29	6.39	0.0027
	24	13.28	6.40	0.0027
	25	13.26	6.40	0.0026
	26	13.24	6.40	0.0027
	27	13.23	6.40	0.0027
	28	13.22	6.39	0.0027
	29	13.21	6.39	0.0027
	30	13.19	6.39	0.0026
	31	13.17	6.39	0.0026
	32	11.54	7.00	0.0023
	33	9.16	7.89	0.0021
	34	8.74	6.86	0.0021
	35	8.32	6.17	0.0020
	36	8.18	5.87	0.0020
	37	7.99	5.78	0.0020
	38	7.87	5.77	0.0020
	39	7.72	5.77	0.0020
	40	7.43	5.82	0.0019
	41	7.35	5.77	0.0019
	42	7.29	5.68	0.0019
	43	7.25	5.62	0.0019
	44	7.07	5.67	0.0019
	45	6.97	5.66	0.0019
	46	7.07	5.43	0.0019
	45	7.05	5.53	0.0019

Location 3.1	Depth (m)	Temperature (deg. C)	Oxygen (mg/L)	Conductivity (S/m)
	1	13.16	6.10	0.0038
	2	13.09	6.20	0.0026
	3	12.92	6.27	0.0026
	4	12.57	6.37	0.0026

	5	12.37	6.34	0.0025
	6	12.30	6.20	0.0025
	7	12.27	6.11	0.0025
	8	12.24	6.05	0.0025
	9	12.22	6.01	0.0025
	10	12.20	6.00	0.0025
	11	12.18	5.98	0.0025
	12	12.16	5.96	0.0025
	13	12.15	5.95	0.0025
	14	12.09	5.96	0.0025
	15	11.97	5.97	0.0025
	16	11.71	6.02	0.0024
	17	11.60	5.97	0.0024
	18	11.46	5.90	0.0024
	19	11.20	5.94	0.0024
	20	11.04	5.92	0.0024
	21	10.76	5.90	0.0023
	22	10.37	5.99	0.0023
	23	9.53	6.18	0.0022
	24	8.75	6.15	0.0021
	25	8.13	5.94	0.0020
	26	7.87	5.62	0.0020
	27	7.62	5.42	0.0019
	28	7.36	5.37	0.0019
	29	7.06	5.37	0.0019
	30	6.83	5.34	0.0018
	31	6.72	5.25	0.0018
	32	6.68	5.15	0.0018
	33	6.67	5.12	0.0018
	34	6.52	5.16	0.0018
	35	6.22	5.26	0.0018
	36	6.08	5.21	0.0017
	37	5.98	5.10	0.0017
	38	5.91	5.05	0.0017
	39	5.86	5.02	0.0017
	40	5.85	4.99	0.0017
	41	5.82	4.96	0.0017
Location 3.2	Depth (m)	Temperature (deg. C)	Oxygen (mg/L)	Conductivity (S/m)
	1	13.57	6.24	0.0027
	2	13.20	6.40	0.0026
	3	13.10	6.40	0.0026
	4	13.04	6.32	0.0026
	5	12.97	6.24	0.0026
	6	12.93	6.18	0.0026
	7	12.87	6.15	0.0026
	8	12.77	6.11	0.0026
	9	12.72	6.09	0.0026
	10	12.66	6.07	0.0026
	11	12.63	6.03	0.0026
	12	12.60	6.00	0.0026
	13	12.50	6.01	0.0026
	14	12.43	6.00	0.0026
	15	12.34	5.99	0.0025

	16	12.31	5.95	0.0025
	17	12.27	5.92	0.0025
	18	11.99	6.00	0.0025
	19	11.55	6.10	0.0024
	20	11.09	6.11	0.0024
	21	10.65	6.03	0.0023
	22	10.11	5.99	0.0022
	23	9.51	5.98	0.0022
	24	9.13	5.80	0.0021
	25	8.97	5.57	0.0021
	26	8.57	5.57	0.0020
	27	8.19	5.62	0.0020
	28	7.71	5.61	0.0019
	29	7.41	5.51	0.0019
	30	6.99	5.38	0.0019
	31	6.84	5.28	0.0018
	32	6.77	5.14	0.0018
	33	6.61	5.10	0.0018
	34	6.45	5.11	0.0018
	35	6.36	5.06	0.0018
	36	6.30	5.00	0.0018
	37	6.17	5.00	0.0018
	38	6.10	4.98	0.0017
	39	6.01	4.95	0.0017
	40	5.88	4.96	0.0017
	41	5.79	4.94	0.0017
	42	5.73	4.89	0.0017
	43	5.66	4.85	0.0017
	44	5.63	4.82	0.0017
	45	5.60	4.80	0.0017
	46	5.58	4.78	0.0017
	47	5.50	4.78	0.0017
	48	5.41	4.79	0.0017
	49	5.32	4.76	0.0017
	50	5.31	4.70	0.0017
	51	5.30	4.65	0.0016
	52	5.23	4.66	0.0017
	53	5.14	4.66	0.0016
	54	5.09	4.63	0.0016
	55	5.07	4.59	0.0016
	56	5.05	4.57	0.0016
	57	5.01	4.56	0.0016
	58	4.98	4.55	0.0016
	59	4.97	4.52	0.0016
	60	4.95	4.51	0.0016
	61	4.89	4.50	0.0016
	62	4.82	4.51	0.0016
	63	4.78	4.49	0.0016
	64	4.77	4.45	0.0016
	65	4.75	4.42	0.0016
	66	4.74	4.41	0.0016
	67	4.71	4.41	0.0016
	68	4.69	4.39	0.0016
	69	4.68	4.37	0.0016

	70	4.67	4.37	0.0016
	71	4.66	4.35	0.0016
	72	4.63	4.35	0.0016
	73	4.62	4.35	0.0016
	74	4.60	4.33	0.0016
	75	4.58	4.31	0.0016
	76	4.57	4.31	0.0016
	77	4.57	4.31	0.0016
	78	4.56	4.28	0.0016
	79	4.55	4.28	0.0016
	80	4.56	4.27	0.0016
	81	4.55	4.27	0.0015
	82	4.52	4.27	0.0016
	83	4.51	4.26	0.0016
	84	4.51	4.24	0.0016
	85	4.51	4.23	0.0016
	86	4.50	4.22	0.0015
	87	4.48	4.23	0.0016
	88	4.47	4.21	0.0016
	89	4.47	4.20	0.0015
	90	4.46	4.19	0.0015
	91	4.44	4.19	0.0016
	92	4.43	4.19	0.0016
	93	4.42	4.16	0.0015
Location 3.3	Depth (m)	Temperature (deg. C)	Oxygen (mg/L)	Conductivity (S/m)
	1	13.88	6.48	0.0017
	2	13.67	6.48	0.0027
	3	13.55	6.48	0.0027
	4	13.48	6.43	0.0027
	5	13.45	6.39	0.0027
	6	13.40	6.38	0.0027
	7	13.29	6.40	0.0027
	8	13.25	6.40	0.0027
	9	13.24	6.36	0.0027
	10	13.24	6.35	0.0027
	11	13.24	6.35	0.0027
	12	13.21	6.37	0.0027
	13	13.18	6.38	0.0027
	14	13.18	6.38	0.0027
	15	13.17	6.38	0.0026
	16	13.12	6.40	0.0026
	17	13.01	6.46	0.0026
	18	12.97	6.44	0.0026
	19	12.67	6.53	0.0026
	20	12.13	6.70	0.0025
	21	11.63	6.72	0.0024
	22	11.20	6.63	0.0024
	23	10.59	6.66	0.0023
	24	9.50	6.84	0.0021
	25	8.32	7.00	0.0020
	26	8.05	6.47	0.0020
	27	7.96	6.05	0.0020
	28	7.77	6.01	0.0020

	29	7.59	6.07	0.0019
	30	7.34	6.11	0.0019
	31	6.82	6.25	0.0018
	32	6.56	6.19	0.0018
	33	6.39	6.01	0.0018
	34	6.27	5.90	0.0018
	35	6.20	5.78	0.0018
	36	6.03	5.79	0.0017
	37	5.84	5.82	0.0017
	38	5.72	5.76	0.0017
	39	5.64	5.69	0.0017
	40	5.46	5.69	0.0017
	41	5.35	5.67	0.0017
	42	5.24	5.60	0.0016
	43	5.19	5.53	0.0016
	44	5.17	5.45	0.0016
	45	5.16	5.41	0.0016
	46	5.14	5.40	0.0016
	47	5.13	5.40	0.0016
	48	5.12	5.37	0.0016
	49	5.12	5.37	0.0016
	50	5.10	5.35	0.0016
	51	5.08	5.35	0.0016
	52	5.06	5.34	0.0016
	53	5.04	5.31	0.0016
	54	5.00	5.30	0.0016
	55	4.97	5.27	0.0016
	56	4.95	5.25	0.0016
	57	4.90	5.22	0.0016
	58	4.89	5.19	0.0016
	59	4.89	5.16	0.0016
	60	4.88	5.14	0.0016
	61	4.88	5.12	0.0016
	62	4.88	5.10	0.0016
	63	4.85	5.09	0.0016
	64	4.81	5.08	0.0016
	65	4.78	5.06	0.0016
	66	4.76	5.03	0.0016
	67	4.75	5.01	0.0016
	68	4.75	4.99	0.0016
	69	4.75	4.96	0.0016
	70	4.75	4.96	0.0016
	71	4.74	4.96	0.0016
	72	4.74	4.95	0.0016
	73	4.73	4.93	0.0016
	74	4.73	4.93	0.0016
	75	4.72	4.90	0.0016
	76	4.71	4.90	0.0016
	77	4.69	4.88	0.0016
	78	4.69	4.88	0.0016
	79	4.68	4.86	0.0016
	80	4.66	4.85	0.0016
	81	4.61	4.85	0.0016
	82	4.58	4.84	0.0016

	83	4.56	4.81	0.0016
	84	4.54	4.79	0.0016
	85	4.54	4.75	0.0016
	86	4.53	4.73	0.0016
	87	4.49	4.73	0.0016
	88	4.47	4.73	0.0016
	89	4.45	4.70	0.0016
	90	4.45	4.68	0.0016
	91	4.45	4.66	0.0016
Location 4.1	Depth (m)	Temperature (deg. C)	Oxygen (mg/L)	Conductivity (S/m)
	1	12.92	6.00	0.0032
	2	12.66	6.11	0.0026
	3	12.36	6.24	0.0025
	4	12.20	6.20	0.0025
	5	12.14	6.02	0.0025
	6	12.01	5.99	0.0025
	7	11.92	5.98	0.0025
	8	11.85	5.93	0.0025
	9	11.67	5.93	0.0024
	10	11.33	5.99	0.0024
	11	11.18	5.93	0.0024
	12	11.06	5.82	0.0024
	13	10.92	5.77	0.0024
	14	10.77	5.77	0.0023
	15	10.69	5.72	0.0023
	16	10.59	5.70	0.0023
	17	10.45	5.73	0.0023
	18	9.94	5.86	0.0022
	19	9.52	5.91	0.0022
	20	9.10	5.79	0.0021
	21	8.49	5.80	0.0020
	22	7.87	5.76	0.0020
	23	7.50	5.55	0.0019
	24	7.19	5.31	0.0019
	25	6.96	5.20	0.0019
	26	6.76	5.14	0.0018
	27	6.50	5.11	0.0018
	28	6.33	5.08	0.0018
	29	6.22	5.00	0.0018
	30	6.10	4.97	0.0017
	31	5.97	4.96	0.0017
	32	5.89	4.93	0.0017
	33	5.80	4.89	0.0017
	34	5.64	4.90	0.0017
	35	5.57	4.87	0.0017
	36	5.49	4.81	0.0017
	37	5.42	4.78	0.0017
	38	5.37	4.75	0.0017
	39	5.30	4.73	0.0017
	40	5.24	4.70	0.0016
	41	5.16	4.69	0.0017
	42	5.13	4.65	0.0016
	43	5.12	4.60	0.0016

	44	5.12	4.58	0.0016
	45	5.11	4.56	0.0016
	46	5.05	4.57	0.0016
	47	4.94	4.59	0.0016
	48	4.87	4.59	0.0016
	49	4.87	4.52	0.0016
	50	4.87	4.46	0.0016
	51	4.86	4.44	0.0016
	52	4.86	4.44	0.0016
	53	4.86	4.45	0.0016
	54	4.86	4.48	0.0016
	55	4.84	4.46	0.0016
	56	4.82	4.43	0.0016
	57	4.83	4.40	0.0016
	58	4.81	4.40	0.0016
	59	4.80	4.40	0.0016
	60	4.80	4.39	0.0016
	61	4.79	4.39	0.0016
	62	4.76	4.37	0.0016
	63	4.73	4.38	0.0016
	64	4.72	4.36	0.0016
	65	4.72	4.34	0.0016
	66	4.72	4.32	0.0016
	67	4.70	4.33	0.0016
	68	4.68	4.32	0.0016
	69	4.66	4.32	0.0016
	70	4.65	4.30	0.0016
	71	4.64	4.28	0.0016
	72	4.63	4.26	0.0016
	73	4.62	4.26	0.0016
	74	4.61	4.25	0.0016
	75	4.61	4.25	0.0016
	76	4.60	4.23	0.0016
	77	4.60	4.23	0.0016
	78	4.60	4.22	0.0015
	79	4.59	4.22	0.0016
	80	4.58	4.21	0.0016
	81	4.57	4.22	0.0016
	82	4.56	4.21	0.0016
	83	4.56	4.19	0.0016
	84	4.55	4.18	0.0016
	85	4.55	4.18	0.0016
	86	4.54	4.18	0.0016
	87	4.54	4.17	0.0016
	88	4.52	4.17	0.0016
	89	4.51	4.16	0.0016
	90	4.51	4.15	0.0015
	91	4.50	4.14	0.0016
	92	4.50	4.14	0.0016
	93	4.48	4.14	0.0016
	94	4.46	4.13	0.0015
	95	4.45	4.12	0.0015
	96	4.44	4.11	0.0015
	97	4.44	4.10	0.0015

Location 4.2	Depth (m)	Temperature (deg. C)	Oxygen (mg/L)	Conductivity (S/m)
	1	13.63	6.18	0.0030
	2	13.21	6.37	0.0026
	3	12.91	6.46	0.0026
	4	12.77	6.38	0.0026
	5	12.74	6.21	0.0026
	6	12.74	6.14	0.0026
	7	12.73	6.11	0.0026
	8	12.71	6.10	0.0026
	9	12.70	6.07	0.0026
	10	12.69	6.06	0.0026
	11	12.68	6.06	0.0026
	12	12.62	6.07	0.0026
	13	12.38	6.14	0.0026
	14	12.20	6.14	0.0025
	15	12.09	6.07	0.0025
	16	11.70	6.13	0.0024
	17	10.51	6.49	0.0023
	18	9.63	6.64	0.0022
	19	8.88	6.27	0.0021
	20	8.72	5.85	0.0021
	21	8.61	5.59	0.0021
	22	8.33	5.60	0.0020
	23	8.05	5.64	0.0020
	24	7.71	5.65	0.0019
	25	7.49	5.59	0.0019
	26	7.21	5.51	0.0019
	27	6.98	5.47	0.0019
	28	6.75	5.41	0.0018
	29	6.62	5.34	0.0018
	30	6.58	5.25	0.0018
	31	6.55	5.21	0.0018
	32	6.53	5.19	0.0018
	33	6.44	5.22	0.0018
	34	6.35	5.24	0.0018
	35	6.11	5.28	0.0017
	36	5.75	5.32	0.0017
	37	5.62	5.20	0.0017
	38	5.55	5.03	0.0017
	39	5.50	4.94	0.0017
	40	5.46	4.91	0.0017
	41	5.42	4.85	0.0017
	42	5.39	4.83	0.0017
	43	5.34	4.80	0.0017
	44	5.29	4.78	0.0016
	45	5.24	4.75	0.0016
	46	5.18	4.71	0.0016
	47	5.07	4.73	0.0016
	48	5.00	4.70	0.0016
	49	4.93	4.65	0.0016
	50	4.89	4.61	0.0016
	51	4.86	4.58	0.0016
	52	4.84	4.56	0.0016

	53	4.75	4.56	0.0016
	54	4.65	4.56	0.0016
	55	4.58	4.53	0.0016
	56	4.56	4.48	0.0016
	57	4.54	4.43	0.0016
	58	4.51	4.42	0.0015
	59	4.48	4.40	0.0015
	60	4.47	4.37	0.0016
	61	4.45	4.36	0.0015
	62	4.44	4.35	0.0015
	63	4.43	4.33	0.0016
	64	4.42	4.31	0.0015
	65	4.42	4.30	0.0015
	66	4.42	4.28	0.0015
	67	4.42	4.27	0.0015
	68	4.41	4.27	0.0015
	69	4.40	4.26	0.0015
	70	4.40	4.25	0.0015
	71	4.38	4.25	0.0015
	72	4.37	4.25	0.0016
	73	4.36	4.22	0.0015
	74	4.36	4.20	0.0015
	75	4.35	4.20	0.0015
	76	4.33	4.20	0.0015
	77	4.33	4.18	0.0015
	78	4.31	4.17	0.0015
	79	4.30	4.17	0.0015
	80	4.29	4.14	0.0015
	81	4.29	4.14	0.0015
	82	4.28	4.12	0.0015
	83	4.28	4.11	0.0015
	84	4.28	4.12	0.0015
	85	4.28	4.11	0.0015
	86	4.28	4.11	0.0015
	87	4.28	4.10	0.0015
	88	4.28	4.10	0.0015
	89	4.28	4.07	0.0015
	90	4.28	4.07	0.0015
Location 4.3	Depth (m)	Temperature (deg. C)	Oxygen (mg/L)	Conductivity (S/m)
	0	13.95	3.83	0.0339
	1	13.70	6.13	0.0062
	2	13.43	6.49	0.0027
	3	13.20	6.56	0.0027
	4	13.12	6.52	0.0026
	5	13.10	6.41	0.0027
	6	13.09	6.35	0.0026
	7	13.09	6.35	0.0027
	8	13.09	6.31	0.0026
	9	13.09	6.31	0.0027
	10	13.09	6.30	0.0027
	11	13.09	6.29	0.0027
	12	13.08	6.28	0.0027
	13	13.08	6.28	0.0026

	14	13.07	6.28	0.0026
	15	13.06	6.27	0.0026
	16	13.06	6.27	0.0026
	17	13.06	6.26	0.0026
	18	13.04	6.26	0.0026
	19	11.90	6.67	0.0023
	20	8.14	8.18	0.0020
	21	7.90	7.23	0.0020
	22	7.46	6.12	0.0019
	23	7.14	5.63	0.0019
	24	6.91	5.51	0.0019
	25	6.72	5.47	0.0018
	26	6.51	5.46	0.0018
	27	6.41	5.44	0.0018
	28	6.36	5.36	0.0018
	29	6.33	5.35	0.0018
	30	6.26	5.36	0.0018
	31	6.21	5.35	0.0018
	32	6.09	5.29	0.0018
Location 5.1	Depth (m)	Temperature (deg. C)	Oxygen (mg/L)	Conductivity (S/m)
	1	13.22	6.12	0.0032
	2	12.82	6.29	0.0026
	3	12.44	6.42	0.0026
	4	12.23	6.36	0.0025
	5	12.13	6.16	0.0025
	6	12.08	6.07	0.0025
	7	12.03	6.00	0.0025
	8	11.99	6.00	0.0025
	9	11.90	5.97	0.0025
	10	11.76	5.99	0.0025
	11	11.62	5.98	0.0024
	12	11.53	5.93	0.0024
	13	11.50	5.88	0.0024
	14	11.50	5.84	0.0024
	15	11.50	5.83	0.0024
	16	11.49	5.82	0.0024
	17	11.45	5.84	0.0024
	18	11.26	5.89	0.0024
	19	10.94	5.96	0.0024
	20	10.72	5.94	0.0023
	21	10.48	5.88	0.0023
	22	9.96	5.93	0.0022
	23	9.27	5.99	0.0021
	24	8.56	5.92	0.0020
	25	8.08	5.68	0.0020
	26	7.75	5.49	0.0020
	27	7.62	5.34	0.0019
	28	7.34	5.31	0.0019
	29	7.14	5.31	0.0019
	30	7.02	5.23	0.0019
	31	6.96	5.17	0.0019
	32	6.85	5.16	0.0018
	33	6.65	5.18	0.0018

	34	6.40	5.19	0.0018
	35	6.26	5.10	0.0018
	36	6.20	4.99	0.0018
	37	6.10	4.95	0.0017
	38	6.00	4.92	0.0017
	39	5.97	4.87	0.0017
	40	5.93	4.84	0.0017
	41	5.85	4.84	0.0017
	42	5.79	4.81	0.0017
	43	5.77	4.77	0.0017
	44	5.73	4.74	0.0017
	45	5.71	4.72	0.0017
	46	5.69	4.70	0.0017
	47	5.66	4.68	0.0017
	48	5.65	4.67	0.0017
	49	5.64	4.65	0.0017
	50	5.50	4.67	0.0017
	51	5.48	4.64	0.0017
	52	5.49	4.58	0.0017
	53	5.51	4.56	0.0017
	54	5.49	4.56	0.0017
	55	5.46	4.51	0.0017
Location 5.2	Depth (m)	Temperature (deg. C)	Oxygen (mg/L)	Conductivity (S/m)
	1	12.94	7.21	-0.0149
	2	12.87	6.16	0.0026
	3	12.69	6.23	0.0026
	4	12.63	6.21	0.0026
	5	12.59	6.15	0.0026
	6	12.54	6.14	0.0026
	7	12.53	6.12	0.0026
	8	12.52	6.09	0.0026
	9	12.51	6.08	0.0026
	10	12.51	6.07	0.0026
	11	12.50	6.07	0.0026
	12	12.49	6.07	0.0026
	13	12.48	6.08	0.0026
	14	12.41	6.09	0.0025
	15	12.15	6.18	0.0025
	16	11.80	6.25	0.0025
	17	10.71	6.56	0.0023
	18	10.20	6.49	0.0023
	19	9.98	6.14	0.0022
	20	9.91	5.90	0.0022
	21	9.68	5.90	0.0022
	22	9.40	6.00	0.0022
	23	9.11	6.01	0.0021
	24	8.72	6.01	0.0021
	25	8.20	6.08	0.0020
	26	7.71	6.07	0.0020
	27	7.55	5.84	0.0019
	28	7.42	5.69	0.0019
	29	7.26	5.63	0.0019
	30	7.07	5.66	0.0019

	31	6.85	5.65	0.0018
	32	6.72	5.63	0.0018
	33	6.63	5.56	0.0018
	34	6.48	5.55	0.0018
	35	6.34	5.54	0.0018
	36	6.27	5.52	0.0018
	37	6.23	5.46	0.0018
	38	6.14	5.45	0.0018
	39	5.91	5.51	0.0017
	40	5.79	5.49	0.0017
	41	5.71	5.43	0.0017
	42	5.67	5.37	0.0017
	43	5.64	5.32	0.0017
	44	5.62	5.31	0.0017
	45	5.60	5.29	0.0017
	46	5.59	5.29	0.0017
	47	5.56	5.29	0.0017
	48	5.50	5.31	0.0017
	49	5.48	5.29	0.0017
	50	5.46	5.26	0.0017
	51	5.40	5.24	0.0017
	52	5.37	5.23	0.0017
	53	5.34	5.21	0.0016
	54	5.27	5.19	0.0017
	55	5.20	5.19	0.0016
	56	5.13	5.15	0.0016
	57	5.02	5.12	0.0016
	58	4.97	5.09	0.0016
	59	4.93	5.02	0.0016
	60	4.91	4.98	0.0016
	61	4.91	4.94	0.0016
	62	4.90	4.91	0.0016
	63	4.88	4.90	0.0016
	64	4.87	4.89	0.0016
	65	4.86	4.88	0.0016
	66	4.84	4.87	0.0016
	67	4.77	4.88	0.0016
	68	4.69	4.88	0.0016
	69	4.60	4.84	0.0016
	70	4.59	4.79	0.0016
	71	4.58	4.73	0.0016
	72	4.58	4.69	0.0015
	73	4.57	4.68	0.0016
	74	4.56	4.67	0.0015
	75	4.55	4.66	0.0016
	76	4.56	4.64	0.0016
	77	4.55	4.63	0.0016
	78	4.54	4.61	0.0016
	79	4.54	4.61	0.0016
	80	4.55	4.58	0.0015
	81	4.54	4.57	0.0015
	82	4.54	4.56	0.0016
	83	4.53	4.54	0.0016
	84	4.52	4.52	0.0016

	85	4.50	4.47	0.0016
Location 5.3	Depth (m)	Temperature (deg. C)	Oxygen (mg/L)	Conductivity (S/m)
	1	13.52	5.76	0.0077
	2	13.39	6.09	0.0027
	3	13.13	6.23	0.0026
	4	12.99	6.16	0.0026
	5	12.93	6.07	0.0026
	6	12.89	6.00	0.0026
	7	12.82	5.99	0.0026
	8	12.74	5.98	0.0026
	9	12.61	5.97	0.0026
	10	12.47	5.99	0.0025
	11	12.33	5.97	0.0025
	12	12.26	5.88	0.0025
	13	12.11	5.86	0.0025
	14	11.84	5.91	0.0025
	15	11.79	5.84	0.0025
	16	11.77	5.76	0.0025
	17	11.76	5.74	0.0025
	18	11.71	5.77	0.0025
	19	11.59	5.81	0.0024
	20	11.49	5.81	0.0024
	21	11.35	5.79	0.0024
	22	11.21	5.80	0.0024
	23	11.12	5.77	0.0024
	24	10.92	5.78	0.0024
	25	10.66	5.81	0.0023
	26	10.32	5.84	0.0023
	27	10.03	5.79	0.0022
	28	9.67	5.72	0.0022
	29	9.32	5.70	0.0021
	30	8.92	5.66	0.0021
	31	8.39	5.65	0.0020
	32	8.09	5.54	0.0020
	33	7.96	5.32	0.0020
	34	7.42	5.37	0.0019
	35	7.02	5.38	0.0019
	36	6.58	5.25	0.0018
	37	6.16	5.17	0.0018
	38	5.97	4.99	0.0017
	39	5.76	4.85	0.0017
	40	5.63	4.75	0.0017
	41	5.53	4.66	0.0017
	42	5.44	4.62	0.0017
	43	5.42	4.58	0.0017
	44	5.42	4.55	0.0017
	45	5.42	4.53	0.0017
	46	5.36	4.55	0.0017
	47	5.29	4.55	0.0017
	48	5.26	4.53	0.0017
	49	5.25	4.52	0.0016
	50	5.24	4.48	0.0016
	51	5.18	4.49	0.0016

	52	5.14	4.50	0.0016
	53	5.10	4.46	0.0016
	54	5.08	4.44	0.0016
	55	5.07	4.41	0.0016
	56	5.07	4.40	0.0016
	57	5.05	4.38	0.0016
	58	5.03	4.38	0.0016
	59	5.02	4.37	0.0016
	60	5.01	4.35	0.0016
	61	5.01	4.33	0.0016
	62	4.99	4.32	0.0016
	63	4.97	4.33	0.0016
	64	4.94	4.31	0.0016
	65	4.89	4.31	0.0016
	66	4.85	4.29	0.0016
	67	4.85	4.26	0.0016
	68	4.85	4.23	0.0016
	69	4.83	4.24	0.0016
	70	4.76	4.10	0.0023
Location 6.1	Depth (m)	Temperature (deg. C)	Oxygen (mg/L)	Conductivity (S/m)
	1	12.41	0.54	0.0026
	2	12.35	6.36	0.0025
	3	12.34	6.10	0.0025
	4	12.34	6.10	0.0026
	5	12.32	6.07	0.0025
	6	12.31	6.11	0.0025
	7	12.30	6.10	0.0025
	8	12.27	6.07	0.0025
	9	12.25	6.05	0.0025
	10	12.24	6.03	0.0025
	11	12.23	6.02	0.0025
	12	12.20	6.02	0.0025
	13	12.15	6.02	0.0025
	14	12.02	6.04	0.0025
	15	11.90	6.04	0.0025
	16	11.67	6.06	0.0024
	17	11.39	6.09	0.0024
	18	10.96	6.11	0.0024
	19	10.81	6.01	0.0023
	20	10.75	5.83	0.0023
	21	10.52	5.85	0.0023
	22	10.02	5.98	0.0022
	23	9.58	6.02	0.0022
	24	9.41	5.81	0.0022
	25	9.22	5.69	0.0022
	26	9.12	5.62	0.0021
	27	9.01	5.58	0.0021
	28	8.68	5.65	0.0021
	29	8.50	5.66	0.0021
	30	8.42	5.53	0.0020
	31	8.29	5.46	0.0020
	32	8.24	5.42	0.0020
	33	8.16	5.40	0.0020

	34	7.94	5.43	0.0020
	35	7.65	5.48	0.0019
	36	6.80	5.62	0.0018
	37	6.56	5.45	0.0018
	38	6.46	5.10	0.0018
	39	6.40	4.95	0.0018
	40	6.25	4.96	0.0018
	41	6.06	4.95	0.0017
	42	5.93	4.94	0.0017
	43	5.91	4.82	0.0017
	44	5.89	4.76	0.0017
	45	5.88	4.73	0.0017
	46	5.83	4.73	0.0017
	47	5.78	4.73	0.0017
	48	5.76	4.69	0.0017
	49	5.71	4.69	0.0017
	50	5.66	4.68	0.0017
	51	5.64	4.64	0.0017
	52	5.63	4.61	0.0017
	53	5.57	4.60	0.0017
	54	5.51	4.60	0.0017
	55	5.47	4.57	0.0017
	56	5.40	4.56	0.0017
	57	5.36	4.53	0.0017
	58	5.33	4.49	0.0017
	59	5.30	4.47	0.0017
	60	5.25	4.46	0.0017
	61	5.22	4.44	0.0016
	62	5.18	4.43	0.0016
	63	5.10	4.43	0.0016
	64	5.05	4.41	0.0016
	65	5.04	4.35	0.0016
	66	5.04	4.33	0.0016
	67	5.02	4.32	0.0016
	68	5.00	4.31	0.0016
	69	4.99	4.29	0.0016
	70	4.97	4.29	0.0016
	71	4.96	4.27	0.0016
	72	4.94	4.26	0.0016
	73	4.88	4.26	0.0016
Location 6.2	Depth (m)	Temperature (deg. C)	Oxygen (mg/L)	Conductivity (S/m)
	1	11.86	5.67	0.0025
	2	11.86	5.70	0.0025
	3	11.85	5.71	0.0025
	4	11.85	5.73	0.0025
	5	11.85	5.74	0.0025
	6	11.83	5.75	0.0025
	7	11.80	5.77	0.0025
	8	11.74	5.79	0.0025
	9	11.71	5.79	0.0025
	10	11.71	5.77	0.0025
	11	11.69	5.77	0.0025
	12	11.67	5.76	0.0025

	13	11.65	5.77	0.0024
	14	11.60	5.79	0.0024
	15	11.58	5.79	0.0024
	16	11.53	5.79	0.0024
	17	11.30	5.86	0.0024
	18	11.10	5.88	0.0024
	19	10.92	5.85	0.0024
	20	10.76	5.82	0.0023
	21	10.54	5.81	0.0023
	22	10.33	5.80	0.0023
	23	10.08	5.79	0.0022
	24	9.82	5.78	0.0022
	25	9.74	5.70	0.0022
	26	9.49	5.68	0.0022
	27	9.35	5.65	0.0022
	28	9.13	5.62	0.0021
	29	8.90	5.63	0.0021
	30	8.83	5.55	0.0021
	31	8.80	5.45	0.0021
	32	8.77	5.44	0.0021
	33	8.67	5.45	0.0021
	34	8.50	5.48	0.0020
	35	8.42	5.46	0.0020
	36	8.32	5.41	0.0020
	37	8.19	5.41	0.0020
	38	8.11	5.38	0.0020
	39	8.05	5.34	0.0020
	40	7.95	5.30	0.0020
	41	7.62	5.38	0.0019
	42	7.03	5.51	0.0019
	43	6.57	5.48	0.0018
	44	6.28	5.23	0.0018
	45	6.12	5.02	0.0018
	46	6.09	4.86	0.0018
	47	6.08	4.77	0.0018
	48	6.05	4.74	0.0017
	49	6.01	4.74	0.0017
	50	5.98	4.74	0.0017
	51	5.90	4.74	0.0017
	52	5.86	4.71	0.0017
	53	5.85	4.67	0.0017
	54	5.51	4.74	0.0017
	55	5.22	4.79	0.0016
	56	5.16	4.64	0.0016
	57	5.22	4.45	0.0016
	58	5.26	4.37	0.0017
	59	5.24	4.39	0.0016
	60	5.20	4.41	0.0016
	61	5.15	4.42	0.0016
	62	5.10	4.41	0.0016
	63	5.06	4.37	0.0016
	64	5.03	4.35	0.0016
	65	5.06	4.32	0.0016
	66	5.09	4.28	0.0016

	67	5.09	4.28	0.0016
	68	5.02	4.31	0.0016
	69	5.05	3.83	0.0018
Location 6.3	Depth (m)	Temperature (deg. C)	Oxygen (mg/L)	Conductivity (S/m)
	1	12.10	5.99	0.0031
	2	12.10	6.21	0.0025
	3	12.10	6.19	0.0025
	4	12.09	6.18	0.0025
	5	12.09	6.17	0.0025
	6	12.09	6.16	0.0025
	7	12.09	6.10	0.0025
	8	12.09	6.04	0.0025
	9	12.08	6.01	0.0025
	10	12.03	6.02	0.0025
	11	12.02	6.00	0.0025
	12	11.84	6.03	0.0025
	13	11.34	6.18	0.0024
	14	11.23	6.12	0.0024
	15	10.82	6.04	0.0023
	16	10.45	6.06	0.0023
	17	10.31	5.85	0.0023
	18	10.24	5.69	0.0023
	19	10.05	5.72	0.0023
	20	9.95	5.69	0.0022
	21	9.89	5.67	0.0022
	22	9.83	5.65	0.0022
	23	9.80	5.63	0.0022
	24	9.78	5.60	0.0022
	25	9.58	5.65	0.0022
	26	9.20	5.76	0.0021
	27	8.80	5.80	0.0021
	28	8.50	5.71	0.0020
	29	8.28	5.57	0.0020
	30	7.98	5.48	0.0020
	31	7.83	5.26	0.0020

GANDER L WATER QUALITY ANALYSIS - JUNE

Parameter	LOQ	Units	1.1-GL-001	1.2-GL-OO1	1.2-GL-001F Filtered	1.2-GI-001F Filtered	1.2-GL-002	1.2-GL-002	1.2-GL-002F Filtered	1.3-GL-001	1.3-GL-001	1.3-GL-002
Data Sampled >			95/06/08	95/06/08	95/06/08	Replicate	95/06/08	Replicate	95/06/08	95/06/08	Replicate	95/06/08
Lead	0.002	mg/L	nd	nd	-	-	nd	nd	-	nd	-	nd
Bromide	0.05	mg/L	nd	nd	-	-	nd	nd	-	nd	-	nd
Chloride	0.05	mg/L	2.06	2.11	-	-	2.03	2.02	-	2.03	-	2.04
Fluoride	0.02	mg/L	nd	nd	-	-	nd	nd	-	nd	-	nd
Nitrate(as N)	0.03	mg/L	0.1	0.1	-	-	0.13	0.13	-	0.09	-	0.1
Nitrite(as N)	0.03	mg/L	nd	nd	-	-	nd	nd	-	nd	-	nd
Orthophosphate(as P)	0.05	mg/L	nd	nd	-	-	nd	nd	-	nd	-	nd
Sulphate	0.05	mg/L	0.99	0.94	-	-	0.92	0.93	-	0.91	-	0.94
Aluminum	0.025	mg/L	0.092	0.111	-	-	0.087	0.075	-	0.112	-	0.093
Barium	0.002	mg/L	nd	0.002	-	-	nd	0.003	-	0.006	-	[illegible]
Beryllium	0.005	mg/L	nd	nd	-	-	nd	nd	-	nd	-	nd
Bismuth	0.05	mg/L	nd	nd	-	-	nd	nd	-	nd	-	nd
Boron	0.01	mg/L	nd	nd	-	-	nd	nd	-	nd	-	nd
Cadmium	0.003	mg/L	nd	nd	-	-	nd	nd	-	nd	-	nd
Calcium	0.01	mg/L	1.34	1.31	-	-	1.29	1.27	-	1.3	-	1.46
Chromium	0.005	mg/L	nd	nd	-	-	nd	nd	-	nd	-	nd
Cobalt	0.005	mg/L	nd	nd	-	-	nd	nd	-	0.005	-	nd
Copper	0.003	mg/L	nd	nd	-	-	nd	nd	-	nd	-	nd
Iron	0.005	mg/L	0.06	0.054	-	-	0.063	0.062	-	0.061	-	0.056
Lead	0.025	mg/L	nd	nd	-	-	nd	nd	-	nd	-	nd
Magnesium	0.02	mg/L	0.71	0.71	-	-	0.66	0.69	-	0.7	-	0.68
Manganese	0.005	mg/L	0.007	0.007	-	-	nd	0.007	-	0.01	-	0.009
Molybdenum	0.01	mg/L	nd	nd	-	-	nd	nd	-	nd	-	nd
Nickel	0.01	mg/L	nd	nd	-	-	nd	nd	-	nd	-	nd
Phosphorus	0.06	mg/L	nd	nd	-	-	nd	nd	-	nd	-	nd
Potassium	0.4	mg/L	nd	nd	-	-	nd	0.7	-	1.1	-	0.9
Silver	0.003	mg/L	nd	nd	-	-	nd	nd	-	nd	-	nd
Sodium	0.04	mg/L	1.98	1.93	-	-	1.86	1.9	-	1.91	-	1.93
Strontium	0.002	mg/L	0.008	0.007	-	-	0.016	0.008	-	0.008	-	0.008
Tin	0.05	mg/L	nd	nd	-	-	nd	nd	-	nd	-	nd
Titanium	0.05	mg/L	nd	nd	-	-	nd	nd	-	nd	-	nd
Vanadium	0.01	mg/L	nd	nd	-	-	nd	nd	-	nd	-	nd
Zinc	0.005	mg/L	nd	nd	-	-	nd	nd	-	0.006	-	nd

(LOQ = Limits of Quantification; 1.1-GL-001 = Location 1.2, Gander Lake, Surface; 1.2-GL-002 = Location 1.2, Gander Lake, 60 metre depth.)

Analysis of Water (Cont'd)

Parameter	LOQ	Units	1.1-GL-001	1.2-GL-001	1.2-GL-001F	1.2-Gl-001F	1.2-GL-002	1.2-GL-002	1.2-GL-002F	1.3-GL-001	1.3-GL-001	1.3-GL-002
					Filtered	Filtered			Filtered			
Data Sampled >			95/06/08	95/06/08	95/06/08	Replicate	95/06/08	Replicate	95/06/08	95/06/08	Replicate	95/06/08
Alkalinity(as CaCO3)	1	mg/L	6	6	-	-	6	6	-	6	-	6
Anion Sum	0.01	meq/L	0.2	0.2	-	-	0.2	0.2	-	0.2 .	-	0.2
Bicarbonate(as CaCO3)	0.1	mg/L	5.7	5.8	-	-	5.8	5.7	-	5.6	-	5.9
Carbonate(as CaCO3)	0.1	mg/L	nd	nd	-	-	nd	nd	-	nd	-	nd
Cation Sum	0.01	meq/L	0.21	0.21	-	-	0.21	0.22	-	0.24	-	0.24
Conductivity - @25°C	1	uS/cm	22	22	-	-	22	22	-	22	-	22
Hardness(as CaCO3)	1	mg/L	6	6	-	-	6	6	-	6	-	6
Ion Balance	0.01	na	1.07	1.03	-	-	1.03	1.12	-	1.21	-	1.18
Langelier Index at 20°C	na	na	-4.43	-4.47	-	-	-4.46	-4.44	-	-4.41	-	-4.38
Langelier Index at 4°C	na	na	-4.83	-4.87	-	-	-4.86	-4.84	-	-4.81	-	-4.78
pH	0.01	Units	6.18	6.14	-	-	6.15	6.17	-	6.2	-	6.23
Saturation pH at 20°C	0.01	na	10.6	10.6	-	-	10.6	10.6	-	10.6	-	10.6
Saturation pH at 4°C	0.01	na	11	11	-	-	11	11	-	11	-	11
l Dissolved Solids(Calcula	1	mg/L	13	13	-	-	14	14	-	14	-	14
Turbidity	0.5	NTU	nd	nd	-	-	nd	nd	-	nd	-	nd
Colour	1	TCU	nd	5	-	-	3	5	-	nd	-	nd
otal Kjeldahl Nitrogen(as	0.02	mg/L	0.13	0.12	-	-	0.24	-	-	0.16	-	0.17
Total Phosphorus	0.004	mg/L	nd	nd	nd	-	0.026	-	0.013	0.012	-	0.01
LEM Laboratory Data												
Total Coliforms	2	/100ml	< 2	< 2						< 2		
Faecal Coliforms	2	/100ml	n/d	n/d						n/d		

GANDER L. VATER QUALITY ANALYSIS - JUNE

Parameter	LOQ	Units	2.1-GL-001	2.1-GL-002	2.2-GL-001	2.2-GL-002	2.3-GL-001	2.3-GL-002	3.1-GL-001	3.1-GL-002	3.2-GL-001	3.2-GL-001
Data Sampled >			95/06/08	95/06/08	95/06/09	95/06/09	95/06/09	95/06/09	95/06/09	95/06/09	95/06/09	Replicate
Lead	0.002	mg/L	nd	nd	nd	nd	nd	nd	nd	nd .	0.002	-
Bromide	0.05	mg/L	nd	nd	nd	nd	nd	nd	nd	nd	nd	-
Chloride	0.05	mg/L	2.11	2.04	2.04	2.02	2.07	2.03	1.97	2	1.99	-
Fluoride	0.02	mg/L	nd	nd	nd	nd	nd	nd	nd	nd	nd	-
Nitrate(as N)	0.03	mg/L	0.1	0.1	0.1	0.16	0.1	0.1	0.09	0.09	0.11	-
Nitrite(as N)	0.03	mg/L	nd	nd	nd	nd	nd	nd	nd	nd	nd	-
Orthophosphate(as P)	0.05	mg/L	nd	nd	nd	nd	nd	nd	nd	nd	nd	-
Sulphate	0.05	mg/L	0.92	0.91	0.94	0.95	0.96	0.97	0.9	1.4	0.92	-
Aluminum	0.025	mg/L	0.111	0.221	0.144	0.107	0.101	0.116	0.134	0.086	0.129	-
Barium	0.002	mg/L	0.003	0.004	0.004	0.002	0.002	0.003	0.004	nd	0.004	-
Beryllium	0.005	mg/L	nd	nd	nd	nd	nd	nd	nd	nd	nd	-
Bismuth	0.05	mg/L	nd	nd	nd	nd	nd	nd	nd	nd	nd	-
Boron	0.01	mg/L	nd	nd	nd	nd	nd	nd	nd	nd	nd	-
Cadmium	0.003	mg/L	nd	nd	nd	nd	nd	nd	nd	nd	nd	-
Calcium	0.01	mg/L	1.29	1.3	1.26	1.29	1.34	1.31	1.28	1.28	1.29	-
Chromium	0.005	mg/L	nd	nd	nd	nd	nd	nd	nd	nd	nd	-
Cobalt	0.005	mg/L	nd	nd	nd	nd	nd	nd	nd	nd	nd	-
Copper	0.003	mg/L	nd	nd	nd	nd	nd	nd	nd	nd	nd	-
Iron	0.005	mg/L	0.06	0.419	0.059	0.061	0.055	0.059	0.059	0.061	0.081	-
Lead	0.025	mg/L	nd	nd	nd	nd	nd	nd	nd	nd	nd	-
Magnesium	0.02	mg/L	0.68	0.7	0.7	0.69	0.7	0.67	0.68	0.66	0.66	-
Manganese	0.005	mg/L	0.009	0.167	0.01	0.009	0.008	0.009	0.008	0.007	0.009	-
Molybdenum	0.01	mg/L	nd	nd	nd	nd	nd	nd	nd	nd	nd	-
Nickel	0.01	mg/L	nd	nd	0.01	nd	nd	nd	nd	nd	0.01	-
Phosphorus	0.06	mg/L	nd	nd	nd	nd	nd	nd	nd	nd	nd	-
Potassium	0.4	mg/L	1.2	0.6	1.2	0.5	0.9	0.8	nd	nd	0.7	-
Silver	0.003	mg/L	nd	nd	nd	nd	nd	nd	nd	nd	nd	-
Sodium	0.04	mg/L	1.92	1.95	1.97	1.94	2	1.91	1.89	1.9	1.9	-
Strontium	0.002	mg/L	0.008	0.008	0.007	0.008	0.008	0.008	0.007	0.008	0.008	-
Tin	0.05	mg/L	nd	nd	nd	nd	nd	nd	nd	nd	nd	-
Titanium	0.05	mg/L	nd	nd	nd	nd	nd	nd	nd	nd	nd	-
Vanadium	0.01	mg/L	nd	nd	nd	nd	nd	nd	nd	nd	nd	-
Zinc	0.005	mg/L	nd	0.017	nd	nd	nd	nd	nd	nd	0.024	-

(LOQ = Limits of Quantification; 1.1-GL-001 = Location 1.2, Gander Lake, Surface; 1.2-GL-002 = Location 1.2, Gander Lake, 60 metre depth.)

Analysis of Water (Cont'd)

Parameter	LOQ	Units	2.1-GL-001	2.1-GL-002	2.2-GL-001	2.2-GL-002	2.3-GL-001	2.3-GL-002	3.1-GL-001	3.1-GL-002	3.2-GL-001	3.2-GL-001
Data Sampled >			95/06/08	95/06/08	95/06/09	95/06/09	95/06/09	95/06/09	95/06/09	95/06/09	95/06/09	Replicate
Alkalinity(as CaCO3)	1	mg/L	6	6	5	6	5	5	5	5	6	-
Anion Sum	0.01	meq/L	0.2	0.2	0.19	0.21	0.19	0.18	0.19	0.2	0.19	-
Bicarbonate(as CaCO3)	0.1	mg/L	5.6	5.7	5.1	6	5.4	4.8	5.5	5.3	5.6	-
Carbonate(as CaCO3)	0.1	mg/L	nd	nd	nd	nd	nd	nd	nd	nd	nd	-
Cation Sum	0.01	meq/L	0.24	0.23	0.24	0.22	0.24	0.23	0.21	0.21	0.22	-
Conductivity - @25°C	1	uS/cm	22	22	22	22	22	22	21	22	21	-
Hardness(as CaCO3)	1	mg/L	6	6	6	6	6	6	6	6	6	-
Ion Balance	0.01	na	1.2	1.18	1.29	1.06	1.22	1.25	1.12	1.05	1.14	-
Langelier Index at 20°C	na	na	-4.37	-4.35	-4.53	-4.52	-4.44	-4.58	-4.46	-4.61	-4.49	-
Langelier Index at 4°C	na	na	-4.77	-4.75	-4.93	-4.92	-4.84	-4.98	-4.86	-5.01	-4.89	-
pH	0.01	Units	6.24	6.26	6.08	6.09	6.17	6.13	6.15	6	6.12	-
Saturation pH at 20°C	0.01	na	10.6	10.6	10.6	10.6	10.6	10.7	10.6	10.6	10.6	-
Saturation pH at 4°C	0.01	na	11	11	11	11	11	11.1	11	11	11	-
l Dissolved Solids(Calcula	1	mg/L	14	15	14	14	14	13	13	13	14	-
Turbidity	0.5	NTU	nd	nd	nd	nd	nd	nd	nd	nd	nd	-
Colour	1	TCU	nd	nd	nd	3	nd	nd	nd	nd	nd	-
otal Kjeldahl Nitrogen(as I	0.02	mg/L	0.12	0.21	0.23	0.14	0.13	0.1	0.14	0.22	0.16	-
Total Phosphorus	0.004	mg/L	0.009	0.009	0.008	0.007	0.006	0.006	0.006	0.01	0.011	-
LEM Laboratory Data												
Total Coliforms	2	/100ml	< 2		< 2		< 2		< 2		< 2	
Faecal Coliforms	2	/100ml	n/d		n/d		n/d		n/d		n/d	

GANDER L. VATER QUALITY ANALYSIS - JUNE

Parameter	LOQ	Units	3.2-GL-001F	3.2-GL-002	3.2-GL-002	3.2-GL-002F	3.3-GL-001	3.3-GL-001	3.3-GL-002	4.1-GL-001	4.1-GL-001	4.1-GL-002
			Filtered			Filtered						
Data Sampled >			95/06/09	95/06/09	Replicate	95/06/09	95/06/09	Replicate	95/06/09	95/06/08	Replicate	95/06/08
Lead	0.002	mg/L	-	nd	-	-	nd	nd	nd	nd .	-	nd
Bromide	0.05	mg/L	-	nd	-	-	nd	nd	nd	nd	-	nd
Chloride	0.05	mg/L	-	1.96	-	-	1.94	1.93	1.99	1.93	-	1.98
Fluoride	0.02	mg/L	-	nd	-	-	nd	nd	nd	nd	-	nd
Nitrate(as N)	0.03	mg/L	-	0.11	-	-	0.09	0.09	0.09	0.1	-	0.1
Nitrite(as N)	0.03	mg/L	-	nd	-	-	nd	nd	nd	nd	-	nd
Orthophosphate(as P)	0.05	mg/L	-	nd	-	-	nd	nd	nd	nd	-	nd
Sulphate	0.05	mg/L	-	0.9	-	-	0.92	0.91	0.93	0.9	-	0.9
Aluminum	0.025	mg/L	-	0.111	-	-	0.105	0.1	0.091	0.062	-	0.119
Barium	0.002	mg/L	-	0.003	-	-	0.004	0.003	0.007	0.002	-	0.002
Beryllium	0.005	mg/L	-	nd	-	-	nd	nd	nd	nd	-	nd
Bismuth	0.05	mg/L	-	nd	-	-	nd	nd	nd	nd	-	nd
Boron	0.01	mg/L	-	nd	-	-	nd	nd	nd	nd	-	nd
Cadmium	0.003	mg/L	-	nd	-	-	nd	nd	0.003	nd	-	nd
Calcium	0.01	mg/L	-	1.27	-	-	1.27	1.27	1.26	1.29	-	1.25
Chromium	0.005	mg/L	-	nd	-	-	nd	nd	nd	nd	-	nd
Cobalt	0.005	mg/L	-	nd	-	-	nd	nd	nd	nd	-	nd
Copper	0.003	mg/L	-	nd	-	-	nd	nd	nd	nd	-	nd
Iron	0.005	mg/L	-	0.06	-	-	0.063	0.06	0.063	0.054	-	0.079
Lead	0.025	mg/L	-	nd	-	-	nd	nd	nd	nd	-	nd
Magnesium	0.02	mg/L	-	0.71	-	-	0.68	0.7	0.66	0.65	-	0.68
Manganese	0.005	mg/L	-	0.008	-	-	0.008	0.008	0.012	0.009	-	0.011
Molybdenum	0.01	mg/L	-	nd	-	-	nd	nd	nd	nd	-	nd
Nickel	0.01	mg/L	-	nd	-	-	nd	nd	nd	nd	-	nd
Phosphorus	0.06	mg/L	-	nd	-	-	nd	nd	nd	nd	-	nd
Potassium	0.4	mg/L	-	nd	-	-	nd	0.6	0.7	nd	-	nd
Silver	0.003	mg/L	-	nd	-	-	nd	nd	nd	nd	-	nd
Sodium	0.04	mg/L	-	1.91	-	-	1.96	1.96	1.97	1.95	-	1.94
Strontium	0.002	mg/L	-	0.008	-	-	0.012	0.008	0.008	0.008	-	0.008
Tin	0.05	mg/L	-	nd	-	-	nd	nd	nd	nd	-	nd
Titanium	0.05	mg/L	-	nd	-	-	nd	nd	nd	nd	-	nd
Vanadium	0.01	mg/L	-	nd	-	-	nd	nd	nd	nd	-	nd
Zinc	0.005	mg/L	-	0.008	-	-	0.006	0.005	0.015	nd	-	0.034

(LOQ = Limits of Quantification; 1.1-GL-001 = Location 1.2, Gander Lake, Surface; 1.2-GL-002 = Location 1.2, Gander Lake, 60 metre depth.)

Analysis of Water (Cont'd)

Parameter	LOQ	Units	3.2-GL-001F	3.2-GL-002	3.2-GL-002	3.2-GL-002F	3.3-GL-001	3.3-GL-001	3.3-GL-002	4.1-GL-001	4.1-GL-001	4.1-GL-002
			Filtered			Filtered						
Data Sampled >			95/06/09	95/06/09	Replicate	95/06/09	95/06/09	Replicate	95/06/09	95/06/08	Replicate	95/06/08
Alkalinity(as CaCO3)	1	mg/L	-	6	-	-	6	6	6	6	-	5
Anion Sum	0.01	meq/L	-	0.2	-	-	0.2	0.19	0.2	0.19.	-	0.19
Bicarbonate(as CaCO3)	0.1	mg/L	-	5.6	-	-	5.8	5.5	5.8	5.5	-	5.5
Carbonate(as CaCO3)	0.1	mg/L	-	nd	-	-	nd	nd	nd	nd	-	nd
Cation Sum	0.01	meq/L	-	0.21	-	-	0.2	0.22	0.22	0.21	-	0.2
Conductivity - @25°C	1	uS/cm	-	21	-	-	21	21	22	21	-	21
Hardness(as CaCO3)	1	mg/L	-	6	-	-	6	6	6	6	-	6
Ion Balance	0.01	na	-	1.07	-	-	1.03	1.14	1.1	1.07	-	1.04
Langelier Index at 20°C	na	na	-	-4.53	-	-	-4.42	-4.42	-4.16	-4.45	-	-4.5
Langelier Index at 4°C	na	na	-	-4.93	-	-	-4.82	-4.82	-4.56	-4.85	-	-4.9
pH	0.01	Units	-	6.08	-	-	6.19	6.19	6.45	6.16	-	6.11
Saturation pH at 20°C	0.01	na	-	10.6	-	-	10.6	10.6	10.6	10.6	-	10.6
Saturation pH at 4°C	0.01	na	-	11	-	-	11	11	11	11	-	11
l Dissolved Solids(Calcula	1	mg/L	-	13	-	-	13	14	14	13	-	13
Turbidity	0.5	NTU	-	nd	-	-	nd	nd	nd	nd	-	nd
Colour	1	TCU	-	nd	-	-	nd	nd	nd	nd	-	nd
otal Kjeldahl Nitrogen(as N	0.02	mg/L	-	0.27	-	-	0.21	-	0.26	0.17	-	0.23
Total Phosphorus	0.004	mg/L	nd	0.005	-	0.004	0.009	-	0.007	0.006	-	0.006
LEM Laboratory Data												
Total Coliforms	2	/100ml					< 2			< 2		
Faecal Coliforms	2	/100ml					n/d			n/d		

GANDER L VATER QUALITY ANALYSIS - JUNE

Parameter	LOQ	Units	4.2-GL-001	4.2-GL-002	4.3-GL-001	4.3-GL-002	5.1-GL-001	5.1-GL-002	5.2-GL-001	5.2-GL-002	5.3-GL-001	5.3-GL-002
Data Sampled >			95/06/08	95/06/08	95/06/08	95/06/08	95/06/08	95/06/08	95/06/08	95/06/08	95/06/08	95/06/08
Lead	0.002	mg/L	nd	nd	nd	nd	nd	nd	nd	nd .	nd	nd
Bromide	0.05	mg/L	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Chloride	0.05	mg/L	1.92	2	1.92	1.93	6.07	5.91	1.97	1.97	2.02	2.01
Fluoride	0.02	mg/L	nd	nd	nd	nd	0.02	nd	nd	0.02	nd	nd
Nitrate(as N)	0.03	mg/L	0.09	0.09	0.09	0.1	0.32	0.31	0.09	0.1	0.1	0.09
Nitrite(as N)	0.03	mg/L	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Orthophosphate(as P)	0.05	mg/L	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Sulphate	0.05	mg/L	0.9	0.9	0.89	0.92	3.08	3.1	0.93	0.93	0.93	0.9
Aluminum	0.025	mg/L	0.104	0.136	0.12	0.117	0.08	0.11	0.086	0.09	0.155	0.151
Barium	0.002	mg/L	0.003	0.009	0.003	0.003	0.003	0.003	0.003	0.004	0.004	0.006
Beryllium	0.005	mg/L	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Bismuth	0.05	mg/L	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Boron	0.01	mg/L	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Cadmium	0.003	mg/L	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Calcium	0.01	mg/L	1.28	1.29	1.25	1.26	1.29	1.29	1.29	1.29	1.28	1.28
Chromium	0.005	mg/L	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Cobalt	0.005	mg/L	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Copper	0.003	mg/L	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Iron	0.005	mg/L	0.065	0.073	0.067	0.063	0.058	0.063	0.064	0.07	0.068	0.067
Lead	0.025	mg/L	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Magnesium	0.02	mg/L	0.67	0.71	0.69	0.68	0.7	0.69	0.67	0.71	0.67	0.69
Manganese	0.005	mg/L	0.008	0.01	0.009	0.009	0.007	0.008	0.007	0.008	0.008	0.008
Molybdenum	0.01	mg/L	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Nickel	0.01	mg/L	nd	nd	nd	nd	nd	nd	nd	nd	0.01	nd
Phosphorus	0.06	mg/L	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Potassium	0.4	mg/L	nd	nd	1.1	0.5	1.5	0.7	0.8	nd	nd	0.6
Silver	0.003	mg/L	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Sodium	0.04	mg/L	1.97	2.1	1.92	1.95	1.85	1.87	1.84	1.9	1.84	1.85
Strontium	0.002	mg/L	0.008	0.008	0.008	0.008	0.007	0.007	0.007	0.007	0.007	0.007
Tin	0.05	mg/L	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Titanium	0.05	mg/L	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Vanadium	0.01	mg/L	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Zinc	0.005	mg/L	nd	0.018	nd	0.015	0.025	0.008	0.006	0.009	0.006	nd

(LOQ = Limits of Quantification; 1.1-GL-001 = Location 1.2, Gander Lake, Surface; 1.2-GL-002 = Location 1.2, Gander Lake, 60 metre depth.)

Analysis of Water (Cont'd)												
Parameter	LOQ	Units	4.2-GL-001	4.2-GL-002	4.3-GL-001	4.3-GL-002	5.1-GL-001	5.1-GL-002	5.2-GL-001	5.2-GL-002	5.3-GL-001	5.3-GL-002
Data Sampled >			95/06/08	95/06/08	95/06/08	95/06/08	95/06/08	95/06/08	95/06/08	95/06/08	95/06/08	95/06/08
Alkalinity(as CaCO3)	1	mg/L	5	5	5	6	5	6	5	6	5	5
Anion Sum	0.01	meq/L	0.19	0.19	0.19	0.19	0.36	0.37	0.18	0.2	0.19	0.19
Bicarbonate(as CaCO3)	0.1	mg/L	5.3	5.3	5.3	5.5	5.1	5.8	5.1	5.7	5.3	5.2
Carbonate(as CaCO3)	0.1	mg/L	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Cation Sum	0.01	meq/L	0.21	0.22	0.23	0.21	0.24	0.22	0.22	0.21	0.21	0.22
Conductivity - @25°C	1	uS/cm	22	21	21	21	21	22	22	22	21	21
Hardness(as CaCO3)	1	mg/L	6	6	6	6	6	6	6	6	6	6
Ion Balance	0.01	na	1.12	1.18	1.22	1.11	0.68	0.6	1.22	1.09	1.1	1.17
Langelier Index at 20°C	na	na	-4.42	-4.48	-4.44	-4.42	-4.33	-4.36	-4.4	-4.46	-4.45	-4.46
Langelier Index at 4°C	na	na	-4.82	-4.88	-4.84	-4.82	-4.73	-4.76	-4.8	-4.86	-4.85	-4.86
pH	0.01	Units	6.19	6.13	6.17	6.19	6.28	6.25	6.21	6.15	6.16	6.15
Saturation pH at 20°C	0.01	na	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6
Saturation pH at 4°C	0.01	na	11	11	11	11	11	11	11	11	11	11
l Dissolved Solids(Calcula	1	mg/L	13	13	14	13	21	21	13	13	13	13
Turbidity	0.5	NTU	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Colour	1	TCU	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
otal Kjeldahl Nitrogen(as N	0.02	mg/L	0.08	0.03	nd	0.08	0.19	0.16	0.15	0.11	0.29	0.14
Total Phosphorus	0.004	mg/L	0.006	0.006	0.006	0.007	nd	nd	nd	0.004	nd	nd
LEM Laboratory Data												
Total Coliforms	2	/100ml	< 2		< 2		2		< 2(< 2)		< 2	
Faecal Coliforms	2	/100ml	n/d		n/d		2		n/d(n/d)		n/d	

GANDER L. VATER QUALITY ANALYSIS - JUNE

Parameter	LOQ	Units	6.1-GL-001	6.1-GL-001F Filtered	6.1-GL-002	6.1-GL-002F Filtered	6.2-GL-001	6.2-GL-002	6.3-GL-001	6.3-GL-001	6.3B-GL-001	6.3B-GL-002
Data Sampled >			95/06/08	95/06/08	95/06/08	95/06/08	95/06/08	95/06/08	95/06/08	Replicate	95/06/08	95/06/08
Lead	0.002	mg/L	nd	-	nd	-	nd	nd	nd	nd	nd	nd
Bromide	0.05	mg/L	nd	-	nd	-	nd	nd	nd	nd	nd	nd
Chloride	0.05	mg/L	5.95	-	6.05	-	1.94	6.28	1.7	1.68	1.95	2
Fluoride	0.02	mg/L	nd	-	nd	-	nd	nd	nd	nd	nd	nd
Nitrate(as N)	0.03	mg/L	0.3	-	0.35	-	0.09	0.33	0.06	0.06	0.09	0.09
Nitrite(as N)	0.03	mg/L	nd	-	nd	-	nd	nd	nd	nd	nd	nd
Orthophosphate(as P)	0.05	mg/L	nd	-	nd	-	nd	nd	nd	nd	nd	nd
Sulphate	0.05	mg/L	3.12	-	3.15	-	0.93	3.11	0.78	0.72	0.89	1.13
Aluminum	0.025	mg/L	0.101	-	0.127	-	0.113	0.119	0.102	0.103	0.098	0.116
Barium	0.002	mg/L	0.003	-	0.004	-	0.003	0.004	nd	nd	0.006	0.004
Beryllium	0.005	mg/L	nd	-	nd	-	nd	nd	nd	nd	nd	nd
Bismuth	0.05	mg/L	nd	-	nd	-	nd	nd	nd	nd	nd	nd
Boron	0.01	mg/L	nd	-	nd	-	nd	nd	nd	nd	nd	nd
Cadmium	0.003	mg/L	nd	-	nd	-	nd	nd	nd	nd	nd	nd
Calcium	0.01	mg/L	1.29	-	1.32	-	1.33	1.33	1.34	1.31	1.28	1.29
Chromium	0.005	mg/L	nd	-	nd	-	nd	nd	nd	nd	nd	nd
Cobalt	0.005	mg/L	nd	-	nd	-	nd	nd	nd	nd	0.006	nd
Copper	0.003	mg/L	nd	-	nd	-	nd	nd	nd	nd	nd	nd
Iron	0.005	mg/L	0.073	-	0.068	-	0.068	0.078	0.097	0.097	0.068	0.057
Lead	0.025	mg/L	nd	-	nd	-	nd	nd	nd	nd	nd	nd
Magnesium	0.02	mg/L	0.69	-	0.69	-	0.7	0.7	0.73	0.71	0.68	0.66
Manganese	0.005	mg/L	0.009	-	0.009	-	0.011	0.01	0.021	0.021	0.012	0.009
Molybdenum	0.01	mg/L	nd	-	nd	-	nd	nd	nd	nd	nd	nd
Nickel	0.01	mg/L	nd	-	nd	-	nd	nd	nd	nd	nd	nd
Phosphorus	0.06	mg/L	nd	-	nd	-	nd	nd	nd	nd	nd	nd
Potassium	0.4	mg/L	nd	-	nd	-	0.4	1.4	1.6	1.2	nd	0.4
Silver	0.003	mg/L	nd	-	nd	-	nd	nd	nd	nd	nd	nd
Sodium	0.04	mg/L	1.84	-	1.85	-	1.9	1.94	1.77	1.76	1.88	1.87
Strontium	0.002	mg/L	0.007	-	0.007	-	0.007	0.007	0.011	0.007	0.008	0.007
Tin	0.05	mg/L	nd	-	nd	-	nd	nd	nd	nd	nd	nd
Titanium	0.05	mg/L	nd	-	nd	-	nd	nd	nd	nd	nd	nd
Vanadium	0.01	mg/L	nd	-	nd	-	nd	nd	nd	nd	nd	nd
Zinc	0.005	mg/L	0.007	-	0.017	-	0.012	0.041	0.013	0.013	0.008	0.016

(LOQ = Limits of Quantification; 1.1-GL-001 = Location 1.2, Gander Lake, Surface; 1.2-GL-002 = Location 1.2, Gander Lake, 60 metre depth.)

Analysis of Water (Cont'd)

Parameter	LOQ	Units	6.1-GL-001	6.1-GL-001F	6.1-GL-002	6.1-GL-002F	6.2-GL-001	6.2-GL-002	6.3-GL-001	6.3-GL-001	6.3B-GL-001	6.3B-GL-002
				Filtered		Filtered						
Data Sampled >			95/06/08	95/06/08	95/06/08	95/06/08	95/06/08	95/06/08	95/06/08	Replicate	95/06/08	95/06/08
Alkalinity(as CaCO3)	1	mg/L	5	-	5	-	5	5	7	6	5	6
Anion Sum	0.01	meq/L	0.35	-	0.37	-	0.19	0.37	0.21	0.19	0.19	0.2
Bicarbonate(as CaCO3)	0.1	mg/L	4.8	-	5.3	-	5.4	5.1	7.1	6.3	5.3	5.5
Carbonate(as CaCO3)	0.1	mg/L	nd	-	nd	-	nd	nd	nd	nd	nd	nd
Cation Sum	0.01	meq/L	0.21	-	0.21	-	0.22	0.25	0.25	0.23	0.21	0.21
Conductivity - @25°C	1	uS/cm	21	-	22	-	21	22	21	21	22	22
Hardness(as CaCO3)	1	mg/L	6	-	6	-	6	6	6	6	6	6
Ion Balance	0.01	na	0.59	-	0.58	-	1.17	0.67	1.17	1.21	1.12	1.09
Langelier Index at 20°C	na	na	-4.49	-	-4.4	-	-4.34	-4.38	-3.81	-3.89	-4.18	-4.37
Langelier Index at 4°C	na	na	-4.89	-	-4.8	-	-4.74	-4.78	-4.21	-4.29	-4.58	-4.77
pH	0.01	Units	6.22	-	6.21	-	6.27	6.23	6.65	6.64	6.43	6.24
Saturation pH at 20°C	0.01	na	10.7	-	10.6	-	10.6	10.6	10.5	10.5	10.6	10.6
Saturation pH at 4°C	0.01	na	11.1	-	11	-	11	11	10.9	10.9	11	11
l Dissolved Solids(Calcula	1	mg/L	19	-	20	-	13	22	16	14	13	14
Turbidity	0.5	NTU	nd	-	nd	-	nd	nd	nd	nd	nd	nd
Colour	1	TCU	nd	-	nd	-	nd	nd	nd	3	2	nd
otal Kjeldahl Nitrogen(as N	0.02	mg/L	0.2	-	nd	-	0.16	0.21	0.24	-	0.26	0.1
Total Phosphorus	0.004	mg/L	nd	0.012	nd	0.011	nd	nd	nd	-	nd	0.02
LEM Laboratory Data												
Total Coliforms	2	/100ml	< 2				< 2		13		< 2	
Faecal Coliforms	2	/100ml	n/d				n/d		5		n/d	

GANDER L. VATER QUALITY ANALYSIS - JUNE

Parameter	LOQ	Units	6.3B-GL-002	A -GL-001	A -GL-002	B -GL-001	B -GL-002	C -GL-001	C -GL-002
Data Sampled >			Replicate	95/06/08	95/06/08	95/06/09	95/06/09	95/06/08	95/06/08
Lead	0.002	mg/L	-	nd	nd	nd	nd	nd	nd
Bromide	0.05	mg/L	-	nd	nd	nd	nd	nd	nd
Chloride	0.05	mg/L	-	2.07	2.03	2.08	2	2.01	1.95
Fluoride	0.02	mg/L	-	nd	nd	nd	nd	nd	nd
Nitrate(as N)	0.03	mg/L	-	0.09	0.09	0.1	0.1	0.1	0.09
Nitrite(as N)	0.03	mg/L	-	nd	nd	nd	nd	nd	nd
Orthophosphate(as P)	0.05	mg/L	-	nd	nd	nd	nd	nd	nd
Sulphate	0.05	mg/L	-	0.92	0.93	0.93	0.93	0.94	0.91
Aluminum	0.025	mg/L	-	0.11	0.099	0.115	0.095	0.078	0.09
Barium	0.002	mg/L	-	0.003	0.016	0.004	0.003	0.003	0.003
Beryllium	0.005	mg/L	-	nd	nd	nd	nd	nd	nd
Bismuth	0.05	mg/L	-	nd	nd	nd	nd	nd	nd
Boron	0.01	mg/L	-	nd	nd	nd	nd	nd	nd
Cadmium	0.003	mg/L	-	nd	nd	nd	nd	nd	nd
Calcium	0.01	mg/L	-	1.32	1.32	1.26	1.29	1.3	1.26
Chromium	0.005	mg/L	-	nd	nd	nd	nd	nd	nd
Cobalt	0.005	mg/L	-	nd	nd	nd	nd	nd	nd
Copper	0.003	mg/L	-	nd	nd	nd	nd	nd	nd
Iron	0.005	mg/L	-	nd	0.056	0.06	0.06	0.058	0.061
Lead	0.025	mg/L	-	nd	nd	nd	nd	nd	nd
Magnesium	0.02	mg/L	-	0.69	0.68	0.69	0.68	0.68	0.68
Manganese	0.005	mg/L	-	0.008	0.007	0.01	0.009	0.009	0.009
Molybdenum	0.01	mg/L	-	nd	nd	nd	nd	nd	nd
Nickel	0.01	mg/L	-	0.01	nd	nd	nd	nd	nd
Phosphorus	0.06	mg/L	-	nd	nd	nd	nd	nd	nd
Potassium	0.4	mg/L	-	nd	1.2	1.2	nd	1.1	nd
Silver	0.003	mg/L	-	nd	nd	nd	nd	nd	nd
Sodium	0.04	mg/L	-	2	1.96	1.95	1.95	1.98	1.92
Strontium	0.002	mg/L	-	0.008	0.008	0.008	0.008	0.008	0.008
Tin	0.05	mg/L	-	nd	nd	nd	nd	nd	nd
Titanium	0.05	mg/L	-	nd	nd	nd	nd	nd	nd
Vanadium	0.01	mg/L	-	nd	nd	nd	nd	nd	nd
Zinc	0.005	mg/L	-	0.007	nd	nd	nd	nd	nd

(LOQ = Limits of Quantification; 1.1-GL-001 = Location 1.2, Gander Lake, Surface; 1.2-GL-002 = Location 1.2, Gander Lake, 60 metre depth.)

nalysis of Water (Cont'd)

Parameter	LOQ	Units	6.3B-GL-002	A -GL-001	A -GL-002	B -GL-001	B -GL-002	C -GL-001	C -GL-002
Data Sampled >			Replicate	95/06/08	95/06/08	95/06/09	95/06/09	95/06/08	95/06/08
Alkalinity(as CaCO3)	1	mg/L	-	6	6	6	6	6	6
Anion Sum	0.01	meq/L	-	0.2	0.19	0.2	0.2	0.2	0.19
Bicarbonate(as CaCO3)	0.1	mg/L	-	5.6	5.5	5.7	5.8	5.8	5.6
Carbonate(as CaCO3)	0.1	mg/L	-	nd	nd	nd	nd	nd	nd
Cation Sum	0.01	meq/L	-	0.22	0.24	0.23	0.21	0.23	0.21
Conductivity - @25°C	1	uS/cm	-	22	22	22	21	21	21
Hardness(as CaCO3)	1	mg/L	-	6	6	6	6	6	6
Ion Balance	0.01	na	-	1.13	1.24	1.15	1.05	1.16	1.08
Langelier Index at 20°C	na	na	-	-4.39	-4.37	-4.36	-4.47	-4.41	-4.42
Langelier Index at 4°C	na	na	-	-4.79	-4.77	-4.76	-4.87	-4.81	-4.82
pH	0.01	Units	-	6.22	6.24	6.25	6.14	6.2	6.19
Saturation pH at 20°C	0.01	na	-	10.6	10.6	10.6	10.6	10.6	10.6
Saturation pH at 4°C	0.01	na	-	11	11	11	11	11	11
l Dissolved Solids(Calcula	1	mg/L	-	14	14	15	14	14	13
Turbidity	0.5	NTU	-	nd	nd	nd	nd	nd	nd
Colour	1	TCU	-	nd	1	nd	nd	nd	nd
otal Kjeldahl Nitrogen(as l	0.02	mg/L	-	0.12	0.23	0.13	0.25	0.17	0.02
Total Phosphorus	0.004	mg/L	-	0.009	0.013	0.006	0.006	0.006	0.006
LEM Laboratory Data									
Total Coliforms	2	/100ml		< 2		< 2		< 2	
Faecal Coliforms	2	/100ml		n/d		n/d		n/d	

GANDER LAKE WATER
SEPTEMBER

Analysis of Water

Parameter	LOQ	Units	1.1-GL-001 @775	1.2-GL-001 @775	1.2"-GL"-001F @775	1.2"-GL"-002 @775	1.2"-GL"-002F @775
Bromide	0.05	mg/L	nd	nd	-	nd	-
Chloride	0.05	mg/L	2.14	2.17	-	2.13	-
Fluoride	0.02	mg/L	nd	nd	-	nd	-
Nitrate(as N)	0.03	mg/L	0.07	0.07	-	0.08	-
Nitrite(as N)	0.03	mg/L	nd	nd	-	nd	-
Orthophosphate	0.05	mg/L	nd	nd	-	nd	-
Sulphate	0.05	mg/L	0.99	0.99	-	0.98	-
Aluminum	0.025	mg/L	0.076	0.09	-	0.09	-
Barium	0.002	mg/L	0.004	0.002	-	nd	-
Beryllium	0.005	mg/L	nd	nd	-	nd	-
Bismuth	0.05	mg/L	nd	nd	-	nd	-
Boron	0.01	mg/L	nd	nd	-	nd	-
Cadmium	0.003	mg/L	nd	nd	-	nd	-
Calcium	0.01	mg/L	1.55	1.39	-	1.38	-
Chromium	0.005	mg/L	nd	nd	-	nd	-
Cobalt	0.005	mg/L	nd	nd	-	nd	-
Copper	0.003	mg/L	nd	0.004	-	0.004	-
Iron	0.005	mg/L	0.022	0.022	-	0.024	-
Lead	0.025	mg/L	nd	nd	-	nd	-
Magnesium	0.02	mg/L	0.67	0.6	-	0.61	-
Manganese	0.005	mg/L	nd	nd	-	nd	-
Molybdenum	0.01	mg/L	nd	nd	-	nd	-
Nickel	0.01	mg/L	nd	nd	-	nd	-
Phosphorus	0.06	mg/L	nd	nd	-	nd	-
Potassium	0.4	mg/L	nd	0.7	-	0.8	-
Silica(as SiO2)	0.05	mg/L	2.06	2.07	-	2.2	-
Silver	0.003	mg/L	nd	nd	-	nd	-

LOQ	Limit of Quantitation-lowest level that can be quantified with confidence.
-	Not Requested
nd	parameter not detected
!	LOQ higher than listed due to dilution
0	Adjusted LOQ
na	Not Applicable

Analysis of Water							
			1.1-GL-001	1.2-GL-001	1.2"-GL"-001F	1.2"-GL"-002	1.2"-GL"-002F
Parameter	LOQ	Units	@775	@775	@775	@775	@775
Sodium	0.04	mg/L	1.8	1.69	-	1.7	-
Strontium	0.002	mg/L	0.008	0.007	-	0.007	-
Tin	0.05	mg/L	nd	nd	-	nd	-
Titanium	0.05	mg/L	nd	nd	-	nd	-
Vanadium	0.01	mg/L	nd	nd	-	nd	-
Zinc	0.005	mg/L	nd	nd	-	nd	-
Alkalinity(as CaCO3)	1	mg/L	3	3	-	3	-
Anion Sum	0.01	meq/L	0.15	0.15	-	0.15	-
Bicarbonate(CaCO3, cal.)	0.1	mg/L	3	3	-	3	-
Carbonate(CaCO3, cal.)	0.1	mg/L	nd	nd	-	nd	-
Cation Sum	0.01	meq/L	0.21	0.21	-	0.21	-
Conductivity - @25°C	1	uS/cm	21	21	-	21	-
Hardness(as CaCO3)	1	mg/L	7	6	-	6	-
Ion Balance	0.01	na	1.46	1.43	-	1.46	-
Langelier Index at 20°C	na	na	-3.86	-3.87	-	-3.85	-
Langelier Index at 4°C	na	na	-4.26	-4.27	-	-4.25	-
pH	0.01	Units	6.97	6.96	-	6.98	-
Saturation pH at 20°C	0.01	na	10.8	10.8	-	10.8	-
Saturation pH at 4°C	0.01	na	11.2	11.2	-	11.2	-
. Dissolved Solids(Calculate	1	mg/L	11	11	-	11	-
Turbidity	0.5	NTU	nd	nd	-	nd	-
Colour	1	TCU	12	5	-	12	-
T. Kjeldahl Nitrogen (N)	0.05	mg/L	0.18	0.28	0.28	0.18	0.38
Phosphorus, Total	0.004	mg/L	nd	nd	nd	nd	nd
Bromodichloromethane	1	ug/L	-	-	-	-	-
Bromoform	1	ug/L	-	-	-	-	-
Chloroform	2	ug/L	-	-	-	-	-
LOQ	Limit of Quantitation-lowest level that can be quantified with confidence.						
-	Not Requested						
nd	parameter not detected						
!	LOQ higher than listed due to dilution						
0	Adjusted LOQ						
na	Not Applicable						
			1.1-GL-001	1.2-GL-001	1.2"-GL"-001F	1.2"-GL"-002	1.2"-GL"-002F
Parameter	LOQ	Units	@775	@775	@775	@775	@775
Dibromochloromethane	1	ug/L	-	-	-	-	-

Analysis of Water							
			1.3-GL-001	2.1-GL-001	2.1"-GL"-001	2.1"-GL"-002	2.2"-GL"-001
Parameter	LOQ	Units	@775	@775	@775	@775	@775
					Replicate		
Bromide	0.05	mg/L	nd	nd	-	nd	nd
Chloride	0.05	mg/L	2.33	2.21	-	2.23	2.16
Fluoride	0.02	mg/L	nd	nd	-	nd	nd
Nitrate(as N)	0.03	mg/L	0.1	0.08	-	0.11	0.09
Nitrite(as N)	0.03	mg/L	nd	nd	-	nd	nd
Orthophosphate(as P)	0.05	mg/L	nd	nd	-	nd	nd
Sulphate	0.05	mg/L	1.03	1.37	-	3.6	0.99
Aluminum	0.025	mg/L	0.077	0.078	-	0.078	0.086
Barium	0.002	mg/L	0.004	nd	-	nd	nd
Beryllium	0.005	mg/L	nd	nd	-	nd	nd
Bismuth	0.05	mg/L	nd	nd	-	nd	nd
Boron	0.01	mg/L	nd	nd	-	nd	nd
Cadmium	0.003	mg/L	nd	nd	-	nd	nd
Calcium	0.01	mg/L	1.4	1.37	-	1.52	1.72
Chromium	0.005	mg/L	nd	nd	-	nd	nd
Cobalt	0.005	mg/L	nd	nd	-	nd	nd
Copper	0.003	mg/L	nd	0.005	-	nd	0.004
Iron	0.005	mg/L	0.021	0.021	-	0.025	0.021
Lead	0.025	mg/L	nd	nd	-	nd	nd
Magnesium	0.02	mg/L	0.61	0.59	-	0.66	0.74
Manganese	0.005	mg/L	nd	nd	-	nd	nd
Molybdenum	0.01	mg/L	nd	nd	-	nd	nd
Nickel	0.01	mg/L	nd	nd	-	nd	nd
Phosphorus	0.06	mg/L	nd	nd	-	nd	nd
Potassium	0.4	mg/L	nd	0.6	-	nd	nd
Silica(as SiO2)	0.05	mg/L	2.07	2.05	-	2.19	2.06
Silver	0.003	mg/L	nd	nd	-	nd	nd
LOQ	Limit of Quantitation-lowest level that can be quantified with confidence.						
-	Not Requested						
nd	parameter not detected						
!	LOQ higher than listed due to dilution						
0	Adjusted LOQ						
na	Not Applicable						

Analysis of Water							
			1.3-GL-001	2.1-GL-001	2.1"-GL"-001	2.1"-GL"-002	2.2"-GL"-001
Parameter	LOQ	Units	@775	@775	@775	@775	@775
					Replicate		
Sodium	0.04	mg/L	1.73	1.66	-	1.75	1.78
Strontium	0.002	mg/L	0.007	0.007	-	0.008	0.009
Tin	0.05	mg/L	nd	nd	-	nd	nd
Titanium	0.05	mg/L	nd	nd	-	nd	nd
Vanadium	0.01	mg/L	nd	nd	-	nd	nd
Zinc	0.005	mg/L	nd	nd	-	nd	nd
Alkalinity(as CaCO3)	1	mg/L	3	3	-	3	3
Anion Sum	0.01	meq/L	0.15	0.16	-	0.21	0.15
Bicarbonate(CaCO3, cal.)	0.1	mg/L	3	3	-	3	3
Carbonate(CaCO3, cal.)	0.1	mg/L	nd	nd	-	nd	nd
Cation Sum	0.01	meq/L	0.2	0.2	-	0.21	0.23
Conductivity - @25°C	1	uS/cm	21	21	-	21	21
Hardness(as CaCO3)	1	mg/L	6	6	-	7	7
Ion Balance	0.01	na	1.28	1.31	-	1.04	1.57
Langelier Index at 20°C	na	na	-3.81	-3.85	-	-3.94	-3.76
Langelier Index at 4°C	na	na	-4.21	-4.25	-	-4.34	-4.16
pH	0.01	Units	7.02	6.98	-	6.89	6.95
Saturation pH at 20°C	0.01	na	10.8	10.8	-	10.8	10.7
Saturation pH at 4°C	0.01	na	11.2	11.2	-	11.2	11.1
Dissolved Solids(Calculate	1	mg/L	11	11	-	14	11
Turbidity	0.5	NTU	nd	nd	-	nd	nd
Colour	1	TCU	30	26	-	7	13
T. Kjeldahl Nitrogen (N)	0.05	mg/L	0.28	0.19	-	0.28	0.28
Phosphorus, Total	0.004	mg/L	nd	nd	-	nd	nd
Bromodichloromethane	1	ug/L	-	nd	nd	nd	-
Bromoform	1	ug/L	-	nd	nd	nd	-
Chloroform	2	ug/L	-	nd	nd	nd	-

LOQ	Limit of Quantitation-lowest level that can be quantified with confidence.
-	Not Requested
nd	parameter not detected
!	LOQ higher than listed due to dilution
0	Adjusted LOQ
na	Not Applicable

Analysis of Water							
			1.3-GL-001	2.1-GL-001	2.1"-GL"-001	2.1"-GL"-002	2.2"-GL"-001
Parameter	LOQ	Units	@775	@775	@775	@775	@775
					Replicate		
Dibromochloromethane	1	ug/L	-	nd	nd	nd	-

Analysis of Water							
			2.2-GL-002	2.3-GL-001	3.1"-GL"-001	3.2"-GL"-001	3.2"-GL"-001F
Parameter	LOQ	Units	@775	@775	@775	@775	@775
Bromide	0.05	mg/L	nd	nd	nd	nd	-
Chloride	0.05	mg/L	2.17	2.13	2.19	2.07	-
Fluoride	0.02	mg/L	nd	nd	nd	nd	-
Nitrate(as N)	0.03	mg/L	0.1	0.08	0.09	0.09	-
Nitrite(as N)	0.03	mg/L	nd	nd	nd	nd	-
Orthophosphate(as P)	0.05	mg/L	nd	nd	nd	nd	-
Sulphate	0.05	mg/L	1.01	0.98	1	0.97	-
Aluminum	0.025	mg/L	0.075	0.065	0.083	0.087	-
Barium	0.002	mg/L	nd	nd	nd	nd	-
Beryllium	0.005	mg/L	nd	nd	nd	nd	-
Bismuth	0.05	mg/L	nd	nd	nd	nd	-
Boron	0.01	mg/L	nd	nd	nd	nd	-
Cadmium	0.003	mg/L	nd	nd	nd	nd	-
Calcium	0.01	mg/L	1.57	1.6	1.82	2.02	-
Chromium	0.005	mg/L	nd	nd	nd	nd	-
Cobalt	0.005	mg/L	nd	nd	nd	nd	-
Copper	0.003	mg/L	nd	nd	nd	0.005	-
Iron	0.005	mg/L	0.025	0.025	0.026	0.027	-
Lead	0.025	mg/L	nd	nd	nd	nd	-
Magnesium	0.02	mg/L	0.68	0.66	0.85	0.84	-
Manganese	0.005	mg/L	nd	nd	nd	nd	-
Molybdenum	0.01	mg/L	nd	nd	nd	nd	-
Nickel	0.01	mg/L	nd	nd	nd	nd	-
Phosphorus	0.06	mg/L	nd	nd	nd	nd	-
Potassium	0.4	mg/L	0.6	nd	nd	nd	-
Silica(as SiO2)	0.05	mg/L	2.2	2.06	2.14	2.08	-
Silver	0.003	mg/L	nd	nd	nd	nd	-
LOQ	Limit of Quantitation-lowest level that can be quantified with confidence.						
-	Not Requested						
nd	parameter not detected						
!	LOQ higher than listed due to dilution						
0	Adjusted LOQ						
na	Not Applicable						

Analysis of Water							
			2.2-GL-002	2.3-GL-001	3.1"-GL"-001	3.2"-GL"-001	3.2"-GL"-001F
Parameter	LOQ	Units	@775	@775	@775	@775	@775
Sodium	0.04	mg/L	1.74	1.74	1.74	1.79	-
Strontium	0.002	mg/L	0.008	0.008	0.009	0.01	-
Tin	0.05	mg/L	nd	nd	nd	nd	-
Titanium	0.05	mg/L	nd	nd	nd	nd	-
Vanadium	0.01	mg/L	nd	nd	nd	nd	-
Zinc	0.005	mg/L	nd	nd	nd	nd	-
Alkalinity(as CaCO3)	1	mg/L	3	3	3	3	-
Anion Sum	0.01	meq/L	0.15	0.15	0.15	0.15	-
Bicarbonate(CaCO3, cal.)	0.1	mg/L	3	3	3	3	-
Carbonate(CaCO3, cal.)	0.1	mg/L	nd	nd	nd	nd	-
Cation Sum	0.01	meq/L	0.23	0.21	0.25	0.25	-
Conductivity - @25°C	1	uS/cm	21	25	23	21	-
Hardness(as CaCO3)	1	mg/L	7	7	8	9	-
Ion Balance	0.01	na	1.51	1.46	1.66	1.72	-
Langelier Index at 20°C	na	na	-3.95	-4.5	-4.33	-4.19	-
Langelier Index at 4°C	na	na	-4.35	-4.9	-4.73	-4.59	-
pH	0.01	Units	6.88	6.33	6.38	6.42	-
Saturation pH at 20°C	0.01	na	10.8	10.8	10.7	10.6	-
Saturation pH at 4°C	0.01	na	11.2	11.2	11.1	11	-
. Dissolved Solids(Calculate	1	mg/L	11	11	12	11	-
Turbidity	0.5	NTU	nd	nd	nd	nd	-
Colour	1	TCU	22	10	24	15	-
T. Kjeldahl Nitrogen (N)	0.05	mg/L	0.28	0.28	0.28	0.19	0.5
Phosphorus, Total	0.004	mg/L	0.006	nd	nd	0.008	nd
Bromodichloromethane	1	ug/L	-	-	-	-	-
Bromoform	1	ug/L	-	-	-	-	-
Chloroform	2	ug/L	-	-	-	-	-

LOQ	Limit of Quantitation-lowest level that can be quantified with confidence.
-	Not Requested
nd	parameter not detected
!	LOQ higher than listed due to dilution
0	Adjusted LOQ
na	Not Applicable

Analysis of Water							
			2.2-GL-002	2.3-GL-001	3.1"-GL"-001	3.2"-GL"-001	3.2"-GL"-001F
Parameter	LOQ	Units	@775	@775	@775	@775	@775
Dibromochloromethane	1	ug/L	-	-	-	-	-

Analysis of Water							
			3.2-GL-001F	3.2-GL-002	3.2"-GL"-002	3.2"-GL"-002F	3.3"-GL"-001
Parameter	LOQ	Units	@775	@775	@775	@775	@775
			Replicate		Replicate		
Bromide	0.05	mg/L	-	nd	nd	-	nd
Chloride	0.05	mg/L	-	2.18	2.17	-	2.1
Fluoride	0.02	mg/L	-	nd	nd	-	nd
Nitrate(as N)	0.03	mg/L	-	0.1	0.1	-	0.07
Nitrite(as N)	0.03	mg/L	-	nd	nd	-	nd
Orthophosphate(as P)	0.05	mg/L	-	nd	nd	-	nd
Sulphate	0.05	mg/L	-	1.01	1.01	-	0.96
Aluminum	0.025	mg/L	-	0.097	0.101	-	0.092
Barium	0.002	mg/L	-	nd	nd	-	nd
Beryllium	0.005	mg/L	-	nd	nd	-	nd
Bismuth	0.05	mg/L	-	nd	nd	-	nd
Boron	0.01	mg/L	-	nd	nd	-	nd
Cadmium	0.003	mg/L	-	nd	nd	-	nd
Calcium	0.01	mg/L	-	1.6	1.57	-	1.71
Chromium	0.005	mg/L	-	nd	nd	-	nd
Cobalt	0.005	mg/L	-	nd	nd	-	nd
Copper	0.003	mg/L	-	nd	nd	-	nd
Iron	0.005	mg/L	-	0.042	0.042	-	0.035
Lead	0.025	mg/L	-	nd	nd	-	nd
Magnesium	0.02	mg/L	-	0.71	0.69	-	0.79
Manganese	0.005	mg/L	-	nd	nd	-	nd
Molybdenum	0.01	mg/L	-	nd	nd	-	nd
Nickel	0.01	mg/L	-	nd	nd	-	nd
Phosphorus	0.06	mg/L	-	nd	nd	-	nd
Potassium	0.4	mg/L	-	nd	nd	-	1.2
Silica(as SiO2)	0.05	mg/L	-	ns	-	-	2.2
Silver	0.003	mg/L	-	nd	nd	-	nd

LOQ	Limit of Quantitation-lowest level that can be quantified with confidence.
-	Not Requested
nd	parameter not detected
!	LOQ higher than listed due to dilution
()	Adjusted LOQ
na	Not Applicable

Analysis of Water							
			3.2-GL-001F	3.2-GL-002	3.2"-GL"-002	3.2"-GL"-002F	3.3"-GL"-001
Parameter	LOQ	Units	@775	@775	@775	@775	@775
			Replicate		Replicate		
Sodium	0.04	mg/L	-	1.74	1.72	-	1.75
Strontium	0.002	mg/L	-	0.008	0.008	-	0.009
Tin	0.05	mg/L	-	nd	nd	-	nd
Titanium	0.05	mg/L	-	nd	nd	-	nd
Vanadium	0.01	mg/L	-	nd	nd	-	nd
Zinc	0.005	mg/L	-	nd	nd	-	nd
Alkalinity(as CaCO3)	1	mg/L	-	3	3	-	3
Anion Sum	0.01	meq/L	-	0.15	0.15	-	0.14
Bicarbonate(CaCO3, cal.)	0.1	mg/L	-	3	3	-	3
Carbonate(CaCO3, cal.)	0.1	mg/L	-	nd	nd	-	nd
Cation Sum	0.01	meq/L	-	0.22	0.21	-	0.26
Conductivity - @25°C	1	uS/cm	-	21	20	-	21
Hardness(as CaCO3)	1	mg/L	-	7	7	-	8
Ion Balance	0.01	na	-	1.44	1.41	-	1.79
Langelier Index at 20°C	na	na	-	-4.44	-4.45	-	-4.37
Langelier Index at 4°C	na	na	-	-4.84	-4.85	-	-4.77
pH	0.01	Units	-	6.39	6.38	-	6.34
Saturation pH at 20°C	0.01	na	-	10.8	10.8	-	10.7
Saturation pH at 4°C	0.01	na	-	11.2	11.2	-	11.1
T. Dissolved Solids(Cal.)	1	mg/L	-	11	11	-	12
Turbidity	0.5	NTU	-	nd	nd	-	nd
Colour	1	TCU	-	18	18	-	26
T. Kjeldahl Nitrogen (N)	0.05	mg/L	-	0.28	-	0.47	0.28
Phosphorus, Total	0.004	mg/L	-	nd	-	nd	nd
Bromodichloromethane	1	ug/L	-	-	-	-	-
Bromoform	1	ug/L	-	-	-	-	-
Chloroform	2	ug/L	-	-	-	-	-

LOQ	Limit of Quantitation-lowest level that can be quantified with confidence.
-	Not Requested
nd	parameter not detected
!	LOQ higher than listed due to dilution
()	Adjusted LOQ
na	Not Applicable

Analysis of Water							
			3.2-GL-001F	3.2-GL-002	3.2"-GL"-002	3.2"-GL"-002F	3.3"-GL"-001
Parameter	LOQ	Units	@775	@775	@775	@775	@775
			Replicate		Replicate		
Dibromochloromethane	1	ug/L	-	-	-	-	-

Analysis of Water							
			3.3-GL-001	3.3-GL-002	4.1"-GL"-001	4.1"-GL"-002	4.1"-GL"-002
Parameter	LOQ	Units	@775	@775	@775	@775	@775
			Replicate				Replicate
Bromide	0.05	mg/L	-	nd	nd	nd	-
Chloride	0.05	mg/L	-	2.22	2.14	2.27	-
Fluoride	0.02	mg/L	-	nd	nd	nd	-
Nitrate(as N)	0.03	mg/L	-	0.11	0.08	0.11	-
Nitrite(as N)	0.03	mg/L	-	nd	nd	nd	-
Orthophosphate(as P)	0.05	mg/L	-	nd	nd	nd	-
Sulphate	0.05	mg/L	-	1.06	1	1.01	-
Aluminum	0.025	mg/L	-	0.076	0.089	0.101	-
Barium	0.002	mg/L	-	nd	nd	nd	-
Beryllium	0.005	mg/L	-	nd	nd	nd	-
Bismuth	0.05	mg/L	-	nd	nd	nd	-
Boron	0.01	mg/L	-	nd	nd	nd	-
Cadmium	0.003	mg/L	-	nd	nd	nd	-
Calcium	0.01	mg/L	-	1.4	1.74	1.65	-
Chromium	0.005	mg/L	-	nd	nd	nd	-
Cobalt	0.005	mg/L	-	nd	nd	nd	-
Copper	0.003	mg/L	-	nd	nd	0.003	-
Iron	0.005	mg/L	-	0.027	0.028	0.029	-
Lead	0.025	mg/L	-	nd	nd	nd	-
Magnesium	0.02	mg/L	-	0.65	0.77	0.74	-
Manganese	0.005	mg/L	-	nd	nd	nd	-
Molybdenum	0.01	mg/L	-	nd	nd	nd	-
Nickel	0.01	mg/L	-	nd	nd	nd	-
Phosphorus	0.06	mg/L	-	nd	nd	nd	-
Potassium	0.4	mg/L	-	nd	nd	nd	-
Silica(as SiO2)	0.05	mg/L	-	2.1	2.21	2.1	-
Silver	0.003	mg/L	-	nd	nd	nd	-
LOQ	Limit of Quantitation-lowest level that can be quantified with confidence.						
-	Not Requested						
nd	parameter not detected						
!	LOQ higher than listed due to dilution						
()	Adjusted LOQ						
na	Not Applicable						
::							

Analysis of Water							
			3.3-GL-001	3.3-GL-002	4.1"-GL"-001	4.1"-GL"-002	4.1"-GL"-002
Parameter	LOQ	Units	@775	@775	@775	@775	@775
			Replicate				Replicate
Sodium	0.04	mg/L	-	1.67	1.71	1.74	-
Strontium	0.002	mg/L	-	0.007	0.009	0.009	-
Tin	0.05	mg/L	-	nd	nd	nd	-
Titanium	0.05	mg/L	-	nd	nd	nd	-
Vanadium	0.01	mg/L	-	nd	nd	nd	-
Zinc	0.005	mg/L	-	nd	nd	nd	-
Alkalinity(as CaCO3)	1	mg/L	-	3	3	3	-
Anion Sum	0.01	meq/L	-	0.15	0.15	0.15	-
Bicarbonate(CaCO3, cal.)	0.1	mg/L	-	3	3	3	-
Carbonate(CaCO3, cal.)	0.1	mg/L	-	nd	nd	nd	-
Cation Sum	0.01	meq/L	-	0.2	0.22	0.22	-
Conductivity - @25°C	1	uS/cm	-	20	21	21	-
Hardness(as CaCO3)	1	mg/L	-	6	7	7	-
Ion Balance	0.01	na	-	1.28	1.52	1.47	-
Langelier Index at 20°C	na	na	-	-4.53	-4.35	-4.46	-
Langelier Index at 4°C	na	na	-	-4.93	-4.75	-4.86	-
pH	0.01	Units	-	6.3	6.36	6.25	-
Saturation pH at 20°C	0.01	na	-	10.8	10.7	10.7	-
Saturation pH at 4°C	0.01	na	-	11.2	11.1	11.1	-
T. Dissolved Solids(Cal.)	1	mg/L	-	11	11	11	-
Turbidity	0.5	NTU	-	nd	nd	nd	-
Colour	1	TCU	-	3	25	10	-
T. Kjeldahl Nitrogen (N)	0.05	mg/L	-	1.12	0.19	0.23	-
Phosphorus, Total	0.004	mg/L	-	nd	0.004	nd	-
Bromodichloromethane	1	ug/L	-	-	-	-	-
Bromoform	1	ug/L	-	-	-	-	-
Chloroform	2	ug/L	-	-	-	-	-

LOQ	Limit of Quantitation-lowest level that can be quantified with confidence.
-	Not Requested
nd	parameter not detected
!	LOQ higher than listed due to dilution
0	Adjusted LOQ
na	Not Applicable

Analysis of Water							
			3.3-GL-001	3.3-GL-002	4.1"-GL"-001	4.1"-GL"-002	4.1"-GL"-002
Parameter	LOQ	Units	@775	@775	@775	@775	@775
			Replicate				Replicate
Dibromochloromethane	1	ug/L	-	-	-	-	-

Analysis of Water							
			4.2-GL-001	4.2-GL-002	4.3"-GL"-001	5.1"-GL"-001	5.1"-GL"-002
Parameter	LOQ	Units	@775	@775	@775	@775	@775
Bromide	0.05	mg/L	nd	nd	nd	nd	nd
Chloride	0.05	mg/L	2.05	2.17	2.1	2.07	2.11
Fluoride	0.02	mg/L	nd	nd	nd	nd	nd
Nitrate(as N)	0.03	mg/L	0.08	0.1	0.07	0.09	0.1
Nitrite(as N)	0.03	mg/L	nd	nd	nd	nd	nd
Orthophosphate(as P)	0.05	mg/L	nd	nd	nd	nd	nd
Sulphate	0.05	mg/L	0.95	1.01	0.95	0.98	1.02
Aluminum	0.025	mg/L	0.102	0.086	0.079	0.094	0.074
Barium	0.002	mg/L	nd	nd	nd	nd	nd
Beryllium	0.005	mg/L	nd	nd	nd	nd	nd
Bismuth	0.05	mg/L	nd	nd	nd	nd	nd
Boron	0.01	mg/L	nd	nd	nd	nd	nd
Cadmium	0.003	mg/L	nd	nd	nd	nd	nd
Calcium	0.01	mg/L	1.73	1.8	1.71	1.6	1.31
Chromium	0.005	mg/L	nd	nd	nd	nd	nd
Cobalt	0.005	mg/L	nd	nd	nd	nd	nd
Copper	0.003	mg/L	0.006	nd	0.004	0.003	nd
Iron	0.005	mg/L	0.036	0.031	0.04	0.03	0.028
Lead	0.025	mg/L	nd	nd	nd	nd	nd
Magnesium	0.02	mg/L	0.79	0.82	0.76	0.74	0.63
Manganese	0.005	mg/L	nd	nd	nd	nd	nd
Molybdenum	0.01	mg/L	nd	nd	nd	nd	nd
Nickel	0.01	mg/L	nd	nd	nd	nd	nd
Phosphorus	0.06	mg/L	nd	nd	nd	nd	nd
Potassium	0.4	mg/L	0.6	0.9	1	0.4	nd
Silica(as SiO2)	0.05	mg/L	2.2	2.08	2.19	2	2.08
Silver	0.003	mg/L	nd	nd	nd	nd	nd

LOQ	Limit of Quantitation-lowest level that can be quantified with confidence.
-	Not Requested
nd	parameter not detected
!	LOQ higher than listed due to dilution
0	Adjusted LOQ
na	Not Applicable
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Analysis of Water							
			4.2-GL-001	4.2-GL-002	4.3"-GL"-001	5.1"-GL"-001	5.1"-GL"-002
Parameter	LOQ	Units	@775	@775	@775	@775	@775
Sodium	0.04	mg/L	1.71	1.75	1.74	1.7	1.68
Strontium	0.002	mg/L	0.009	0.009	0.01	0.008	0.007
Tin	0.05	mg/L	nd	nd	nd	nd	nd
Titanium	0.05	mg/L	nd	nd	nd	nd	nd
Vanadium	0.01	mg/L	nd	nd	nd	nd	nd
Zinc	0.005	mg/L	nd	nd	nd	nd	nd
Alkalinity(as CaCO3)	1	mg/L	3	2	3	3	3
Anion Sum	0.01	meq/L	0.14	0.13	0.14	0.15	0.15
Bicarbonate(CaCO3, cal.)	0.1	mg/L	3	2	3	3	3
Carbonate(CaCO3, cal.)	0.1	mg/L	nd	nd	nd	nd	nd
Cation Sum	0.01	meq/L	0.24	0.26	0.25	0.23	0.2
Conductivity - @25°C	1	uS/cm	21	20	21	21	20
Hardness(as CaCO3)	1	mg/L	8	8	7	7	6
Ion Balance	0.01	na	1.7	2.01	1.73	1.56	1.33
Langelier Index at 20°C	na	na	-4.09	-4.43	-4.19	-4.37	-4.37
Langelier Index at 4°C	na	na	-4.49	-4.83	-4.59	-4.77	-4.77
pH	0.01	Units	6.62	6.46	6.52	6.46	6.46
Saturation pH at 20°C	0.01	na	10.7	10.9	10.7	10.8	10.8
Saturation pH at 4°C	0.01	na	11.1	11.3	11.1	11.2	11.2
T. Dissolved Solids(Cal.)	1	mg/L	11	11	12	11	11
Turbidity	0.5	NTU	nd	nd	nd	nd	nd
Colour	1	TCU	26	26	17	19	21
T. Kjeldahl Nitrogen (N)	0.05	mg/L	0.38	0.38	0.38	0.47	0.38
Phosphorus, Total	0.004	mg/L	nd	nd	nd	nd	nd
Bromodichloromethane	1	ug/L	-	-	-	-	-
Bromoform	1	ug/L	-	-	-	-	-
Chloroform	2	ug/L	-	-	-	-	-
LOQ	Limit of Quantitation-lowest level that can be quantified with confidence.						
-	Not Requested						
nd	parameter not detected						
!	LOQ higher than listed due to dilution						
0	Adjusted LOQ						
na	Not Applicable						
Analysis of Water							
			4.2-GL-001	4.2-GL-002	4.3"-GL"-001	5.1"-GL"-001	5.1"-GL"-002
Parameter	LOQ	Units	@775	@775	@775	@775	@775
Dibromochloromethane	1	ug/L	-	-	-	-	-

Analysis of Water							
			5.2-GL-001	5.2-GL-002	5.3"-GL"-001	6.1"-GL"-001	6.1"-GL"-001F
Parameter	LOQ	Units	@775	@775	@775	@775	@775
Bromide	0.05	mg/L	nd	nd	nd	nd	-
Chloride	0.05	mg/L	2.24	2.3	2.15	2.22	-
Fluoride	0.02	mg/L	nd	nd	nd	nd	-
Nitrate(as N)	0.03	mg/L	0.09	0.11	0.1	0.1	-
Nitrite(as N)	0.03	mg/L	nd	nd	nd	nd	-
Orthophosphate(as P)	0.05	mg/L	nd	nd	nd	nd	-
Sulphate	0.05	mg/L	1	1.05	1.03	1.03	-
Aluminum	0.025	mg/L	0.083	0.075	0.083	0.1	-
Barium	0.002	mg/L	nd	nd	nd	nd	-
Beryllium	0.005	mg/L	nd	nd	nd	nd	-
Bismuth	0.05	mg/L	nd	nd	nd	nd	-
Boron	0.01	mg/L	nd	nd	nd	nd	-
Cadmium	0.003	mg/L	nd	nd	nd	nd	-
Calcium	0.01	mg/L	1.71	1.39	1.58	1.71	-
Chromium	0.005	mg/L	nd	nd	nd	nd	-
Cobalt	0.005	mg/L	nd	nd	nd	nd	-
Copper	0.003	mg/L	nd	nd	nd	0.005	-
Iron	0.005	mg/L	0.03	0.029	0.026	0.027	-
Lead	0.025	mg/L	nd	nd	nd	nd	-
Magnesium	0.02	mg/L	0.74	0.64	0.71	0.78	-
Manganese	0.005	mg/L	nd	nd	nd	nd	-
Molybdenum	0.01	mg/L	nd	nd	nd	nd	-
Nickel	0.01	mg/L	nd	nd	nd	nd	-
Phosphorus	0.06	mg/L	nd	nd	nd	nd	-
Potassium	0.4	mg/L	0.4	0.8	nd	0.5	-
Silica(as SiO2)	0.05	mg/L	2.19	2.1	2.19	2.1	-
Silver	0.003	mg/L	nd	nd	nd	nd	-

LOQ	Limit of Quantitation-lowest level that can be quantified with confidence.
-	Not Requested
nd	parameter not detected
!	LOQ higher than listed due to dilution
()	Adjusted LOQ
na	Not Applicable
::	

Analysis of Water							
			5.2-GL-001	5.2-GL-002	5.3"-GL"-001	6.1"-GL"-001	6.1"-GL"-001F
Parameter	LOQ	Units	@775	@775	@775	@775	@775
Sodium	0.04	mg/L	1.69	1.7	1.76	1.77	-
Strontium	0.002	mg/L	0.009	0.007	0.008	0.009	-
Tin	0.05	mg/L	nd	nd	nd	nd	-
Titanium	0.05	mg/L	nd	nd	nd	nd	-
Vanadium	0.01	mg/L	nd	nd	nd	nd	-
Zinc	0.005	mg/L	nd	nd	nd	nd	-
Alkalinity(as CaCO3)	1	mg/L	3	3	3	3	-
Anion Sum	0.01	meq/L	0.15	0.16	0.15	0.15	-
Bicarbonate(CaCO3, cal.)	0.1	mg/L	3	3	3	3	-
Carbonate(CaCO3, cal.)	0.1	mg/L	nd	nd	nd	nd	-
Cation Sum	0.01	meq/L	0.23	0.22	0.21	0.24	-
Conductivity - @25°C	1	uS/cm	21	21	21	21	-
Hardness(as CaCO3)	1	mg/L	7	6	7	7	-
Ion Balance	0.01	na	1.54	1.4	1.44	1.59	-
Langelier Index at 20°C	na	na	-4.24	-4.42	-4.45	-4.38	-
Langelier Index at 4°C	na	na	-4.64	-4.82	-4.85	-4.78	-
pH	0.01	Units	6.47	6.41	6.38	6.33	-
Saturation pH at 20°C	0.01	na	10.7	10.8	10.8	10.7	-
Saturation pH at 4°C	0.01	na	11.1	11.2	11.2	11.1	-
T. Dissolved Solids(Cal.)	1	mg/L	11	11	11	12	-
Turbidity	0.5	NTU	nd	nd	nd	nd	-
Colour	1	TCU	24	19	11	7	-
T. Kjeldahl Nitrogen (N)	0.05	mg/L	0.28	0.28	0.56	0.56	0.56
Phosphorus, Total	0.004	mg/L	nd	nd	nd	nd	nd
Bromodichloromethane	1	ug/L	-	-	-	-	-
Bromoform	1	ug/L	-	-	-	-	-
Chloroform	2	ug/L	-	-	-	-	-
LOQ	Limit of Quantitation-lowest level that can be quantified with confidence.						
-	Not Requested						
nd	parameter not detected						
!	LOQ higher than listed due to dilution						
()	Adjusted LOQ						
na	Not Applicable						

Analysis of Water							
			5.2-GL-001	5.2-GL-002	5.3"-GL"-001	6.1"-GL"-001	6.1"-GL"-001F
Parameter	LOQ	Units	@775	@775	@775	@775	@775
Dibromochloromethane	1	ug/L	-	-	-	-	-

Analysis of Water							
			6.1-GL-002	6.1-GL-002F	6.2"-GL"-001	6.2"-GL"-001	6.2"-GL"-002
Parameter	LOQ	Units	@775	@775	@775	@775	@775
						Replicate	
Bromide	0.05	mg/L	nd	-	nd	nd	nd
Chloride	0.05	mg/L	2.22	-	2.02	2.01	2.17
Fluoride	0.02	mg/L	nd	-	nd	nd	nd
Nitrate(as N)	0.03	mg/L	0.12	-	0.17	0.17	0.11
Nitrite(as N)	0.03	mg/L	nd	-	nd	nd	nd
Orthophosphate(as P)	0.05	mg/L	nd	-	nd	nd	nd
Sulphate	0.05	mg/L	1.11	-	1.04	1.04	1.06
Aluminum	0.025	mg/L	0.093	-	0.084	0.091	0.089
Barium	0.002	mg/L	nd	-	nd	nd	nd
Beryllium	0.005	mg/L	nd	-	nd	nd	nd
Bismuth	0.05	mg/L	nd	-	nd	nd	nd
Boron	0.01	mg/L	nd	-	nd	nd	nd
Cadmium	0.003	mg/L	nd	-	nd	nd	nd
Calcium	0.01	mg/L	1.35	-	1.6	1.67	1.73
Chromium	0.005	mg/L	nd	-	nd	nd	nd
Cobalt	0.005	mg/L	nd	-	nd	nd	nd
Copper	0.003	mg/L	0.004	-	nd	nd	nd
Iron	0.005	mg/L	0.034	-	0.028	0.03	0.035
Lead	0.025	mg/L	nd	-	nd	nd	nd
Magnesium	0.02	mg/L	0.61	-	0.75	0.76	0.77
Manganese	0.005	mg/L	nd	-	nd	nd	nd
Molybdenum	0.01	mg/L	nd	-	nd	nd	nd
Nickel	0.01	mg/L	nd	-	nd	nd	nd
Phosphorus	0.06	mg/L	nd	-	nd	nd	nd
Potassium	0.4	mg/L	nd	-	nd	0.5	nd
Silica(as SiO2)	0.05	mg/L	2.14	-	2.15	2.12	2.21
Silver	0.003	mg/L	nd	-	nd	nd	nd

LOQ	Limit of Quantitation-lowest level that can be quantified with confidence.
-	Not Requested
nd	parameter not detected
!	LOQ higher than listed due to dilution
0	*Adjusted LOQ*
na	Not Applicable
::	

Analysis of Water							
			6.1-GL-002	6.1-GL-002F	6.2"-GL"-001	6.2"-GL"-001	6.2"-GL"-002
Parameter	LOQ	Units	@775	@775	@775	@775	@775
						Replicate	
Sodium	0.04	mg/L	1.63	-	1.77	1.75	1.73
Strontium	0.002	mg/L	0.007	-	0.008	0.009	0.009
Tin	0.05	mg/L	nd	-	nd	nd	nd
Titanium	0.05	mg/L	nd	-	nd	nd	nd
Vanadium	0.01	mg/L	nd	-	nd	nd	nd
Zinc	0.005	mg/L	nd	-	nd	nd	nd
Alkalinity(as CaCO3)	1	mg/L	2	-	3	2	3
Anion Sum	0.01	meq/L	0.13	-	0.15	0.13	0.15
Bicarbonate(CaCO3, cal.)	0.1	mg/L	2	-	3	2	3
Carbonate(CaCO3, cal.)	0.1	mg/L	nd	-	nd	nd	nd
Cation Sum	0.01	meq/L	0.19	-	0.22	0.24	0.23
Conductivity - @25°C	1	uS/cm	21	-	21	20	20
Hardness(as CaCO3)	1	mg/L	6	-	7	7	8
Ion Balance	0.01	na	1.4	-	1.48	1.81	1.55
Langelier Index at 20°C	na	na	-4.65	-	-4.53	-4.59	-4.42
Langelier Index at 4°C	na	na	-5.05	-	-4.93	-4.99	-4.82
pH	0.01	Units	6.36	-	6.3	6.3	6.29
Saturation pH at 20°C	0.01	na	11	-	10.8	10.9	10.7
Saturation pH at 4°C	0.01	na	11.4	-	11.2	11.3	11.1
T. Dissolved Solids(Cal.)	1	mg/L	10	-	11	11	11
Turbidity	0.5	NTU	nd	-	nd	nd	nd
Colour	1	TCU	26	-	18	19	22
T. Kjeldahl Nitrogen (N)	0.05	mg/L	0.47	0.28	0.28	-	0.28
Phosphorus, Total	0.004	mg/L	nd	nd	nd	-	nd
Bromodichloromethane	1	ug/L	-	-	-	-	-
Bromoform	1	ug/L	-	-	-	-	-
Chloroform	2	ug/L	-	-	-	-	-

LOQ	Limit of Quantitation-lowest level that can be quantified with confidence.
-	Not Requested
nd	parameter not detected
!	LOQ higher than listed due to dilution
0	Adjusted LOQ
na	Not Applicable

Analysis of Water							
			6.1-GL-002	6.1-GL-002F	6.2"-GL"-001	6.2"-GL"-001	6.2"-GL"-002
Parameter	LOQ	Units	@775	@775	@775	@775	@775
						Replicate	
Dibromochloromethane	1	ug/L	-	-	-	-	-

Analysis of Water							
			6.3-GL-001	A-GL-001	B"-GL"-001	B"-GL"-001	B"-GL"-002
Parameter	LOQ	Units	@775	@775	@775	@775	@775
						Replicate	
Bromide	0.05	mg/L	nd	nd	nd	nd	nd
Chloride	0.05	mg/L	1.95	2.45	2.11	2.11	2.1
Fluoride	0.02	mg/L	nd	nd	nd	nd	nd
Nitrate(as N)	0.03	mg/L	0.07	0.06	0.09	0.09	0.1
Nitrite(as N)	0.03	mg/L	nd	nd	nd	nd	nd
Orthophosphate(as P)	0.05	mg/L	nd	nd	nd	nd	nd
Sulphate	0.05	mg/L	0.98	1	1	0.99	1
Aluminum	0.025	mg/L	0.099	0.082	0.058	0.07	0.073
Barium	0.002	mg/L	nd	0.003	nd	nd	nd
Beryllium	0.005	mg/L	nd	nd	nd	nd	nd
Bismuth	0.05	mg/L	nd	nd	nd	nd	nd
Boron	0.01	mg/L	nd	nd	nd	nd	nd
Cadmium	0.003	mg/L	nd	nd	nd	nd	nd
Calcium	0.01	mg/L	2.05	1.89	1.44	1.44	1.47
Chromium	0.005	mg/L	0.006	nd	nd	nd	nd
Cobalt	0.005	mg/L	0.005	nd	nd	nd	nd
Copper	0.003	mg/L	0.006	nd	nd	nd	nd
Iron	0.005	mg/L	0.083	0.031	0.023	0.026	0.022
Lead	0.025	mg/L	0.037	nd	nd	nd	nd
Magnesium	0.02	mg/L	0.97	0.79	0.62	0.62	0.62
Manganese	0.005	mg/L	nd	nd	nd	nd	nd
Molybdenum	0.01	mg/L	nd	nd	nd	nd	nd
Nickel	0.01	mg/L	nd	nd	nd	nd	nd
Phosphorus	0.06	mg/L	nd	nd	nd	nd	nd
Potassium	0.4	mg/L	nd	nd	nd	nd	nd
Silica(as SiO2)	0.05	mg/L	2.02	2.15	2.04	2.06	2.09
Silver	0.003	mg/L	nd	nd	nd	nd	nd

LOQ	Limit of Quantitation-lowest level that can be quantified with confidence.
-	Not Requested
nd	parameter not detected
!	LOQ higher than listed due to dilution
0	Adjusted LOQ
na	Not Applicable
::	

Analysis of Water							
			6.3-GL-001	A-GL-001	B"-GL"-001	B"-GL"-001	B"-GL"-002
Parameter	LOQ	Units	@775	@775	@775	@775	@775
						Replicate	
Sodium	0.04	mg/L	1.7	1.96	1.71	1.71	1.72
Strontium	0.002	mg/L	0.011	0.009	0.007	0.007	0.007
Tin	0.05	mg/L	nd	nd	nd	nd	nd
Titanium	0.05	mg/L	nd	nd	nd	nd	nd
Vanadium	0.01	mg/L	nd	nd	nd	nd	nd
Zinc	0.005	mg/L	nd	nd	nd	nd	nd
Alkalinity(as CaCO3)	1	mg/L	3	3	3	3	2
Anion Sum	0.01	meq/L	0.14	0.15	0.15	0.15	0.13
Bicarbonate(CaCO3, cal.)	0.1	mg/L	3	3	2.9	2.9	2
Carbonate(CaCO3, cal.)	0.1	mg/L	nd	nd	nd	nd	nd
Cation Sum	0.01	meq/L	0.26	0.25	0.21	0.21	0.21
Conductivity - @25°C	1	uS/cm	21	24	21	21	21
Hardness(as CaCO3)	1	mg/L	9	8	6	6	6
Ion Balance	0.01	na	1.83	1.63	1.41	1.4	1.64
Langelier Index at 20°C	na	na	-4.31	-4.33	-2.91	-2.94	-4.12
Langelier Index at 4°C	na	na	-4.71	-4.73	-3.31	-3.34	-4.52
pH	0.01	Units	6.3	6.38	7.92	7.89	6.89
Saturation pH at 20°C	0.01	na	10.6	10.7	10.8	10.8	11
Saturation pH at 4°C	0.01	na	11	11.1	11.2	11.2	11.4
T. Dissolved Solids(Cal.)	1	mg/L	11	12	11	11	10
Turbidity	0.5	NTU	nd	nd	nd	nd	nd
Colour	1	TCU	15	5	30	28	38
T. Kjeldahl Nitrogen (N)	0.05	mg/L	0.19	0.28	nd	-	nd
Phosphorus, Total	0.004	mg/L	nd	nd	nd	-	0.015
Bromodichloromethane	1	ug/L	-	-	-	-	-
Bromoform	1	ug/L	-	-	-	-	-
Chloroform	2	ug/L	-	-	-	-	-

LOQ	Limit of Quantitation-lowest level that can be quantified with confidence.
-	Not Requested
nd	parameter not detected
!	LOQ higher than listed due to dilution
0	Adjusted LOQ
na	Not Applicable

Analysis of Water							
			6.3-GL-001	A-GL-001	B"-GL"-001	B"-GL"-001	B"-GL"-002
Parameter	LOQ	Units	@775	@775	@775	@775	@775
						Replicate	
Dibromochloromethane	1	ug/L	-	-	-	-	-

Analysis of Water							
			B-GL-002	C-GL-001	C"-GL"-001		
Parameter	LOQ	Units	@775	@775	@775		
			Replicate		Replicate		
Bromide	0.05	mg/L	-	nd	-		
Chloride	0.05	mg/L	-	2.07	-		
Fluoride	0.02	mg/L	-	nd	-		
Nitrate(as N)	0.03	mg/L	-	0.07	-		
Nitrite(as N)	0.03	mg/L	-	nd	-		
Orthophosphate(as P)	0.05	mg/L	-	nd	-		
Sulphate	0.05	mg/L	-	0.97	-		
Aluminum	0.025	mg/L	-	0.076	-		
Barium	0.002	mg/L	-	nd	-		
Beryllium	0.005	mg/L	-	nd	-		
Bismuth	0.05	mg/L	-	nd	-		
Boron	0.01	mg/L	-	nd	-		
Cadmium	0.003	mg/L	-	nd	-		
Calcium	0.01	mg/L	-	1.47	-		
Chromium	0.005	mg/L	-	nd	-		
Cobalt	0.005	mg/L	-	nd	-		
Copper	0.003	mg/L	-	nd	-		
Iron	0.005	mg/L	-	0.027	-		
Lead	0.025	mg/L	-	0.031	-		
Magnesium	0.02	mg/L	-	0.65	-		
Manganese	0.005	mg/L	-	nd	-		
Molybdenum	0.01	mg/L	-	nd	-		
Nickel	0.01	mg/L	-	nd	-		
Phosphorus	0.06	mg/L	-	nd	-		
Potassium	0.4	mg/L	-	0.9	-		
Silica(as SiO2)	0.05	mg/L	-	2.03	-		
Silver	0.003	mg/L	-	nd	-		
LOQ	Limit of Quantitation-lowest level that can be quantified with confidence.						
-	Not Requested						
nd	parameter not detected						
!	LOQ higher than listed due to dilution						
0	Adjusted LOQ						
na	Not Applicable						

Analysis of Water							
			B-GL-002	C-GL-001	C"-GL"-001		
Parameter	LOQ	Units	@775	@775	@775		
			Replicate		Replicate		
Sodium	0.04	mg/L	-	1.73	-		
Strontium	0.002	mg/L	-	0.007	-		
Tin	0.05	mg/L	-	nd	-		
Titanium	0.05	mg/L	-	nd	-		
Vanadium	0.01	mg/L	-	nd	-		
Zinc	0.005	mg/L	-	nd	-		
Alkalinity(as CaCO3)	1	mg/L	-	3	-		
Anion Sum	0.01	meq/L	-	0.14	-		
Bicarbonate(CaCO3, cal.)	0.1	mg/L	-	3	-		
Carbonate(CaCO3, cal.)	0.1	mg/L	-	nd	-		
Cation Sum	0.01	meq/L	-	0.23	-		
Conductivity - @25°C	1	uS/cm	-	21	-		
Hardness(as CaCO3)	1	mg/L	-	6	-		
Ion Balance	0.01	na	-	1.58	-		
Langelier Index at 20°C	na	na	-	-3.78	-		
Langelier Index at 4°C	na	na	-	-4.18	-		
pH	0.01	Units	-	7.05	-		
Saturation pH at 20°C	0.01	na	-	10.8	-		
Saturation pH at 4°C	0.01	na	-	11.2	-		
T. Dissolved Solids(Cal.)	1	mg/L	-	11	-		
Turbidity	0.5	NTU	-	nd	-		
Colour	1	TCU	-	33	-		
T. Kjeldahl Nitrogen (N)	0.05	mg/L	-	0.18	-		
Phosphorus, Total	0.004	mg/L	-	nd	-		
Bromodichloromethane	1	ug/L	-	-	-		
Bromoform	1	ug/L	-	-	-		
Chloroform	2	ug/L	-	-	-		

LOQ	Limit of Quantitation-lowest level that can be quantified with confidence.
-	Not Requested
nd	parameter not detected
!	LOQ higher than listed due to dilution
0	Adjusted LOQ
na	Not Applicable

Analysis of Water							
			B-GL-002	C-GL-001	C"-GL"-001		
Parameter	LOQ	Units	@775	@775	@775		
			Replicate		Replicate		
Dibromochloromethane	1	ug/L	-	-	-		

APPENDIX C
WATER QUALITY DATA FOR SOULIS BROOK AND GANDER AIRPORT DITCH

FIG. 4-1

MacLAREN ATLANTIC LIMITED
HALIFAX · MONCTON

LOCATION: SOULIS BROOK AT TRANS CANADA HIGHWAY

ANALYSIS ↓ / STATION → / DATE →	D MAY 1-2	D MAY 7	D MAY 9	D MAY 14	D MAY 16	D MAY 22	D MAY 23	D MAY 28	D MAY 30	D JUNE 4	D JUNE 6	D JUNE 11
DISSOLVED OXYGEN	6.3	6.3	8.5	7.2	8.3	8.1	7.7					
BOD_5 (mg/l)	4.2	3.4	1.4	1.7	7.8	1.0	6.6					
SUSPENDED SOLIDS (mg/l)	9	5	5	7	3							
pH VALUE	—	6.2	6.4	6.25	6.08							
CADMIUM (mg/l)	0	0	.01'	0	0	0	0	—	—	—	—	—
COPPER (mg/l)	0	0	0	.022	0	0	0	—	—	—	—	—
IRON (TOTAL) (mg/l)	0.0917	.059	.045	.055	.055	.076	.097	—	—	—	—	—
LEAD (mg/l)	0	.011	0	0	0	0	0	—	—	—	—	—
ZINC (mg/l)	0.0018	.006	0	0	0	0	—	—	—	—	—	—
TEMPERATURE (°F)	39	38	39	40	44	45	49					
TURBIDITY	3.3	1.2	1.7	0.5	0.3	0.5	0.6					
CONDUCTIVITY (u-mohs/cm)	182	30	32	29	29	31	33					
TOTAL DISSOLVED SOLIDS (mg/l)	20	18	30	14								
ALKALINITY (bicarbonate)		1.8										
TOTAL HARDNESS — Ca	1.49	1.16	1.14	1.09	0.99	0.98	0.88					
TOTAL HARDNESS — Mg	0.72	0.65	0.61	0.63	0.30	0.33	0.31					
AMMONIACAL NITROGEN AS N	1.50	2.58	1.16	0		0.74	0.88					
NITRATE AS N	N.A.	0.03	0.02	0.02	0.03	0.03	0.02					
TOTAL KJELDAHL NITROGEN AS N		1.98	2.69	1.08	9.05	7.74	0.38					
SOLUBLE PHOSPHATES AS P	0.007	0.009	0.452?	0.007	0.01	0	0.0					
TOTAL PHOSPHORUS AS P	0.034	0.0	0.15	0.18	1.59	0.01	0.01					
TOTAL COLIFORMS	< 2	5		10	0	12	36					

GANDER INT'L AIRPORT

JANUARY 1995
TO
MARCH 1995

STORMWATER MONITORING RESULTS

Transport Canada
Airports Group
Safety and Technical Services
Environmental Services

Services de l'environnement
Sécurité et services techniques
Groupe des aéroports
Transports Canada

Gander Int'l Airport

Stormwater Monitoring for Period: January 1, 1995 to March 31, 1995

A.. _/95

PARAMETERS	Units	FEDERAL GUIDELINES Storm Sewer	RESULTS BY DATE						
Date Collected			Jan. 3/94	Jan. 10/95	Jan. 17/95	Jan. 24/95	Jan. 31/95	?	Feb. 27,28
Date Received			Jan. 4/94	Jan. 11/95	Jan. 18/95	Jan. 25/95	Feb. 1/95	Feb. 8/95	Mar. 1/95
pH	mg/L	6.0-9.0	7.42	6.31	6.14	6.97	7.09	7.46	6.90
Oil & Grease	mg/L	15	<1	2	6	<1	5	<1	2
BOD (5 day)	mg/L	20	2	4	4	<1	3	7	5
Total Suspended Solids (TSS)	mg/L	25	8	4	2	1	2	<1	7
Total Phosphorus (as P)	mg/L	1.0	<0.01	<0.05	0.02	<0.01	<0.05	<0.05	0.05
TKN	mg/L	-	0.67	34.5	22.8	14.3	8.19	4.8	17.2
TOC	mg/L	-	2	6	8	1	8	5	5
Phenolics	mg/L	0.020	0.003	<0.002	0.004	0.002	0.002	0.002	<0.002
Alkalinity (as CaCO3)	mg/L	-	33	27	36	48	47	42	32
Glycols, Total	mg/L	100	<1	1	1	<1	1	1	<1
Ammonia (as N)	mg/L	-	0.26	7.56	7.87	10.43	7.3	4.11	7.17
Nitrite (as N)	mg/L	-	<0.1	0.4	0.4	<0.1	<0.1	<0.1	<0.1
Nitrate (as N)	mg/L	-	0.8	2.4	1.8	1.5	1.6	1.4	3.3
Volatile Organics, Total	mg/L	-	0.002	0.001	0.002	0.001	0.001	<0.001	0.004
Fecal Coliform	cts/100ml	400	-	-	-	-	-	-	-
Iron	mg/L	-	1.38	0.76	0.38	0.43	0.75	0.68	0.69
Aluminum	mg/L	-	0.28	0.34	0.21	0.13	0.15	0.12	0.29
Antimony	mg/L	-	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Arsenic	mg/L	-	<0.020	<0.002	0.003	0.005	0.008	<0.002	<0.002
Boron	mg/L	-	0.01	<0.01	<0.01	0.03	<0.01	<0.01	0.01
Barium	mg/L	-	<0.01	<0.01	<0.01	0.09	<0.01	<0.01	0.01
Cadmium	mg/L	-	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Chromium	mg/L	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cobalt	mg/L	-	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Copper	mg/L	-	0.01	0.07	<0.01	0.01	<0.01	<0.01	0.01
Manganese	mg/L	-	0.626	0.175	0.136	0.128	0.245	0.263	0.276
Mercury	mg/L	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Molybdenum	mg/L	-	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Nickel	mg/L	-	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Lead	mg/L	-	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Selenium	mg/L	-	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Silver	mg/L	-	<0.01	<0.01	0.18	0.15	<0.01	<0.01	<0.01
Silica	mg/L	-	8.02	3.94	4.51	3.81	6.57	7.20	5.72
Vanadium	mg/L	-	<0.01	0.02	0.07	0.02	<0.01	<0.01	<0.01
Zinc	mg/L	-	0.07	0.08	0.04	0.04	0.05	0.04	0.07

Gander Int'l Airport

Stormwater Monitoring for Period: January 1, 1995 to March 31, 1995

PARAMETERS	Units	FEDERAL GUIDELINES Storm Sewer	RESULTS BY DATE						
Date Collected			Mar. 13-14	Mar. 19-20					
Date Received			Mar. 15/95	Mar. 22/95					
pH	mg/L	6.0-9.0	7.37	7.87					
Oil & Grease	mg/L	15	2	3					
BOD (5 day)	mg/L	20	5	2					
Total Suspended Solids (TSS)	mg/L	25	2	3					
Total Phosphorus (as P)	mg/L	1.0							
TKN	mg/L	-							
TOC	mg/L	-	5	9					
Phenolics	mg/L	0.020	0.002	<0.002					
Alkalinity (as CaCO3)	mg/L	-	67	132					
Glycols, Total	mg/L	100	<1	<1					
Ammonia (as N)	mg/L	-	18.5	42.1					
Nitrite (as N)	mg/L	-	0.3	0.2					
Nitrate (as N)	mg/L	-	2.8	3.2					
Volatile Organics, Total	mg/L	-	0.003						
Fecal Coliform	cts/100ml	400	-	-					
Iron	mg/L	-	0.39						
Aluminum	mg/L	-	0.18						
Antimony	mg/L	-	<0.04						
Arsenic	mg/L	-	0.002						
Boron	mg/L	-	<0.01						
Barium	mg/L	-	<0.01						
Cadmium	mg/L	-	<0.004						
Chromium	mg/L	-	<0.01						
Cobalt	mg/L	-	<0.02						
Copper	mg/L	-	<0.01						
Manganese	mg/L	-	0.163						
Mercury	mg/L	-	<0.05						
Molybdenum	mg/L	-	<0.03						
Nickel	mg/L	-	<0.02						
Lead	mg/L	-	<0.04						
Selenium	mg/L	-	<0.002						
Silver	mg/L	-	<0.01						
Silica	mg/L	-	4.24	4.25					
Vanadium	mg/L	-	<0.01						
Zinc	mg/L	-	0.04						

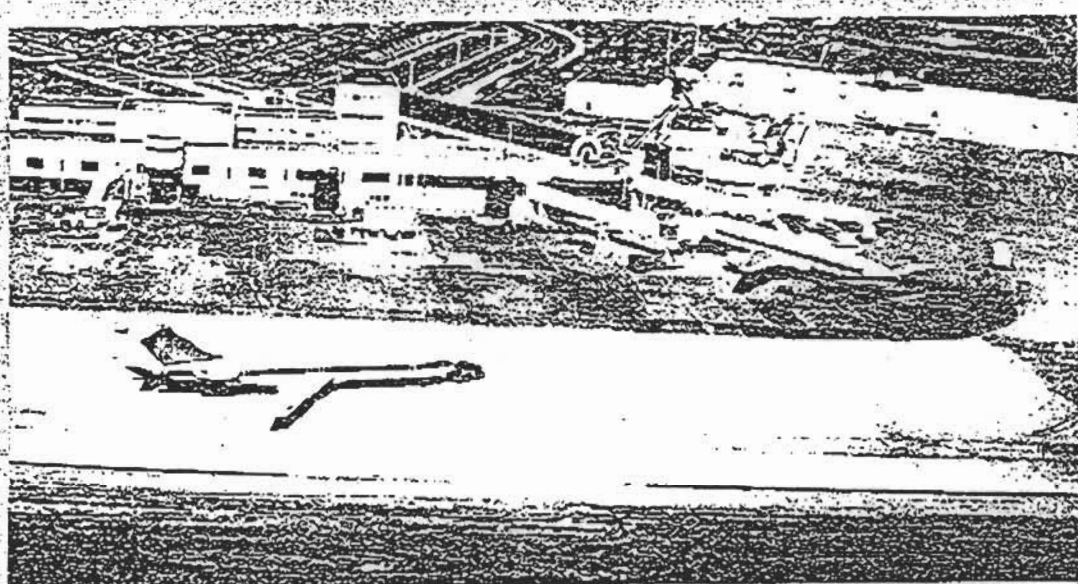
Transport Canada Airports | Transports Canada Aéroports

Safety and Technical Services | Sécurité et services techniques

GANDER INT'L AIRPORT

1994 ANNUAL

STORMWATER MONITORING RESULTS



Canada

Gander Int'l Airport Stormwater Monitoring for Period: January 1, 1994 to December 31, 1994 2/2/98

PARAMETERS	Units	FEDERAL GUIDELINES Storm Sewer	RESULTS BY DATE						
Date Collected			Apr. 18/19	?	?	?	May 16-17	May 23-24	May 30-31
Date Received			Apr. 21	Apr. 28	May-6	May-13	May-19	May-26	Jun-2
pH	mg/L	6.0-9.0	6.65	7.23	7.11	7.70	7.27	7.42	7.82
Oil & Grease	mg/L	15	4	8	3	5	1	1	<1
BOD (5 day)	mg/L	20	5	7	2	8	6	7	2
Total Suspended Solids (TSS)	mg/L	25	11	<1	6	52	6	6	1
Total Phosphorus (as P)	mg/L	1.0	0.05	<0.01	<0.01	<0.01	<0.01	0.01	<0.01
TKN	mg/L	-	2.3	4.2	3.1	1.3	1.3	1.6	2.0
TOC	mg/L	-	6	2	7	2	4	6	2
Phenolics	mg/L	0.020	<0.002	<0.002	0.004	0.003	<0.002	0.020	<0.002
Alkalinity (as CaCO3)	mg/L	-	47	24	13	11	19	23	19
Glycols, Total	mg/L	100	<1	1	<1	<1	<1	<1	<1
Ammonia (as N)	mg/L	-	1.65	0.14	2.33	1.07	1.02	1.12	1.88
Nitrite (as N)	mg/L	-	0.3	0.8	0.3	<0.1	<0.1	0.4	1.5
Nitrate (as N)	mg/L	-	1.3	3.6	2.3	1.6	2.7	3.3	5.0
Volatile Organics, Total	mg/L	-	<0.001	0.025	0.011	<0.001	0.002	0.159	<0.001
Fecal Coliform	cts/100ml	400	-	-	-	-	-	-	-
Iron	mg/L	-	0.31	0.37	0.17	0.35	0.61	0.63	0.24
Aluminum	mg/L	-	0.20	0.12	0.15	0.3	0.16	<0.05	0.11
Antimony	mg/L	-	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Arsenic	mg/L	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Boron	mg/L	-	0.03	0.01	0.04	0.02	<0.01	<0.01	<0.01
Barium	mg/L	-	<0.01	<0.01	0.06	0.02	0.01	<0.01	0.01
Cadmium	mg/L	-	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Chromium	mg/L	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cobalt	mg/L	-	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Copper	mg/L	-	0.01	<0.01	0.01	0.01	<0.01	<0.01	<0.01
Manganese	mg/L	-	0.128	0.198	0.067	0.058	0.407	0.265	0.455
Mercury	mg/L	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Molybdenum	mg/L	-	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Nickel	mg/L	-	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Lead	mg/L	-	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Selenium	mg/L	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Silver	mg/L	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silica	mg/L	-	2.32	3.47	3.37	2.36	3.76	3.18	2.82
Vanadium	mg/L	-	0.01	0.01	<0.01	0.02	<0.01	0.01	<0.01
Zinc	mg/L	-	0.06	0.05	0.06	0.05	0.04	0.08	0.10

PARAMETERS	Units	FEDERAL GUIDELINES Storm Sewer	RESULTS BY DATE						
Date Collected			June 13-14	June 20-21	June 27-28	July 4-5	?	July 18-19	July 25-26
Date Received			Jun-15	Jun-22	Jun-30	Jul-7	Jul-15	Jul-21	Jul-28
pH	mg/L	6.0-9.0	7.68	7.99	7.41	8.46	7.46	7.11	7.22
Oil & Grease	mg/L	15	3	18	1	15	2	2	<1
BOD (5 day)	mg/L	20	5	3	2	1	9	3	2
Total Suspended Solids (TSS)	mg/L	25	5	9	18	4	6	13	7
Total Phosphorus (as P)	mg/L	1.0	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	0.20
TKN	mg/L	-	0.7	0.6	0.6	1.1	0.8	0.6	1.5
TOC	mg/L	-	2	<2	3	6	6	11	10
Phenolics	mg/L	0.020	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Alkalinity (as CaCO3)	mg/L	-	22	32	30	21	23	38	21
Glycols, Total	mg/L	100	<1	1	<1	<1	<1	<1	<1
Ammonia (as N)	mg/L	-	0.4	0.24	0.22	0.39	0.18	0.33	0.69
Nitrite (as N)	mg/L	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Nitrate (as N)	mg/L	-	3.2	2.1	2.9	4.1	4.2	3.2	3.5
Volatile Organics, Total	mg/L	-	0.098	<0.001	<0.001	0.001	0.001	<0.001	<0.001
Fecal Coliform	cts/100ml	400	-	-	-	-	-	-	-
Iron	mg/L	-	0.97	0.57	1.27	0.78	0.57	1.12	0.51
Aluminum	mg/L	-	0.26	0.09	0.39	0.13	0.15	0.13	0.21
Antimony	mg/L	-	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Arsenic	mg/L	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Boron	mg/L	-	0.02	0.02	0.02	0.01	0.02	<0.01	0.01
Barium	mg/L	-	0.01	0.01	0.01	0.01	0.01	0.01	<0.01
Cadmium	mg/L	-	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Chromium	mg/L	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cobalt	mg/L	-	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Copper	mg/L	-	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Manganese	mg/L	-	0.293	0.284	0.504	0.403	0.279	0.608	0.219
Mercury	mg/L	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Molybdenum	mg/L	-	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Nickel	mg/L	-	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Lead	mg/L	-	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Selenium	mg/L	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Silver	mg/L	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silica	mg/L	-	2.36	2.52	2.79	2.87	3.58	5.46	5.47
Vanadium	mg/L	-	0.03	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	mg/L	-	0.08	0.03	0.12	0.06	0.07	0.03	0.08

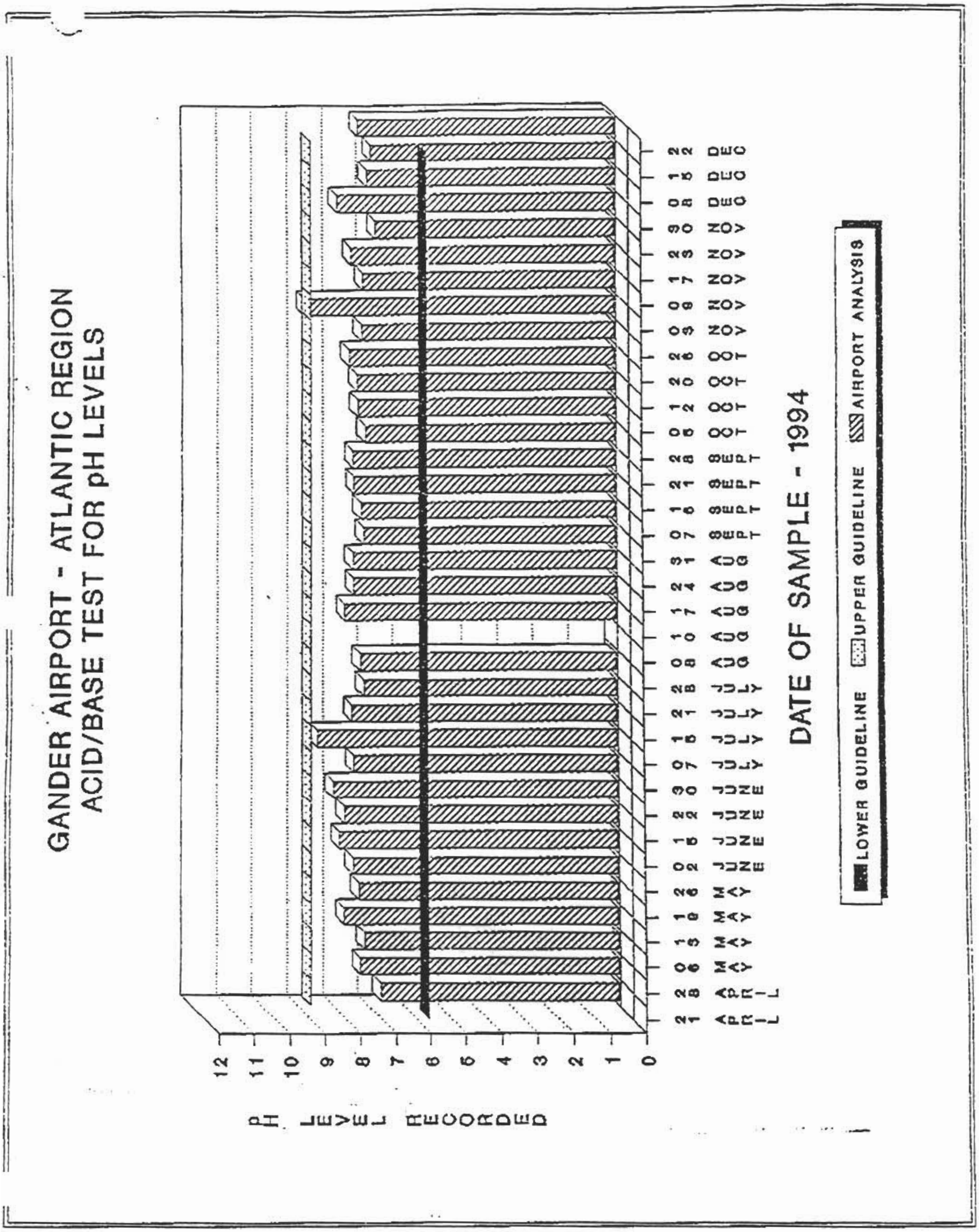
Gand^ ^nt'l Airport Stormwater Monitoring for Period: ^nuary 1, 1994 to December 31, 1994 2/2/95

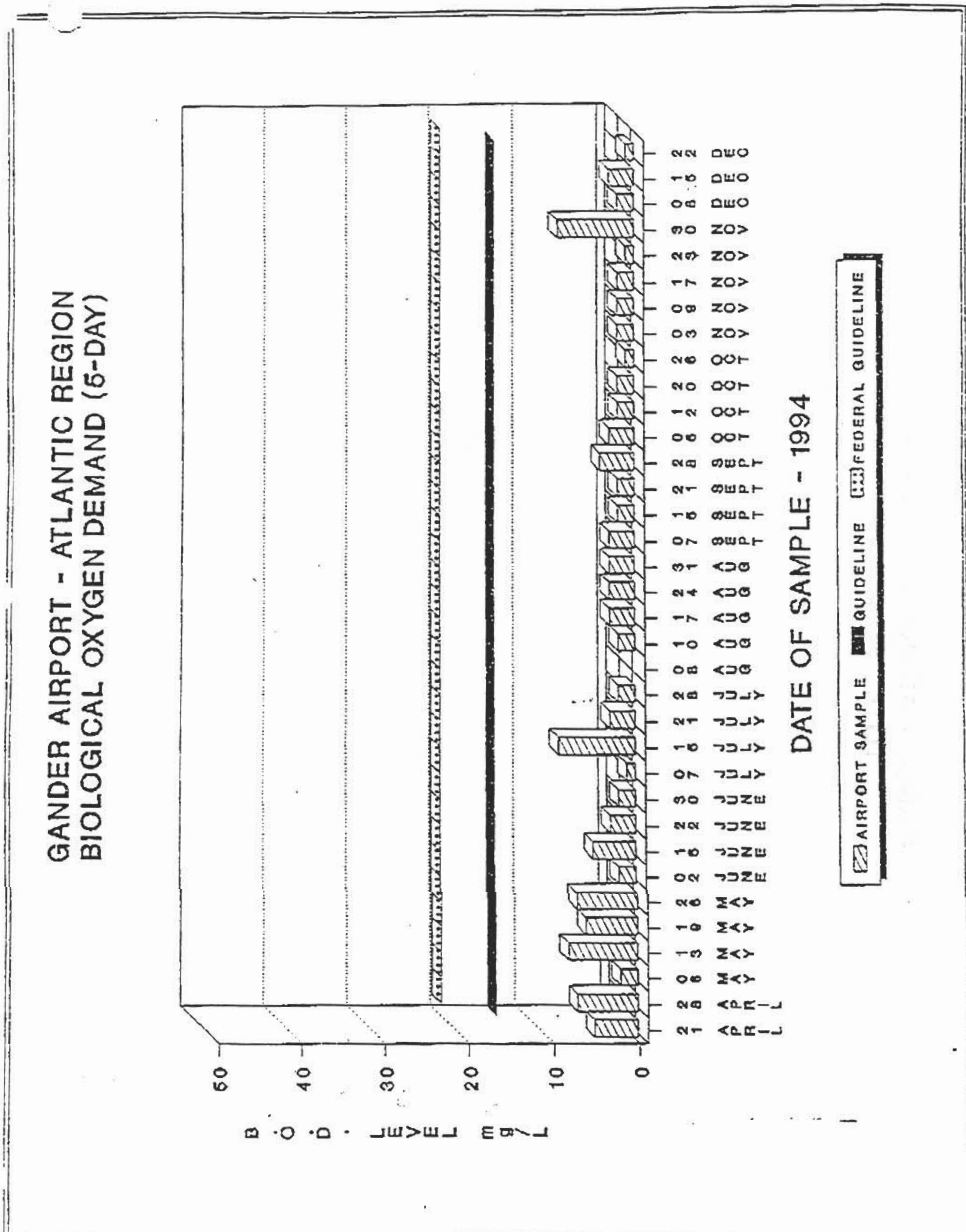
PARAMETERS	Units	FEDERAL GUIDELINES Storm Sewer	RESULTS BY DATE						
			Jar Broken						
Date Collected			Aug. 1-2	Aug. 8-9	Aug. 15-16	Aug. 22-23	Aug. 29-30	Sept. 5-6	Sept. 12-13
Date Received			Aug. 8	Aug. 10	Aug. 17	Aug. 24	Aug. 31	Sept. 7	Sept. 15
pH	mg/L	6.0-9.0		7.67	7.41	7.43	7.12	7.19	7.38
Oil & Grease	mg/L	15		3	3	<1	4	1	2
BOD (5 day)	mg/L	20		2	3	3	3	3	2
Total Suspended Solids (TSS)	mg/L	25		7	105	74	57	30	91
Total Phosphorus (as P)	mg/L	1.0		0.01	<0.01	<0.01	<0.01	<0.01	<0.01
TKN	mg/L	-		1.0	1.2	0.9	0.9	1.1	1.0
TOC	mg/L	-		8	4	4	<2	6	6
Phenolics	mg/L	0.020		<0.002	<0.002	0.004	0.004	0.004	<0.002
Alkalinity (as CaCO3)	mg/L	-		28	43	47	40	46	13
Glycols, Total	mg/L	100	<1	<1	<1	<1	<1	<1	<1
Ammonia (as N)	mg/L	-		0.16	0.36	0.42	0.38	0.47	<0.03
Nitrite (as N)	mg/L	-		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Nitrate (as N)	mg/L	-		2.7	1.4	0.8	1.3	0.9	2.8
Volatile Organics, Total	mg/L	-	0.001	0.003	0.001	0.001	0.001	0.001	<0.001
Fecal Coliform	cts/100ml	400	-	-	-	-	-	-	-
Iron	mg/L	-		0.45	5.00	4.25	4.04	2.74	4.53
Aluminum	mg/L	-		0.23	2.75	1.45	0.56	0.50	2.41
Antimony	mg/L	-		<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Arsenic	mg/L	-		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Boron	mg/L	-		<0.01	0.01	0.01	<0.01	<0.01	0.02
Barium	mg/L	-		0.01	0.03	0.03	0.02	0.01	0.03
Cadmium	mg/L	-		<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Chromium	mg/L	-		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cobalt	mg/L	-		<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Copper	mg/L	-		0.01	0.01	<0.01	<0.01	<0.01	0.01
Manganese	mg/L	-		0.260	1.13	1.53	1.31	0.711	0.640
Mercury	mg/L	-		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Molybdenum	mg/L	-		<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Nickel	mg/L	-		<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Lead	mg/L	-		<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Selenium	mg/L	-		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Silver	mg/L	-		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silica	mg/L	-		5.97	7.07	7.76	7.64	8.65	4.73
Vanadium	mg/L	-		0.01	<0.01	0.02	0.02	<0.01	<0.01
Zinc	mg/L	-		0.02	0.19	0.21	0.14	0.14	0.06

PARAMETERS	Units	FEDERAL GUIDELINES Storm Sewer	RESULTS BY DATE						
Date Collected			Sept. 19-20	Sept. 26-27	Oct. 3-4	Oct. 10-11	Oct. 17-18	Oct. 24-25	Nov. 1-2
Date Received			Sept. 21	Sept. 28/94	Oct. 5/94	Oct. 12/94	Oct. 20/94	Oct. 26/94	Nov. 3/94
pH	mg/L	6.0-9.0	7.41	7.06	7.27	7.29	7.53	7.17	6.81
Oil & Grease	mg/L	15	2	3	6	<1	<1	2	8
BOD (5 day)	mg/L	20	2	4	3	2	2	1	2
Total Suspended Solids (TSS)	mg/L	25	90	556	144	29	6	9	<1
Total Phosphorus (as P)	mg/L	1.0		0.38	<0.01	<0.01	0.17	<0.01	<0.01
TKN	mg/L	-		3.7	0.4		0.53	0.24	^0.50
TOC	mg/L	-	5	26	6	4	3	<1	13
Phenolics	mg/L	0.020	0.002	<0.002	<0.002	0.004	<0.002	0.004	0.004
Alkalinity (as CaCO3)	mg/L	-		25	19	35	13	14	27
Glycols, Total	mg/L	100	<1	<1	2	<1	<1	1	<1
Ammonia (as N)	mg/L	-	0.16	0.2	0.11	0.2	0.25	0.05	0.08
Nitrite (as N)	mg/L	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1.	0.8
Nitrate (as N)	mg/L	-	2.8	3.4	3.2	2	2.6	2.1	3.3
Volatile Organics, Total	mg/L	-	0.002	0.001	0.001	<0.001	0.001	0.002	<0.001
Fecal Coliform	cts/100ml	400	-	-	-	-	-	-	-
Iron	mg/L	-	3.40	16.7	4.97	1.74	0.46	^0.90	0.53
Aluminum	mg/L	-	1.39	11.1	2.37	1.01	0.35	0.82	0.19
Antimony	mg/L	-	<0.04	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04
Arsenic	mg/L	-	<0.05	<0.05	<0.05	<0.04	<0.05	<0..05	<0.05
Boron	mg/L	-	0.01	0.07	<0.01	<0.01	0.02	0.02	<0.01
Barium	mg/L	-	0.02	0.09	0.02	0.01	0.01	<0.01	<0.01
Cadmium	mg/L	-	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Chromium	mg/L	-	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01
Cobalt	mg/L	-	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Copper	mg/L	-	0.02	0.04	0.03	0.02	<0.01	<0.01	<0.01
Manganese	mg/L	-	0.425	1.27	0.471	0.429	0.117	0.097	0.135
Mercury	mg/L	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Molybdenum	mg/L	-	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Nickel	mg/L	-	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Lead	mg/L	-	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Selenium	mg/L	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Silver	mg/L	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silica	mg/L	-	6.06	6.11	6.20	6.4	5.07	4.63	7.02
Vanadium	mg/L	-	0.01	0.08	<0.01	<0.01	<0.01	0.01	<0.01
Zinc	mg/L	-	0.11	0.19	0.13	0.04	0.01	0.03	0.02

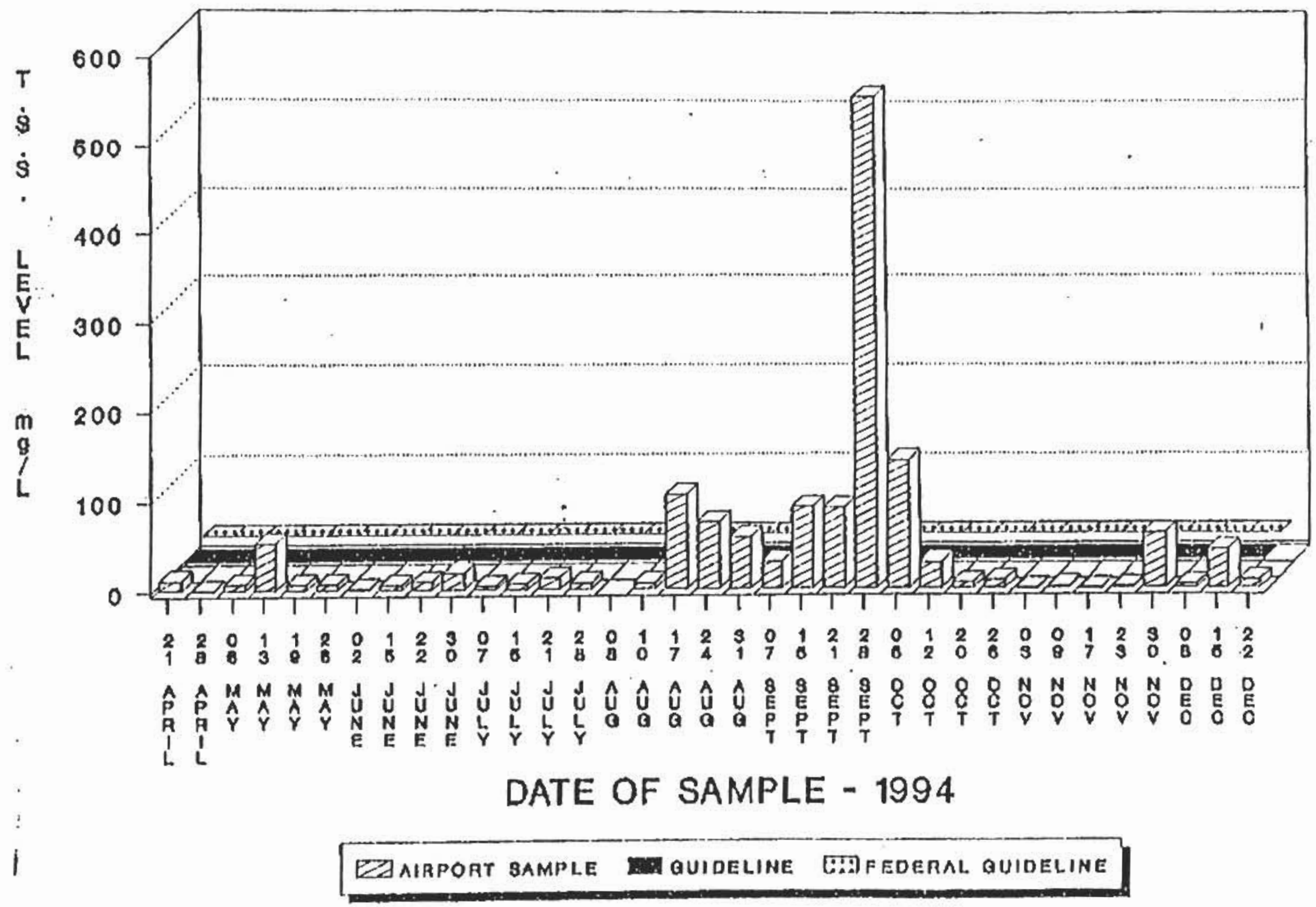
Ganc nt'l Airport Stormwater Monitoring for Period nuary 1, 1994 to December 31, 1994 2/2/95

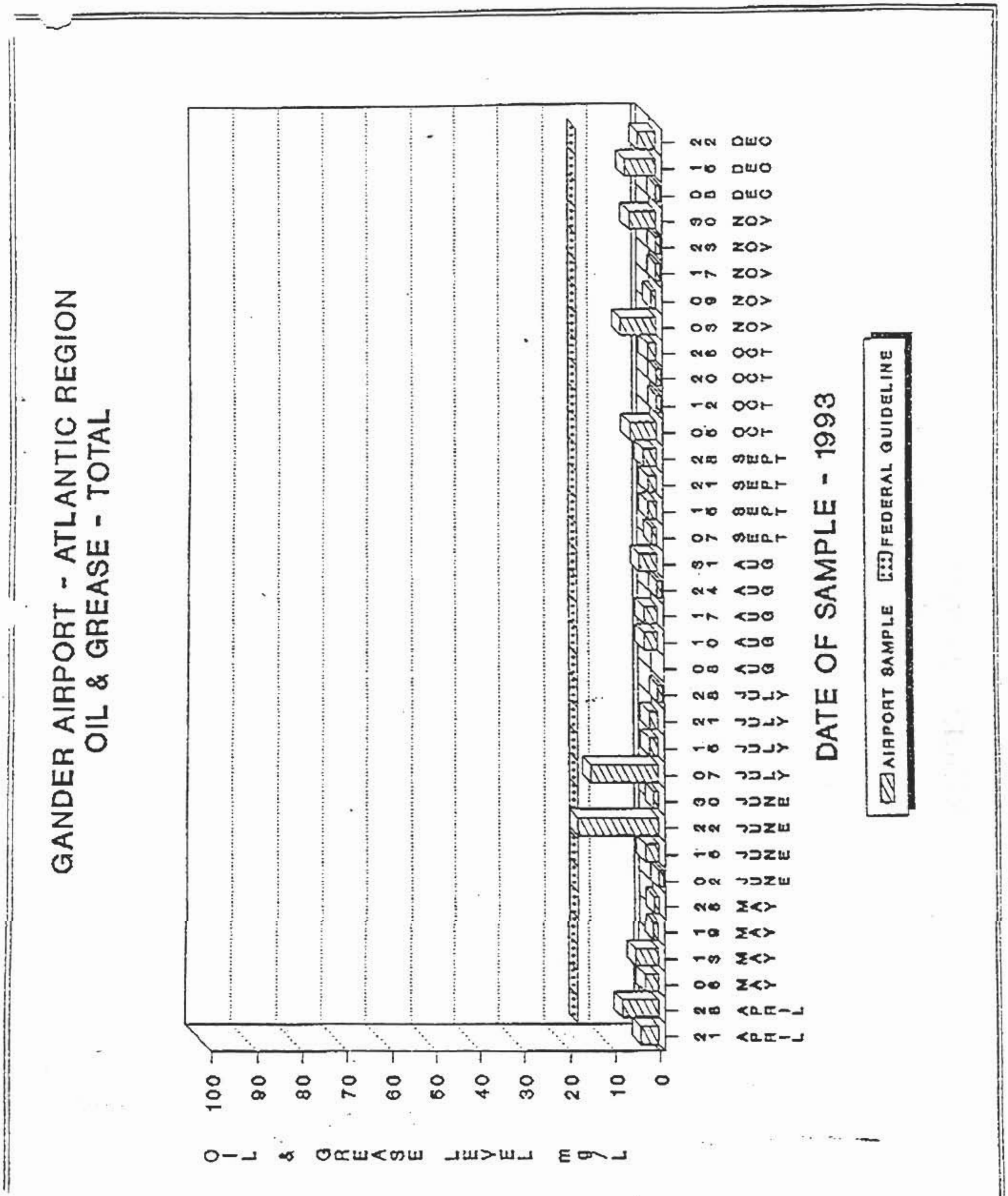
PARAMETERS	Units	FEDERAL GUIDELINES Storm Sewer	RESULTS BY DATE						
Date Collected			Nov. 8/94	Nov. 16/94	Nov. 22/94	Nov. 29.94	Dec. 6/94	Dec. 13/94	Dec. 20/94
Date Received			Nov. 9/94	Nov. 17/94	Nov. 23/94	Nov. 30/94	Dec. 8/94	Dec. 15/94	Dec. 22/94
pH	mg/L	6.0-9.0	7.13	7.46	6.76	7.87	7.01	6.89	7.26
Oil & Grease	mg/L	15	1	<1	<1	6	<1	7	4
BOD (5 day)	mg/L	20	2	2	1	9	2	3	1
Total Suspended Solids (TSS)	mg/L	25	2	<1	1	61	4	43	9
Total Phosphorus (as P)	mg/L	1.0	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
TKN	mg/L	-	0.75	1.56	0.86	0.61	0.41	1.06	2.23
TOC	mg/L	-	3	<1	3	14	10	11	3
Phenolics	mg/L	0.020	0.004	0.003	0.004	<0.002	0.003	<0.002	<0.002
Alkalinity (as CaCO3)	mg/L	-	16	21	28	199	34	31	30
Glycols, Total	mg/L	100	<1	<1	<1	<1	1	<1	<1
Ammonia (as N)	mg/L	-	0.24	0.57	0.51	0.05	<0.03	0.32	0.27
Nitrite (as N)	mg/L	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Nitrate (as N)	mg/L	-	1.9	2.1	1.9	0.5	1.3	1.1	^1.0
Volatile Organics, Total	mg/L	-	0.007	0.001	<0.001	0.002	0.001	0.004	<0.001
Fecal Coliform	cts/100ml	400	-	-	-	-	-	-	-
Iron	mg/L	-	0.35	0.30	0.48	1.54	0.76	1.22	0.88
Aluminum	mg/L	-	0.19	0.13	0.12	0.50	0.14	0.25	0.16
Antimony	mg/L	-	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Arsenic	mg/L	-	<0.05	<0.002	0.054	<0.02	0.008	0.037	0.014
Boron	mg/L	-	<0.01	<0.01	<0.01	0.02	<0.01	0.01	<0.01
Barium	mg/L	-	<0.01	<0.01	<0.01	0.04	<0.01	0.02	0.01
Cadmium	mg/L	-	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Chromium	mg/L	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cobalt	mg/L	-	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Copper	mg/L	-	<0.01	<0.01	0.01	<0.01	<0.01	0.02	0.02
Manganese	mg/L	-	0.085	0.120	0.207	0.072	0.306	0.541	^0.460
Mercury	mg/L	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Molybdenum	mg/L	-	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Nickel	mg/L	-	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Lead	mg/L	-	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Selenium	mg/L	-	<0.1	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Silver	mg/L	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silica	mg/L	-	5.39	6.00	7.05	5.13	7.42	8.22	7.78
Vanadium	mg/L	-	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	mg/L	-	0.05	0.07	0.08	0.04	0.08	^0.10	0.09

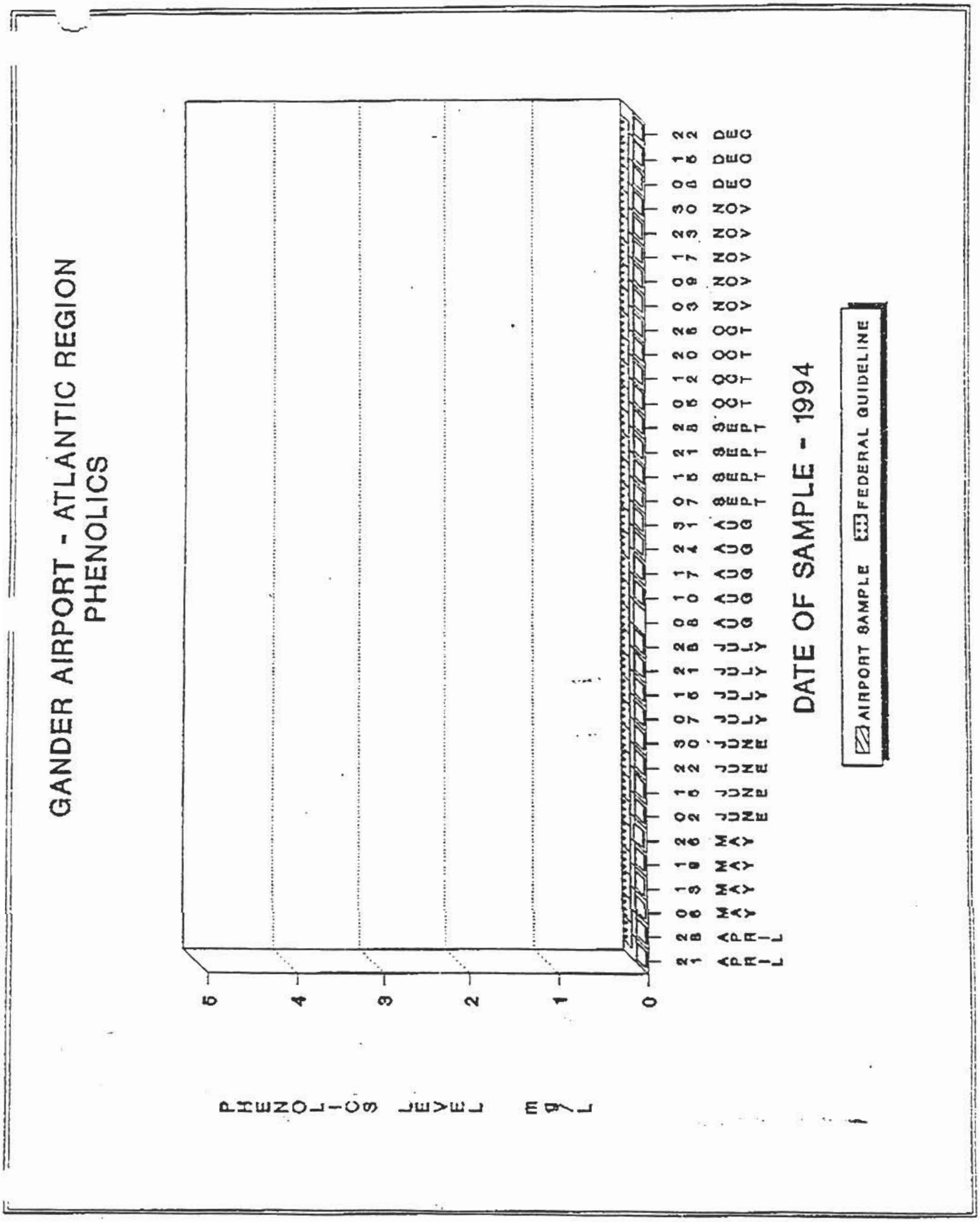

GANDER AIRPORT - ATLANTIC REGION
ACID/BASE TEST FOR pH LEVELS
pH LEVEL RECORDED
0
1
2
3
4
5
6
7
8
9
10
11
12
21 APRIL
28 APRIL
06 MAY
13 MAY
16 MAY
26 MAY
02 JUNE
15 JUNE
22 JUNE
30 JUNE
07 JULY
15 JULY
21 JULY
28 JULY
08 AUG
10 AUG
17 AUG
24 AUG
31 AUG
07 SEPT
16 SEPT
21 SEPT
28 SEPT
05 OCT
12 OCT
20 OCT
26 OCT
03 NOV
09 NOV
17 NOV
23 NOV
30 NOV
08 DEC
15 DEC
22 DEC
DATE OF SAMPLE - 1994
LOWER GUIDELINE
UPPER GUIDELINE
AIRPORT ANALYSIS

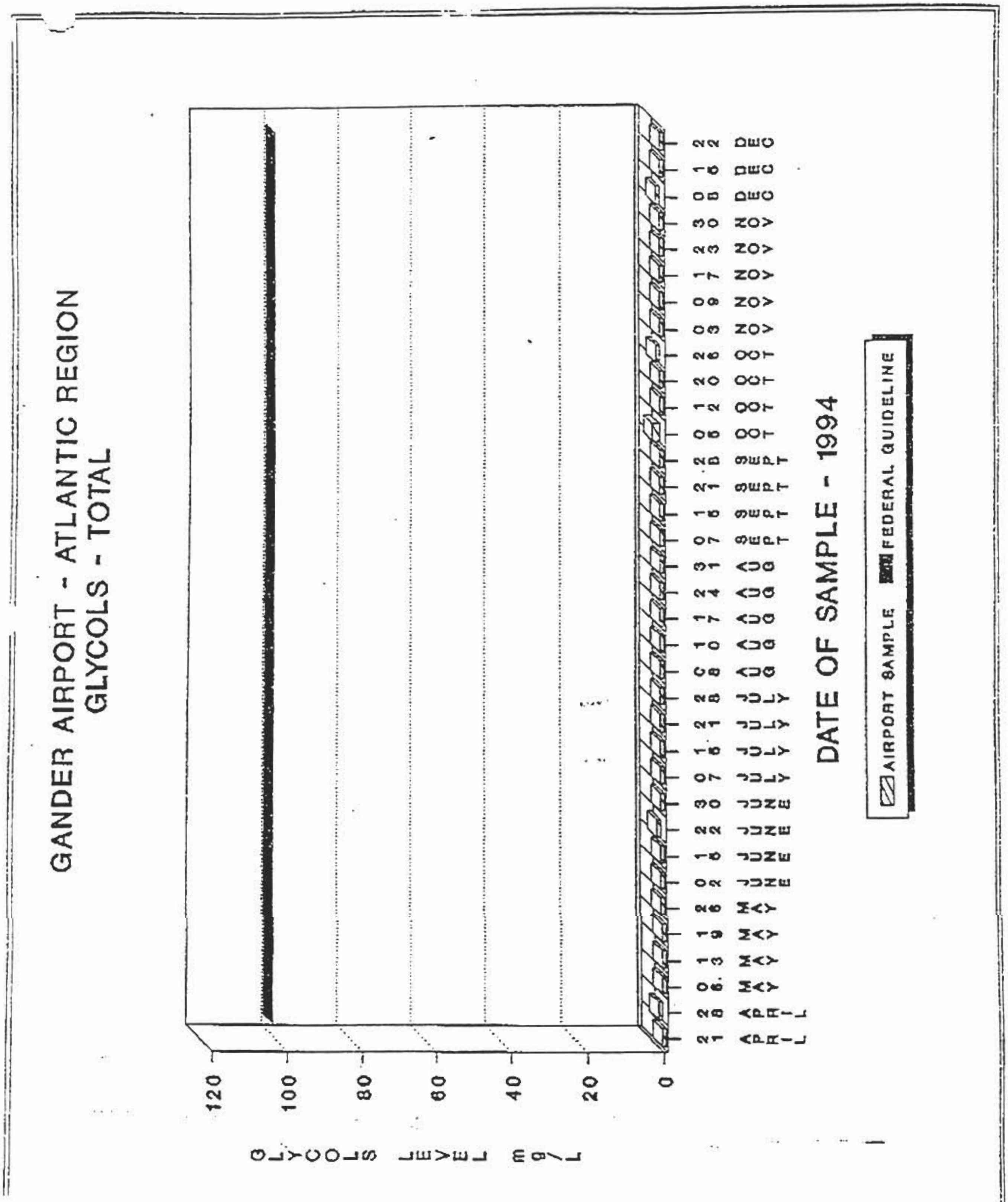

GANDER AIRPORT - ATLANTIC REGION
BIOLOGICAL OXYGEN DEMAND (5-DAY)
B.O.D. LEVEL mg/L
60
40
30
20
10
0
21 APRIL
28 APRIL
08 MAY
13 MAY
19 MAY
26 MAY
02 JUNE
15 JUNE
22 JUNE
30 JUNE
07 JULY
15 JULY
21 JULY
28 JULY
08 AUG
10 AUG
17 AUG
24 AUG
31 AUG
07 SEPT
15 SEPT
21 SEPT
28 SEPT
06 OCT
12 OCT
20 OCT
26 OCT
03 NOV
09 NOV
17 NOV
23 NOV
30 NOV
06 DEC
15 DEC
22 DEC
DATE OF SAMPLE - 1994
AIRPORT SAMPLE
GUIDELINE
FEDERAL GUIDELINE

GANDER AIRPORT - ATLANTIC REGION
TOTAL SUSPENDED SOLIDS




GANDER AIRPORT - ATLANTIC REGION
OIL & GREASE - TOTAL
OIL & GREASE LEVEL mg/L
100
90
80
70
60
50
40
30
20
10
0
DATE OF SAMPLE - 1993
AIRPORT SAMPLE
FEDERAL GUIDELINE


GANDER AIRPORT - ATLANTIC REGION
PHENOLICS
PHENOLICS LEVEL ug/L
0
1
2
3
4
5
21 APRIL
28 APRIL
06 MAY
13 MAY
19 MAY
26 MAY
02 JUNE
15 JUNE
22 JUNE
30 JUNE
07 JULY
15 JULY
21 JULY
28 JULY
03 AUG
10 AUG
17 AUG
24 AUG
31 AUG
07 SEPT
15 SEPT
21 SEPT
28 SEPT
05 OCT
12 OCT
20 OCT
26 OCT
03 NOV
09 NOV
17 NOV
23 NOV
30 NOV
08 DEC
15 DEC
22 DEC
DATE OF SAMPLE - 1994
AIRPORT SAMPLE
FEDERAL GUIDELINE


GANDER AIRPORT - ATLANTIC REGION
GLYCOLS - TOTAL
GLYCOLS LEVEL mg/L
120
100
80
60
40
20
0
21 APRIL
28 APRIL
06 MAY
13 MAY
19 MAY
26 MAY
02 JUNE
16 JUNE
22 JUNE
30 JUNE
07 JULY
15 JULY
21 JULY
28 JULY
05 AUG
10 AUG
17 AUG
24 AUG
31 AUG
07 SEPT
15 SEPT
21 SEPT
28 SEPT
05 OCT
12 OCT
20 OCT
26 OCT
03 NOV
09 NOV
17 NOV
23 NOV
30 NOV
08 DEC
16 DEC
22 DEC
DATE OF SAMPLE - 1994
AIRPORT SAMPLE
FEDERAL GUIDELINE

APPENDIX D
WESTERN BROOK POND

WESTERN BROOK POND

J. KEREKES

Canadian Wildlife Service
Bedford Institute of Oceanography
Dartmouth, Nova Scotia B2Y 4A2

A. LOCATION

Administrative district: *Gros Morne National Park, Newfoundland*
Latitude and longitude: *49 ° 44' N 57° 46' W*
Altitude: *30m above sea-level, cryptodepression 135m*

Fig.1. Western Brook

B. INTRODUCTORY DESCRIPTION OF THE LAKE

The ultraoligotrophic Western Brook Pond in Gros Morne National Park is a fjord lake which, after the retreat of the ice and the rebound of the land, became separated from the sea. It is accessible by a foot trail of about 4.8 km from the main road along the seashore. Although more than 60% of the lake's volume is below sea level, its water is entirely fresh. The scenic grandeur of Western Brook Pond is overwhelming. It is certainly among the most grandiose lakes in Canada's National Parks. The wide western end of the lake is surrounded by relatively flat, low-lying land. In the gorge where the lake narrows and the topography rises suddenly, the lake is confined by steep rock walls 600m high. The sudden change in elevation often contributes to sudden atmospheric turbulences and strong shifting winds which make the lake very hazardous for small crafts. The lake was first surveyed in 1972 with the formation of Gros Morne National Park. Prior to that, only the occasional local person visited the lake. It is now a popular destination for park visitors for hiking, sightseeing and taking a cruise on a small tour boat.

The catchment basin is 7.4 times the size of the lake surface area. The lake receives drainage from more than 20 streams. The majority of these streams fall down or cascade from the highland plateau, draining areas lying over igneous rocks with poorly developed soils. These waters are very dilute, low in calcium, and pH is around 5.5. By contrast, the largest inflow, Stag Brook, at the western end of the lake, carries drainage from sedimentary rocks with higher calcium and pH. The frequent atmospheric turbulences keep the water mass well mixed along the length of the lake basin which is sufficient to maintain near circumneutral pH in the lake.

The lake water is very clear, with values of close to 5 Hazen units, but it may reach 10 Hazen units near the surface owing to the dispersion of coloured water from some of the inflows.

The productivity of the lake is extremely low which is well reflected in the hypolimnetic oxygen depletion rate. The oxygen concentration remains very high throughout the water column during stratification period and the depletion of oxygen is almost unmeasurable. Taking differences in water temperature into account and expressing dissolved oxygen as percent air saturation, the water column remains supersaturated from the surface to the bottom (165m) at the end of summer with dissolved oxygen concentration higher near the bottom than at the surface.

The lake supports Atlantic salmon (both land locked and anadromous) and land locked arctic char. The lake was frequented by small groups of anglers in the 1970's, but after a few years of angling, the catches greatly declined. The lake is now closed to angling.

C. PHYSICAL DIMENSIONS

Surface area: *22.8 km^2*
Volume: *1.65 km^3*
Maximum depth: *165 m*
Mean depth: *72.5m*

Normal range of annual of water level fluctuation:
Lake's water level artificially controlled: *No*

Length of shoreline: *42.5 km*

Residence time: *15.38 yrs*

Catchment area: *171.2 km^2*

D. PHYSIOGRAPHIC FEATURES

D_1 GEOGRAPHICAL

Bathymetric map: *Fig.3*

Names and areas of main islands on the lake: *2.3 hectares*
Outflowing rivers and channels: *(1) Western Brook*

D_2 CLIMATIC

Place name: *Rocky Harbour, 27 km distance [7]*
Period of observation: *1987*

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp ºC	-9.1	-6.4	-4.9	3.7	6.5	11.5	16.4	15.3	11.7	8.1	0.6	-3.5	4.2
Precip. [mm]	105.7	100.0	25.8	71.7	50.7	78.1	32.9	82.4	167.3	159.6	115.3	114.8	1103.9

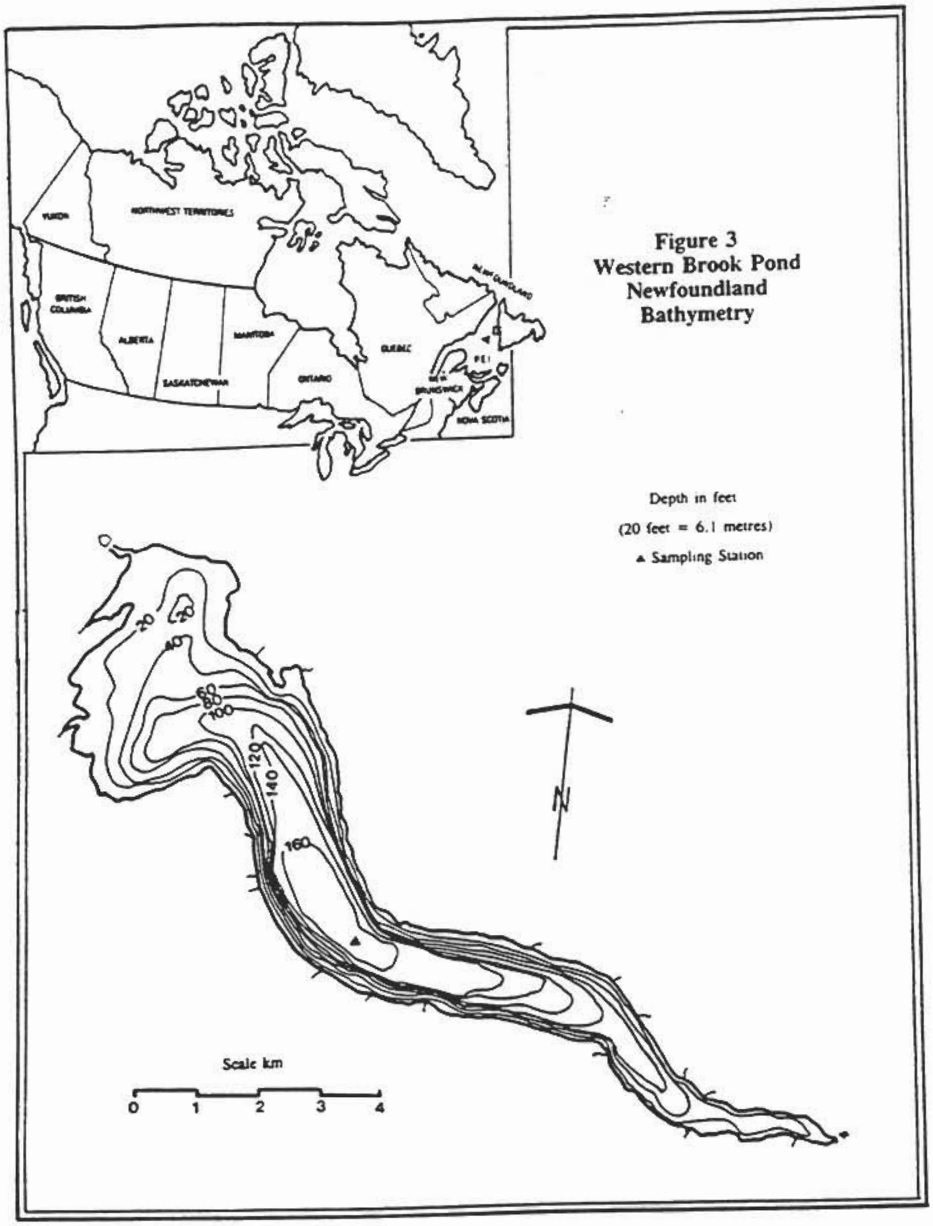


Figure 3
Western Brook Pond
Newfoundland
Bathymetry

Water temperature [°C]:

Station name: **Period of observation:** *July 26, 1972, Aug. 10, 1972, Dec. 11, 1973, Sept. 8, 1982 [5]*

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface												
0m							13.0	13.2	12.0			5.05
10m							12.2	12.9	12.0			5.05
20m							10.6	12.3	11.5			5.05
40m							7.7	7.4	9.5			5.05
60m							5.7	5.8	6.5			5.05
90m							4.9	5.0	5.0			5.05
120m							4.7	4.7	4.5			5.05
150m							4.6	4.5	4.5			5.05

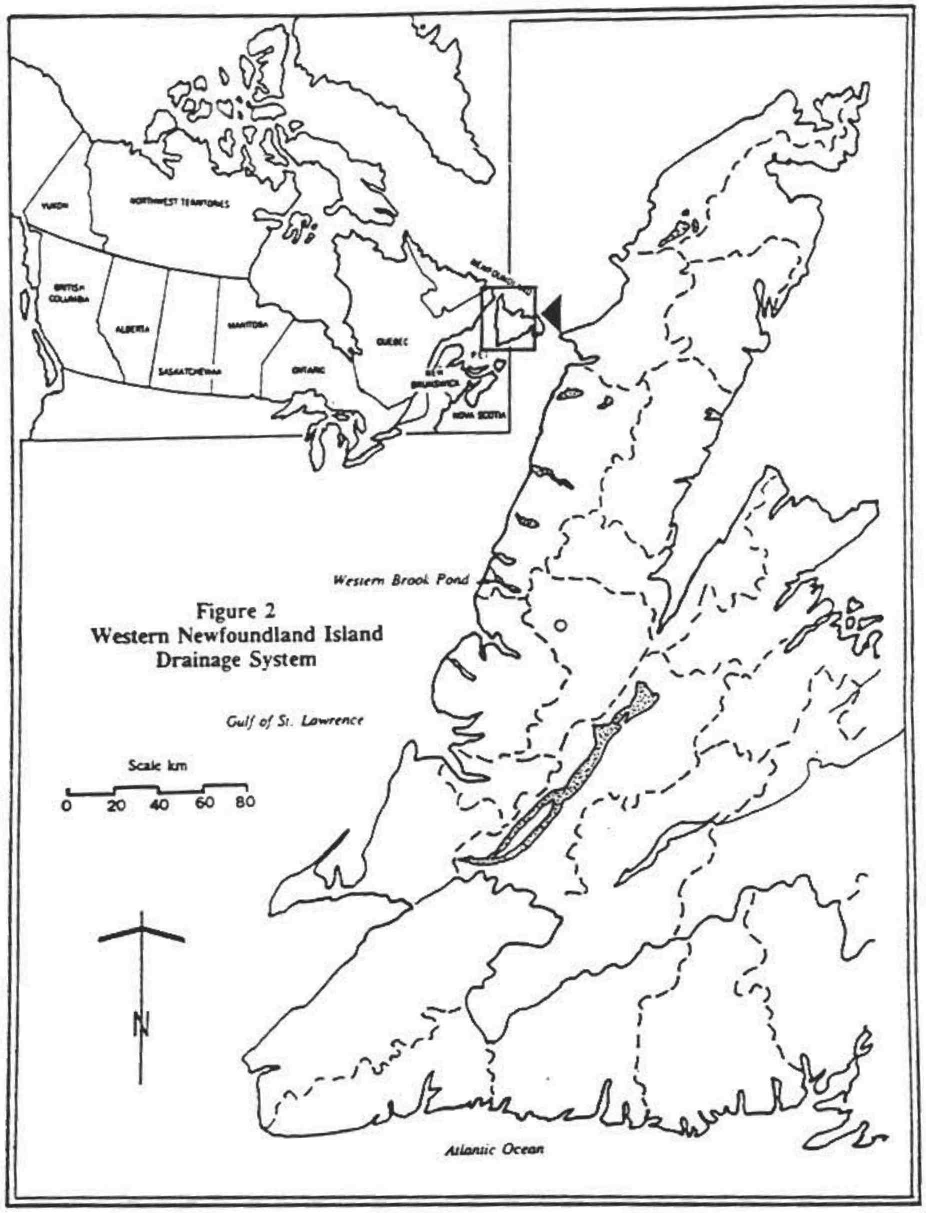


Figure 2
Western Newfoundland Island
Drainage System

Number of hours of bright sunshine per year: *1432 at Stephenville A. [2], 148 km distance.*

Average solar radiation: *11.1 MJ $m^{-2}day^{-1}$ at St. John's West CDA, 475 km distance from lake.*

MEAN DAILY GLOBAL SOLAR RADIATION (MJ m^{-2})

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
4.14	7.08	10.42	13.60	16.54	19.60	19.94	15.72	12.02	6.82	4.11	3.03

E_6 CHLOROPHYLL a CONCENTRATION [µg l^{-1}]:

Station name: *Deep Station* **Period of observation:** *1973* *[5]*

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Aug	Sep	Oct	Dec
0							0.4	0.8				0.3
5							0.4					
10							0.4	0.6				0.3
20							0.4	0.2				0.3
30							0.2	0.2				0.3
40							0.2	0.1				0.3

E_8 TOTAL-P CONCENTRATION [mg l^{-1}]:

Station name: *Deep Station* **Period of observation:** *1972* *[5]*

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Aug	Sep	Oct	Dec
0							2.5	3.1				1.9
30							-	1.6				
100							1.9	1.6				1.9

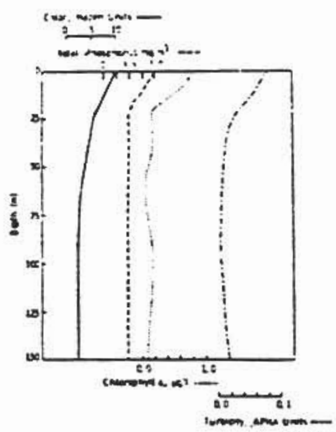


Fig.5. *Vertical distribution of water color, turbidity, total phosphorus and chlorophyll a concentration in Western Brook Pond, August, 1973.* *[6].*

E_9 CHLORIDE ION CONCENTRATION [mg l^{-1}]:

Station name: *Deep Station* **Period of observation:** *July 26, 1972* *[6]*

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
							4.8 mg					

F. BIOLOGICAL FEATURES

Station name and the year of observation: *1973* *[6]*

F_1 FLORA:

Emergent macrophytes: *Typha latifolin, Scirpus validus*

Freezing period: *From February to March (varying greatly from year to year, it may not freeze over in some years)*

Mixing type: *Dimictic*

E. LAKE WATER QUALITY

E_1 TRANSPARENCY [m]:

Station name: *Deep* **Period of observation:** *1972 [5]*

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Secchi meters								10.0	6.5			9.8

E_2 pH:

Station name: *Deep Station* **Period of observation:** *July & August 1972, Dec. 11, 1973, Sept. '82 [5]*

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0m							7.4	7.05	6.7			6.94
10m							7.6	7.0				
20m							7.3					
30m							7.2					
40m							7.4					
100m							7.0	6.9	6.8			6.90
150m							7.2	6.9	6.6			

E_3 SS [mg l^{-1}]: *extremely low*

E_4 DO [mg l^{-1}]:

Station name: *Deep Station* **Period of observation:** *1973. [5]*

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0								10.0				
20								10.4				
30								10.4				
50								12.3				
70								12.5				
90								12.6				
120								12.7				
150								12.8				

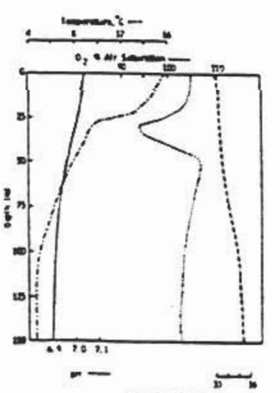


Fig.4. *Vertical distribution of water temperature, dissolved oxygen, pH and specific conductance in Western Brook Pond, August, 1973. [6]*

Floating macrophytes: *Nuphar variegatum*

Submerged macrophytes: *Potamogeton richardsonii*

F_2 FAUNA

Zooplankton: *Kellicottia sp. Gastropus sp., Asplanchna sp., Polyarthra sp., Hexarthra sp., Conochilus sp., Holopedium gibberum, Eurosmina sp., Epischura lacustris, Diaptomus minutus, Diaptomus sp.*

Benthos: *Table 1. List of benthic fauna obtained by a 232 cm^2 Eckman dredge in 1973. [6]*

Pond	Date 1973	No. of grabs	Depth	Organism	No. of individuals
western Brook No. 422-44	9 Aug.	3	3.	Chironomidae	
				Prodiamesa sp.	1
				Chironomus sp.	12
				Stictochironomus sp.	16
				Parametriocnemus sp.	2
				Tanytarsus sp.	7
				Huridinea	
				Helobdella sp.	6
				Mollusca	
				Sphaeridae (too soft to identify)	8
				Trichoptera	
				Drusinus sp.	1
				Oligocneata	
				Lumbriculus sp.	17
	16 Aug.	1	158m	Nematoda	2
				Chironomidae	
				Harnischia sp.	1
				Terrestial insects (exogeneous)	21

continued....

Fish (economically important species marked with asterisks): *Atlantic salmon, Brook trout, Arctic char, Threespine stickleback, American eel*

F_7 NOTES ON THE REMARKABLE CHANGES OF BIOTA IN THE LAKE:

In the 70's the angling catches decreased greatly and the lake is now closed to angling.

G. SOCIO-ECONOMIC CONDITIONS

G_1 LAND USE IN THE CATCHMENT AREA (in 1976):

	Area (km^2)	[%]
	171.2	
Natural landscape		
Woody vegetation "forested"		
Herbaceous vegetation	*The lake and its catchment is in Gros Morne National*	
Swamp "wetland"	*Park*	
Others "lakes & ponds"	*A large proportion of its catchment is "non forested" tundra on the high plateau.*	

G$_2$ INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE (in 1988): *None*

Numbers of domestic animals in the catchment area: *None*

G$_3$ POPULATION IN THE CATCHMENT AREA (IN *1988*): *None*

H. LAKE UTILIZATION

H$_1$ LAKE UTILIZATION:

Sightseeing and tourism *June 2 to Oct. 3*
Number of visitors per year (in 1988): *9200*

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I$_1$ ENHANCED SILTATION

Extent of damage: *None*

I$_2$ TOXIC CONTAMINATION

Present status of toxic contamination: None

I$_3$ EUTROPHICATION

Nuisance caused by eutrophication: *None*

Phosphorous loadings to the lake (in 1973) *[6]*
77.1mg P m^{-2} yr^{-1}

Sources	Industrial	Domestic	Agricultural	Natural	Total
T-N *					
T-P *				*100%*	

I$_4$ ACIDIFICATION

Extent of damage: *Detected but not serious*

Supplementary notes on the recent history of acidification and countermeasures implemented:

The drainage basin receives 10 - 15 kg ha. yr^{-1} wet excess SO_4 deposition which is causing depressed pH levels in the inflows (very low in calcium concentration), draining catchments lying over ingenous rocks on the highland plateau. By contrast inflows at low elevation, such as Stag Brook (Ca 6.1 mg l^{-1},pH 7.4) drain soils lying over sedimentary rock formation. The frequent strong winds mix well the lake water resulting in relatively high concentration of calcium (2.2 mg l^{-1}) and near circumneutral pH along the length of the lake. A regular monitoring program of sampling of surface waters in lakes on the highland plateau is conducted by Environment Canada. Other federal agencies may conduct monitoring at the request or in cooperation with the Canadian Parks Service.

[3] Kerekes, J. and Schwinghamer, P. 1975. Lake Drainage and Morphometry. Aquatic Resources Inventory, Gros Morne National Park, Nfld. Can. Wildlife Service Ms. Report. 155 pp.

[4] Kerekes, J. and Schwinghamer, P. 1975. Hydrographic Maps, Area and Volume Curves. Aquatic Resources Inventory, Gros Morne National Park, Nfld. Canadian Wildlife Service Ms. Report. 101 pp.

[5] Kerekes, J. and Schwinghamer, P. 1975. Selected Limnological Measurements in 43 lakes and 72 streams. Aquatic Resources Inventory, Gros Morne National Park, Nfld. Canadian Wildlife Service Ms. Report. 44 pp.

[6] Kerekes, J. 1978. Limnological Conditions. Aquatic Resources Inventory, Gros Morne National Park, Nfld. Canadian Wildlife Service Ms. Report. 155 pp.

[7] Gros Morne National Park. 1989. Unpublished data.

J. WASTEWATER TREATMENTS

J_1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA:

No major human settlements or activities producing significant pollution (pristine lake environments)

J_2 APPROXIMATE PERCENTAGE DISTRIBUTION OF POLLUTANT LOADS

	Percentage
Non-point sources (natural)	*100%*

L. DEVELOPMENT PLANS

The only existing development is a tour boat service to carry approx. 30 persons. A modest well controlled expansion of the boat service is planned with the construction of a small docking facility at the western end of the lake. A foot trail to encircle the lake, leading to the high plateau is planned. The lake has only foot access and the construction of vehicle access is not contemplated. The Canadian Parks Service intends to maintain the pristine character of Western Brook Pond.

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS

M_1 NATIONAL AND LOCAL LAWS CONCERNED

Names of the laws (the year of legislation):

(1) *National Parks Act (1930, last amendment C48 in 1988)*
(2) *Gros Morne National Park is designated as a World Heritage Site*

Responsible authorities:

(1) *Canadian Parks Service*
(2) *UNESCO designation at the recommendation of the Canadian Government*

Main items of control:

(1) *Canadian Parks Service controls access and all development on the basin of Western Brook Pond which is entirely within the boundaries of Gros Morne National Park.*

M_2 INSTITUTIONAL MEASURES:

(1) *Gros Morne National Park , Rocky Harbour, Nfld.*

M_3 RESEARCH INSTITUTE ENGAGED IN THE LAKE ENVIRONMENT STUDY:

The same as above

N. SOURCES OF INFORMATION

[1] Dadswell, M. J. 1970. A physical and biological survey of the aquatic environment (Freshwater) of the proposed Gros Morne National Park, Newfoundland. Canadian Wildlife Service Ms. Reports. 76 pp.

[2] Canadian Climate Normals. 1951-1980. Environment Canada. Atmospheric Environment Service.

APPENDIX E
PHOTOGRAPHS ILLUSTRATING LAND CONDITIONS

Burned areas may be extremely slow to regenerate.

Regenerating cutover. Note, buffer maintained along the Lake.

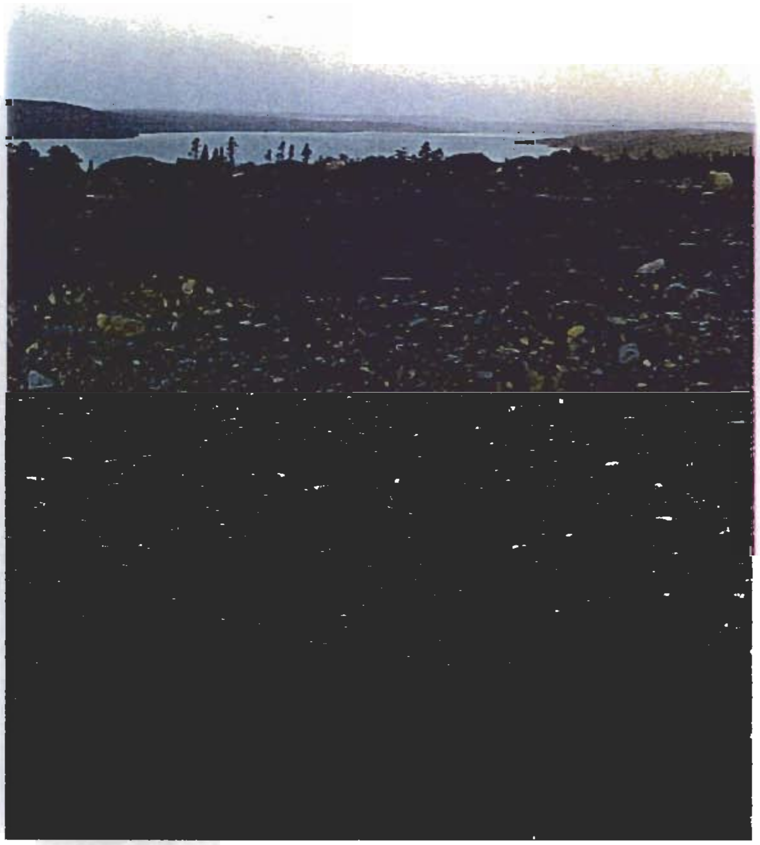
Recent clearcut near Denty's Pit; cut has been planted.

Ditch beside logging road near recent clearcut illustrates sediment load.

Recreation area/ski hill west of the Town of Gander may cause siltation problems at the drinking water intake.

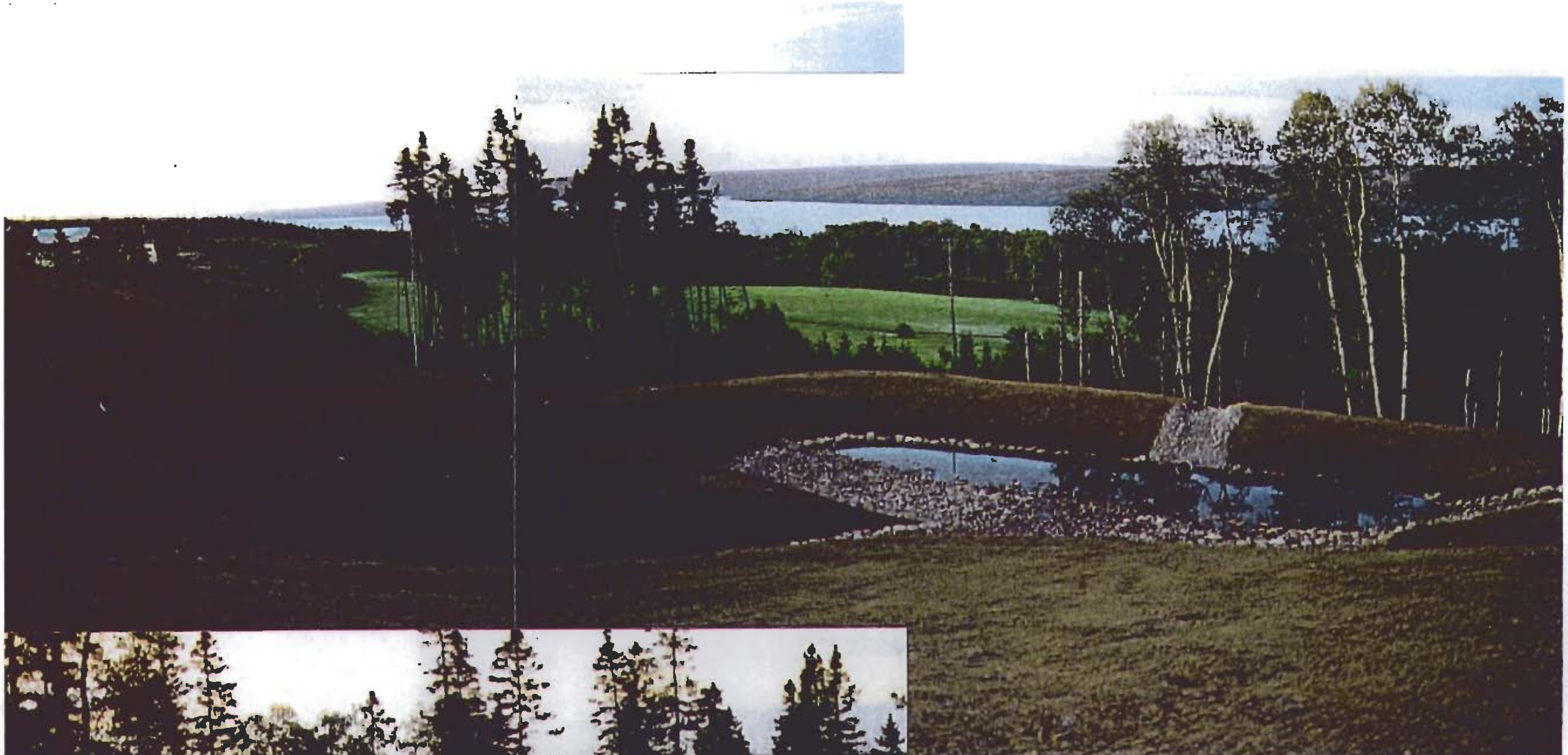
Gravel pit west of Gander.

A large cutover west of Gander (green square is Glenwood Provincial Park).
Cut occured in 1980's-90's; high sediment loads would have resulted.



Land cleared for development.

Golf course expansion on the slopes in Gander.



Control measures for flood control. These measures are the opposite of what should be occurring for erosion and sediment control.

The Town of Gander is clean and well maintained.

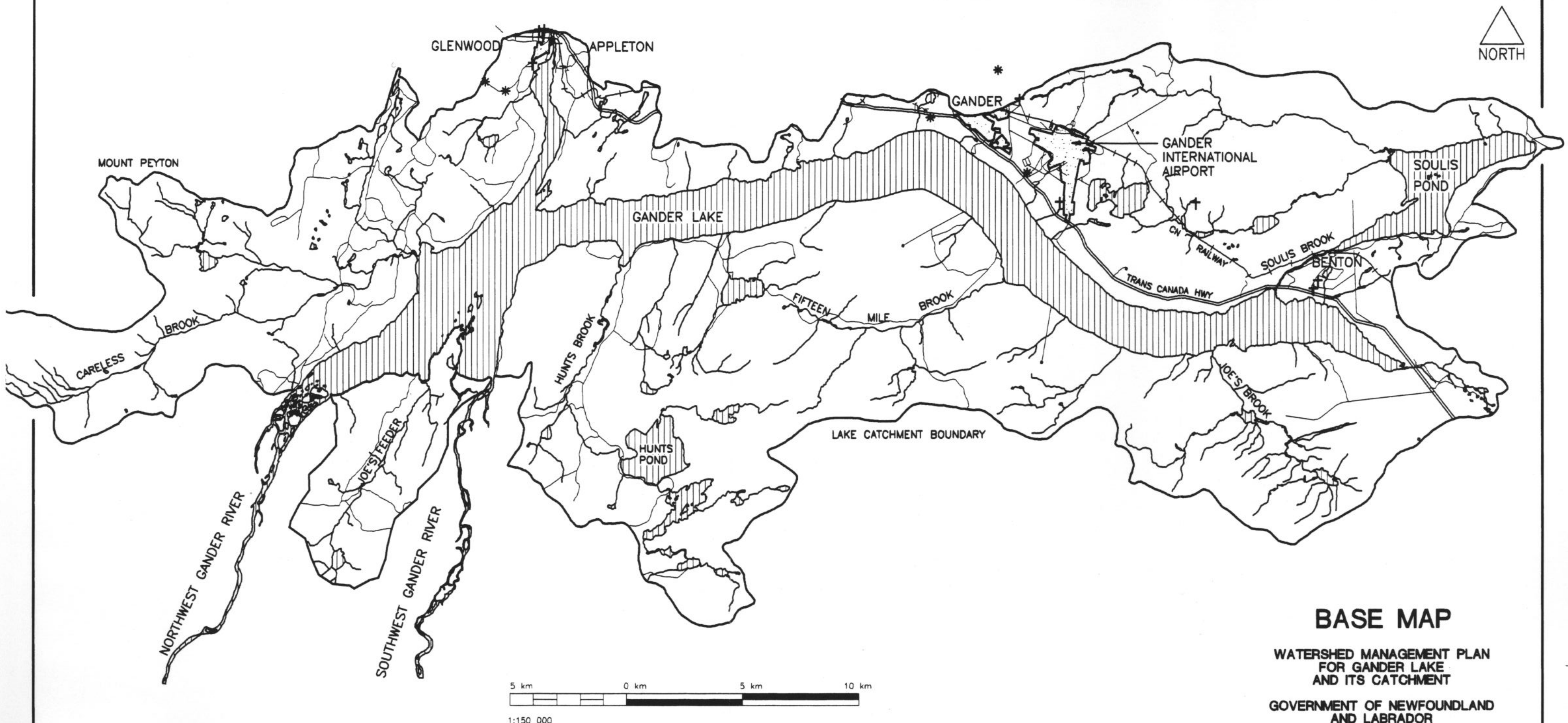
Garbage can contribute TSS and nutrients to urban stormwater.
This is obviously not a big problem in Gander.

Small marina at Little Harbour - unlikely to cause significant water quality problems.

Appleton Marina

Temporary structures on the NW Gander River.

Cottages on the NW Gander River.



BASE MAP

WATERSHED MANAGEMENT PLAN
FOR GANDER LAKE
AND ITS CATCHMENT

GOVERNMENT OF NEWFOUNDLAND
AND LABRADOR
DEPARTMENT OF ENVIRONMENT

DATE
FEBRUARY 1996

EDM
ENVIRONMENTAL
DESIGN AND MANAGEMENT LTD.
Suite 707, 1959 Upper Water Street
Halifax, Nova Scotia B3J 3N2
Phone (902) 425-7900

FIGURE
1.1

* LANDFILL
\+ CEMETERY
· COMMUNICATIONS TOWER

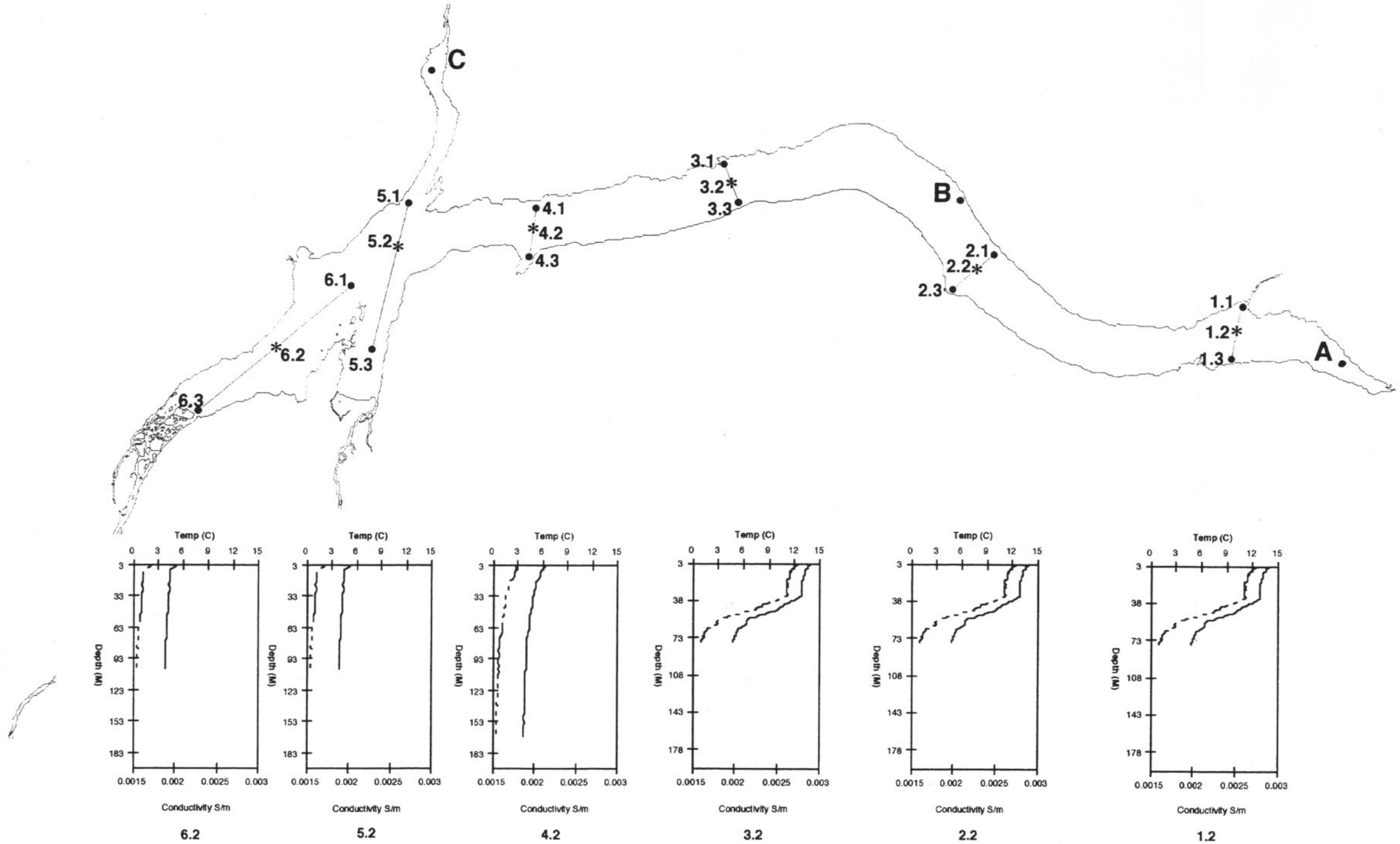
EDM Environmental Design and Management Limited
Watershed Management Plan for Gander Lake and its Catchment
Table 1.3 - Summary of Lake Water Quality Results

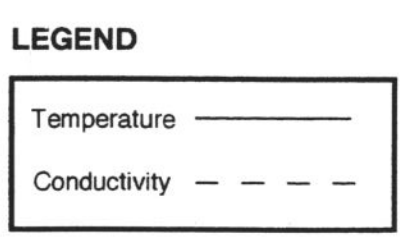
Transect	Location	Sample	Chloride mg/l LOQ .05		Zinc mg/l LOQ .005		Aluminum mg/l LOQ .025		Potassium mg/l LOQ 0.4		Silica mg/l LOQ .05		Alkalinity mg/l LOQ 1.0		pH Units LOQ .01		TDS mg/l LOQ 1		Colour TCU LOQ 1	
			t=1	t=2	t=1	t=2	t=1	t=2	t=1	t=2	t=1	t=2	t=1	t=2	t=1	t=2	t=1	t=2	t=1	t=2
1	Soulis Brook	1.1 a Surface	2.06	2.14	N/D	N/D	0.092	0.076	N/D	N/D	N/T	2.06	6	3	6.18	6.97	13	11	N/D	12
		b 60 m.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		1.2 a Surface	2.11	2.17	N/D	N/D	0.111	0.090	N/D	0.7	N/T	2.07	6	3	6.14	6.96	13	11	5	5
		b 60 m.	2.03	2.13	N/D	N/D	0.087	0.090	0.7	0.8	N/T	2.20	6	3	6.15	6.98	14	11	3	12
		1.3 a Surface	2.03	2.33	0.006	N/D	1.100	0.077	1.1	N/D	N/T	2.07	6	3	6.20	7.02	14	11	N/D	30
		b 60 m.	2.04	N/A*	N/D	N/A*	0.900	N/A*	0.9	N/A*	N/T	N/A*	6	N/A*	6.23	N/A*	14	N/A*	N/D	N/A*
2	Fifteen Mile Brook	2.1 a Surface	2.11	2.21	N/D	N/D	1.200	0.078	1.2	0.6	N/T	2.05	6	3	6.24	6.98	14	11	N/D	26
		b 60 m.	2.04	2.23	0.017	N/D	0.600	0.078	0.6	N/D	N/T	2.19	6	3	6.26	6.89	15	14	N/D	7
		2.2 a Surface	2.04	2.16	N/D	N/D	1.200	0.086	1.2	N/D	N/T	2.06	5	3	6.08	6.95	14	11	3	13
		b 60 m.	2.02	2.17	N/D	N/D	0.500	0.075	0.5	0.6	N/T	2.20	6	3	6.09	6.88	14	11	N/D	22
		2.3 a Surface	2.07	2.13	N/D	N/D	0.900	0.065	0.9	N/D	N/T	2.06	5	3	6.17	6.33	14	11	N/D	10
		b 60 m.	2.03	N/A*	N/D	N/A*	0.800	N/A*	0.8	N/A*	N/T	N/A*	5	N/A*	6.13	N/A*	13	N/A*	N/D	N/A*
3	Marina	3.1 a Surface	1.97	2.19	N/D	N/D	N/D	0.083	N/D	N/D	N/T	2.14	5	3	6.15	6.38	13	12	N/D	24
		b 60 m.	2.00	N/A*	N/D	N/A*	N/D	N/A*	N/D	N/A*	N/T	N/A*	5	N/A*	6.00	N/A*	13	N/A*	N/D	N/A*
		3.2 a Surface	1.99	2.07	0.024	N/D	0.700	0.087	0.7	N/D	N/T	2.08	6	3	6.12	6.42	14	11	N/D	15
		b 60 m.	1.96	2.18	0.008	N/D	0.111	0.097	N/D	N/D	N/T	N/S	6	3	6.08	6.39	13	11	N/D	18
		3.3 a Surface	1.94	2.10	0.006	N/D	0.105	0.092	0.6	N/D	N/T	N/S	6	3	6.19	6.34	13	12	N/D	26
		b 60 m.	1.99	2.22	0.015	N/D	0.091	0.076	0.7	N/D	N/T	2.10	6	3	6.45	6.30	14	11	N/D	3
4	Hunts Cove	4.1 a Surface	1.93	2.14	N/D	N/D	0.062	0.089	N/D	N/D	N/T	2.21	6	3	6.16	6.36	13	11	N/D	25
		b 60 m.	1.98	2.27	0.034	N/D	0.119	0.101	N/D	N/D	N/T	2.10	5	3	6.11	6.25	13	11	N/D	10
		4.2 a Surface	1.92	2.05	N/D	N/D	0.104	0.102	N/D	0.6	N/T	2.20	5	3	6.19	6.62	13	11	N/D	26
		b 60 m.	2.00	2.17	0.018	N/D	0.136	0.086	N/D	0.9	N/T	2.08	5	2	6.13	6.46	13	11	N/D	26
		4.3 a Surface	1.92	2.10	N/D	N/D	0.120	0.079	1.1	1.0	N/T	2.19	5	3	6.17	6.52	14	12	N/D	17
		b 60 m.	1.93	N/A*	0.015	N/A*	0.117	N/A*	0.5	N/A*	N/T	N/A*	6	N/A*	6.19	N/A*	13	N/A*	N/D	N/A*
5	Lukeman to SW Gander R.	5.1 a Surface	6.07	2.07	0.025	N/D	0.080	0.094	1.5	0.4	N/T	2.00	5	3	6.28	6.46	21	11	N/D	19
		b 60 m.	5.91	2.11	0.008	N/D	0.110	0.074	0.7	N/D	N/T	2.08	6	3	6.25	6.46	21	11	N/D	21
		5.2 a Surface	1.97	2.24	0.006	N/D	0.086	0.083	0.8	0.4	N/T	2.19	5	3	6.21	6.47	13	11	N/D	24
		b 60 m.	1.97	2.30	0.009	N/D	0.090	0.075	N/D	0.8	N/T	2.10	6	3	6.15	6.41	13	11	N/D	19
		5.3 a Surface	2.02	2.15	0.006	N/D	0.155	0.083	N/D	N/D	N/T	2.19	5	3	6.16	6.38	13	11	N/D	11
		b 60 m.	2.01	N/A*	N/D	N/A*	0.151	N/A*	0.6	N/A*	N/T	N/A*	5	N/A*	6.15	N/A*	13	N/A*	N/D	N/A*
6	Joe's Feeder	6.1 a Surface	5.95	2.22	0.007	N/D	0.101	0.100	N/D	0.5	N/T	2.10	5	3	6.22	6.33	19	12	N/D	7
		b 60 m.	6.05	2.22	0.017	N/D	0.127	0.093	N/D	N/D	N/T	2.14	5	2	6.21	6.36	20	10	N/D	26
		6.2 a Surface	1.94	2.02	0.012	N/D	0.113	0.084	0.4	N/D	N/T	2.15	5	3	6.27	6.30	13	11	N/D	18
		b 60 m..	6.28	2.17	0.041	N/D	0.119	0.089	1.4	N/D	N/T	2.21	5	3	6.23	6.29	22	11	N/D	22
		6.3 a Surface	1.95	1.95	0.008	N/D	0.098	0.099	N/D	N/D	N/T	2.02	5	3	6.43	6.30	13	11	2	15
		b 60 m.	2.00	N/A*	0.016	N/A*	0.116	N/A*	0.4	N/A*	N/T	N/A*	6	N/A*	6.24	N/A*	14	N/A*	N/D	N/A*
A.	East End	A a Surface	2.07	2.45	0.007	N/D	0.110	0.082	N/D	N/D	N/T	2.15	6	3	6.22	6.38	14	12	N/D	5
		b 60 m.	2.03	N/A*	N/D	N/A*	0.099	N/A*	1.2	N/A*	N/T	N/A*	6	N/A*	6.24	N/A*	14	N/A*	1	N/A*
B.	Pumping Station	B a Surface	2.08	2.11	N/D	N/D	0.115	0.058	1.2	N/D	N/T	2.04	6	3	6.25	7.92	15	11	N/D	30
		b 60 m..	2.00	2.10	N/D	N/D	0.095	0.073	N/D	N/D	N/T	2.09	6	2	6.14	6.89	14	10	N/D	38
C.	The Outflow	C a Surface	2.01	2.07	N/D	N/D	0.078	0.076	1.1	0.9	N/T	2.03	6	3	6.20	7.05	14	11	N/D	33
		b 60 m.	1.95	N/A*	N/D	N/A*	0.090	N/A*	N/D	N/A*	N/T	N/A*	6	N/A*	6.19	N/A*	13	N/A*	N/D	N/A*

Transect	Location	Sample	Total P mg/l LOQ .004		Nitrate mg/l LOQ .02		Total Coliform /100ml LOQ 2		Fecal Coliform /100ml LOQ 2		Chlorophyll a. mg/m3		Secchi Depth (m) Meters		Surface Air Temp Celsius (C)	
			t=1	t=2	t=1	t=2	t=1	t=2	t=1	t=2	t=1	t=2	t=1	t=2	t=1	t=2
1	Soulis Brook	1.1 a Surface	N/D	N/D	0.13	0.18	<2	<20	N/D	10	4.2	1.5	N/T	2.5	19.0	15.8
		b 60 m.	N/A	N/A	N/A	N/A	N/T	N/T	N/T	N/T	N/T	N/T				
		1.2 a Surface	N/D	N/D	0.12	0.28	<2	<20	N/D	10	3.6	1.1	N/T	3.0	19.0	16.1
		b 60 m.	0.026	N/D	0.24	0.18	N/T	N/T	N/T	N/T	N/T	N/T				
		1.3 a Surface	0.012	N/D	0.16	0.28	<2	<20	N/D	<10	1.1	1.3	N/T	2.0	19.0	15.8
		b 60 m.	0.010	N/A*	0.17	N/A*	N/T	N/T	N/T	N/T	N/T	N/T				
2	Fifteen Mile Brook	2.1 a Surface	0.009	N/D	0.12	0.19	<2	<20	N/D	<10	3.8	1.2	N/T	3.0	23.0	16.8
		b 60 m.	0.009	N/D	0.21	0.28	N/T	N/T	N/T	N/T	N/T	N/T				
		2.2 a Surface	0.008	N/D	0.23	0.28	<2	<20	N/D	<10	3.8	1.0	N/T	3.0	23.0	18.7
		b 60 m.	0.007	0.006	0.14	0.28	N/T	N/T	N/T	N/T	N/T	N/T				
		2.3 a Surface	0.006	N/D	0.13	0.28	<2	20	N/D	10	1.7	0.5	N/T	3.0	23.7	17.6
		b 60 m.	0.006	N/A*	0.10	N/A*	N/T	N/T	N/T	N/T	N/T	N/T				
3	Marina	3.1 a Surface	0.006	N/D	0.14	0.28	<2	<20	N/D	<10	1.7	<.1	N/T	3.5	20.9	16.7
		b 60 m.	0.010	N/A*	0.22	N/A*	N/T	N/T	N/T	N/T	N/T	N/T				
		3.2 a Surface	0.011	0.008	0.16	0.19	<2	<20	N/D	<10	4.5	1.9	N/T	3.0	22.8	19.3
		b 60 m.	0.005	N/D	0.27	0.28	N/T	N/T	N/T	N/T	N/T	N/T				
		3.3 a Surface	0.009	N/D	0.21	0.47	<2	<20	N/D	30	1.9	1.0	N/T	3.0	19.3	19.0
		b 60 m.	0.007	N/D	0.26	1.12	N/T	N/T	N/T	N/T	N/T	N/T				
4	Hunts Cove	4.1 a Surface	0.006	0.004	0.17	0.19	<2	<20	N/D	<10	3.5	2.6	N/T	3.0	17.5	17.8
		b 60 m.	0.006	N/D	0.23	0.23	N/T	N/T	N/T	N/T	N/T	N/T				
		4.2 a Surface	0.006	N/D	0.08	0.38	<2	<20	N/D	20	4.9	0.1	N/T	2.8	17.5	17.6
		b 60 m.	0.006	N/D	0.03	0.38	N/T	N/T	N/T	N/T	N/T	N/T				
		4.3 a Surface	0.006	N/D	N/D	0.38	<2	<20	N/D	30	2.0	0.7	N/T	3.0	18.4	18.5
		b 60 m.	0.007	N/A*	0.08	N/A*	N/T	N/T	N/T	N/T	N/T	N/T				
5	Lukeman to SW Gander R.	5.1 a Surface	N/D	N/D	0.19	0.47	2	20	2	<10	1.0	0.2	N/T	3.5	17.0	15.4
		b 60 m.	N/D	N/D	0.16	0.38	N/T	N/T	N/T	N/T	N/T	N/T				
		5.2 a Surface	N/D	N/D	0.15	0.28	<2	N/D		20	2.0	<.1	N/T	3.5	16.7	15.0
		b 60 m.	0.004	N/D	0.11	0.28	N/T	N/T	N/T	N/T	N/T	N/T				
		5.3 a Surface	N/D	N/D	0.29	0.56	<2	<20	N/D	<10	2.4	<.1	N/T	3.5	16.7	17.2
		b 60 m.	N/D	N/A*	0.14	N/A*	N/T	N/T	N/T	N/T	N/T	N/T				
6	Joe's Feeder	6.1 a Surface	0.012	N/D	0.20	0.56	<2	<20	N/D	<10	0.8	<.1	N/T	2.8	13.3	12.4
		b 60 m.	0.011	N/D	N/D	N/D	N/T	N/T	N/T	N/T	N/T	N/T				
		6.2 a Surface	N/D	N/D	0.16	N/D	<2	20	N/D	<10	9.2	<.1	N/T	2.5	13.0	12.2
		b 60 m..	N/D	N/D	0.21	N/D	N/T	N/T	N/T	N/T	N/T	N/T				
		6.3 a Surface	N/D	N/D	0.24	0.19	13	80	5	50	0.7	<.1	N/T	2.5	13.0	13.0
		b 60 m.	0.020	N/A*	0.10	N/A*	N/T	N/T	N/T	N/T	N/T	N/T				
A.	East End	A a Surface	0.009	N/D	0.12	0.28	<2	<20	N/D	<10	3.1	1.6	N/T	3.0	19.0	15.0
		b 60 m.	0.013	N/A*	0.23	N/A*	N/T	N/T	N/T	N/T	N/T	N/T				
B.	Pumping Station	B a Surface	0.006	N/D	0.13	N/D	<2	<20	N/D	<10	0.9	1.5	N/T	3.0	23.0	17.0
		b 60 m..	0.006	0.015	0.25	N/D	N/T	N/T	N/T	N/T	N/T	N/T				
C.	The Outflow	C a Surface	0.006	N/D	0.17	0.18	<2	<20	N/D	<10	3.6	1.3	N/T	3.0	N/A	N/A
		b 60 m.	0.006	N/A*	0.02	N/A*	N/T	N/T	N/T	N/T	N/T	N/T				

LEGEND

N/A - Not Applicable (60 Metres Does Not Exist)
N/A* - Sampling Station Moved Closer to Shore
N/D - Not Detected
N/T - Not Taken
N/S - Sample Not Sufficent

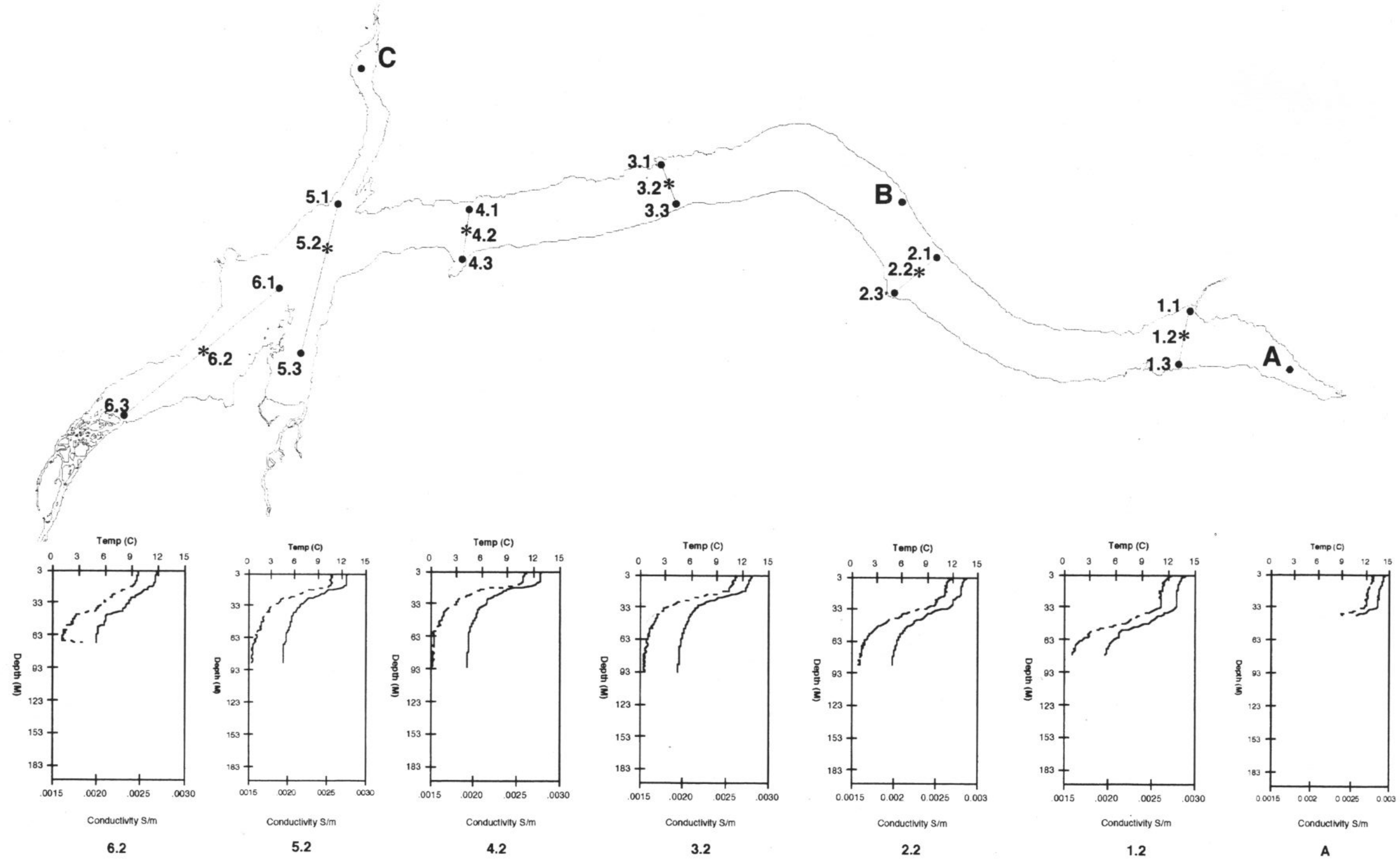




LAKE TEMPERATURE AND CONDUCTIVITY PROFILES
June 1995

Watershed Management Plan for Gander Lake and its Catchment

Figure1.5a



LEGEND

Temperature ————

Conductivity – – – –

LAKE TEMPERATURE AND CONDUCTIVITY PROFILES
September 1995

Watershed Management Plan for Gander Lake and its Catchment

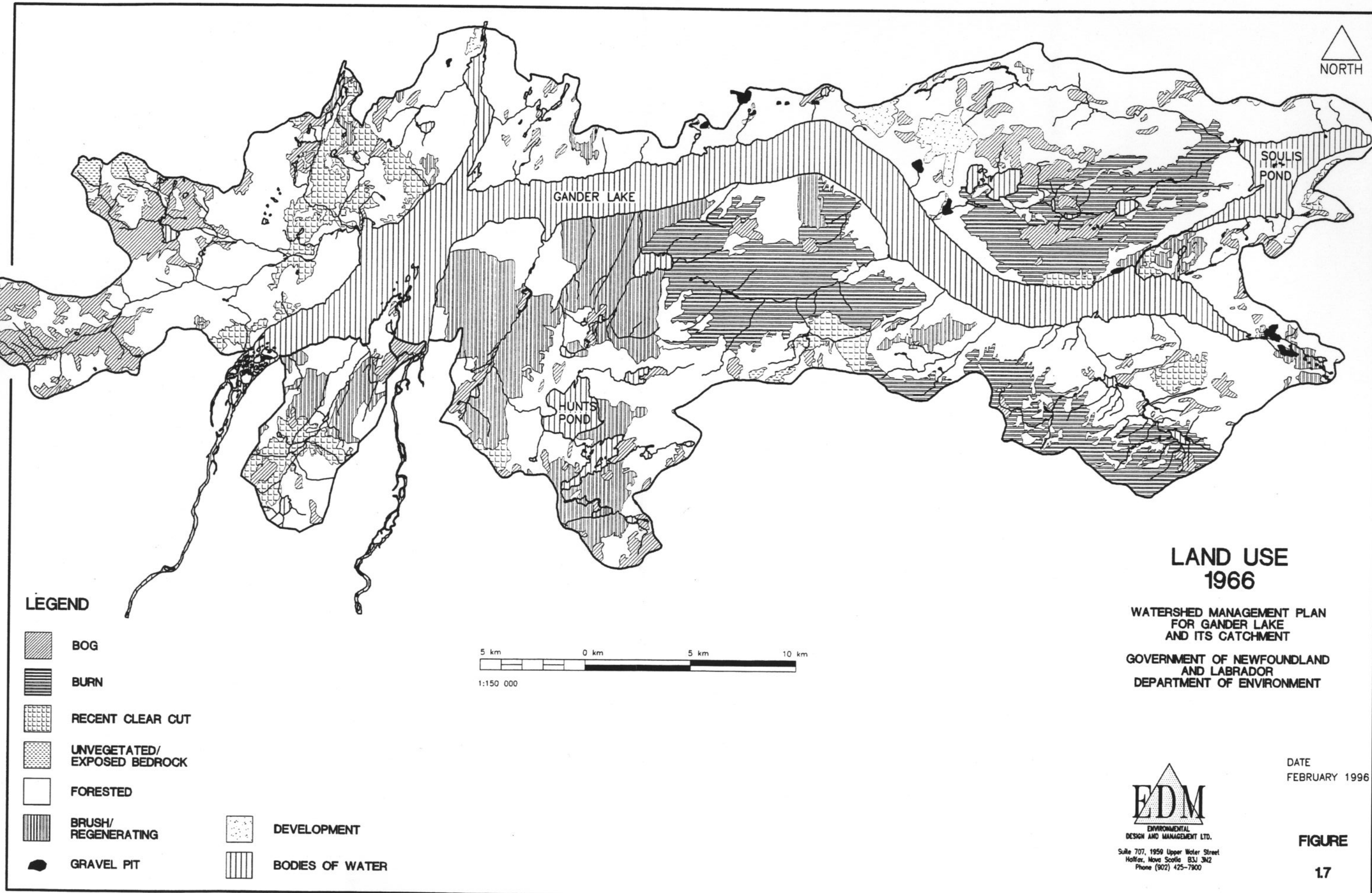
Figure1.5b

Figure 1.6 a: Summary Time Line of Land and Lake Use and Related Data

YEAR	1936	1941	1946	1951	1956	1961	1966 (MAP)
LAND AND LAKE USE TYPE							
Forestry	•no commercial harvesting			•large cutover Hunts Brook			•extensive forest cutting began
Urban Development	•railroad	•airport construction		•new population in temporary housing at Airport	•new Town of Gander & Trans Canada Highway		•hospital constructed
Agriculture	•sustenance only		•Wareham Sod and Hay Farm, near Benton				
Mining	•none noted	•local aggregate to build airport			•gravel extraction to build Town & TCH		
Lake Use				• logging camps on Gillinghams Pond, Fifteen Mile Brook, and Soulis Brook		•cottages on west shore of Gander Lake from Lukeman's Head to Long Island	•squatters on SW Gander River
				•trickling filter sewage treatment system at airport drains into Soulis Pond			
Other Related Events						•major forest fire, both sides of TCH, east of the Town of Gander	
DATA DESCRIPTION							
Census Data							
Gander		603		4780		5725	7183
Glenwood							
Appleton							
Benton							
Total for Catchment Area		**603**		**4780**		**5725**	**7183**
Black & White Aerial Photography							Complete Coverage 1: 50000
Orthophoto Maps							
Colour Infared Aerial Photography							
Colour Aerial Photography							
Hydrometric Station Data							
Gander River at Big Chute				Gander River Big Chute, 1949-Present			
Northwest Gander							
Southwest Gander							
Water Quality Data							
Gander River at Glenwood							
Gander River at 0004							
Gander River at Bay d'Espoir Highway							
Gander River at Appleton							
Airport Ditch Discharge Data							

Figure 1.6 b: Summary Time Line of Land and Lake Use and Related Data

LAND AND LAKE USE TYPE	1971	1976	1981	1986	1991 (MAP)	1996	Proposed Future
Forestry					•silviculture programs	•finished cutting at Denty's Pit, east end	•large cut, Fifteen Mile Brook
Urban Development			•golf course first 3 holes		•golf course upgraded to 9 holes		•golf course to18 holes, highway by-pass, recreation between TCH and Lake
Agriculture			•first crop at Provincial potato seed farm 15 acres/yr ongoing	•first fur farm developed	•2 new fur farms added		•proposed Pelly Farm
Mining		•3-4000 m3 gravel/year extracted at east end of Gander Lake		•Twin Ponds area active		•active near Glenwood and Appleton	•antimony mine, North West Gander River •gravel for local urban uses only
Lake Use	•commercial outfitting lodge mouth of NW Gander River		•many cottages between of NW and SW	•busses along NW Gander River	•cottages around Joe's Feeder		• cottage management on NW Gander River • ad hoc development on SW Gander River, Soulis Pond, and Fifteen Mile Brook
	•new sewage treatment plant to Soulis Pond		•new water pumphouse commissioned on Gander Lake				
Other Related Events		•Spruce Budworm infestation killed many Balsam Fir in the area			AERO air crash on north Lake edge		
DATA DESCRIPTION							
Census Data							
Gander	7880	9301	10404	10205	10339		
Glenwood	979	1128	1129	1035	984		
Appleton	347	342	420	500	526		
Benton	199	279	275	190	188		
Total for Catchment Area	**9405**	**11050**	**12228**	**11930**	**12037**		
Black & White Aerial Photography							
Orthophoto Maps		complete coverage, 1:12500					
Colour Infared Aerial Photography			incomplete coverage, 1:40000				
Colour Aerial Photography					complete coverage, 1:12,500		
Hydrometric Station Data Gander River at Big Chute Northwest Gander Southwest Gander				NW Gander, 1983-Present	SW Gander 1987-Present		
Water Quality Data Gander River at Big Chute Gander River at 0004 Gander River at Bay d'Espoir Highway Gander River at Appleton	Gander River at Glenwood, 1968-1978				Gander River 0004, 1986-1989 Gander River Bay deEspoir, 1986-1994 Gander River Appleton, 1989-1994		
Airport Ditch Discharge Data							



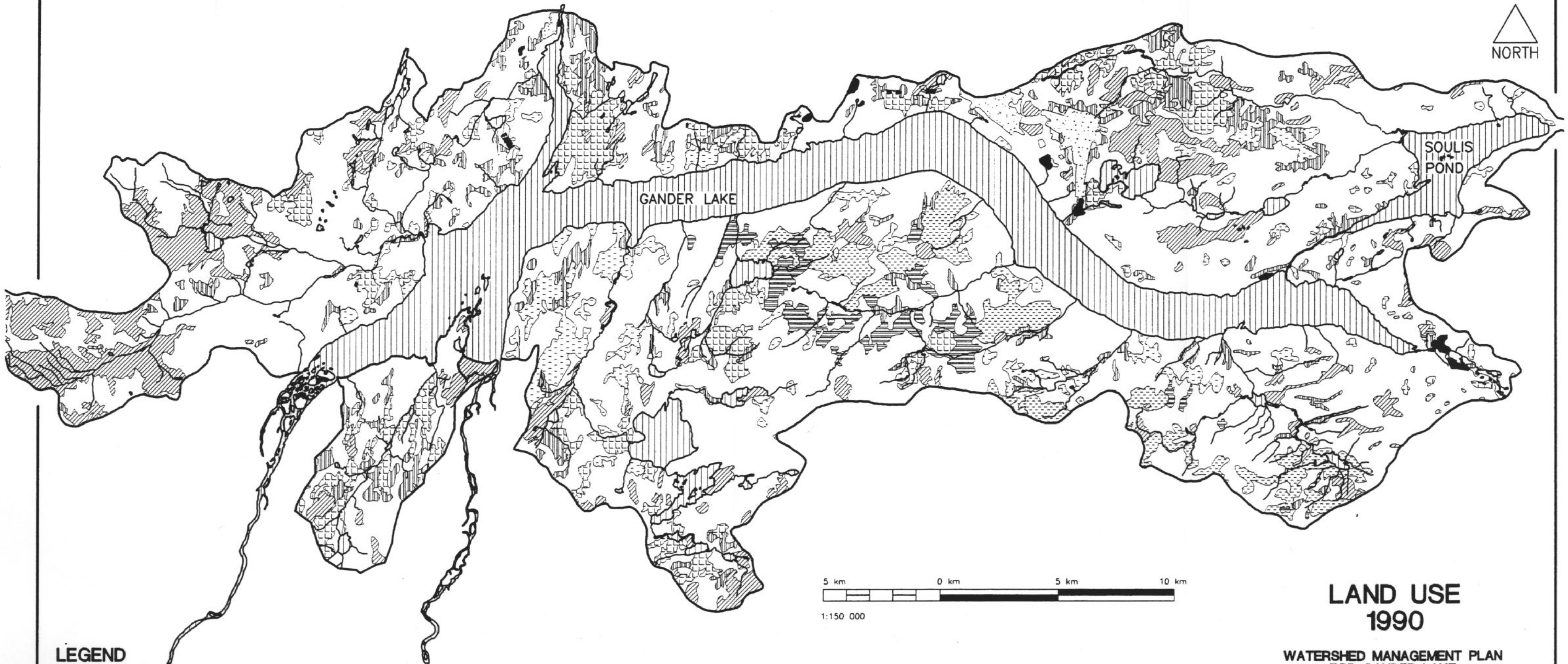
LAND USE 1966

WATERSHED MANAGEMENT PLAN
FOR GANDER LAKE
AND ITS CATCHMENT

GOVERNMENT OF NEWFOUNDLAND
AND LABRADOR
DEPARTMENT OF ENVIRONMENT

DATE
FEBRUARY 1996

FIGURE
17



LEGEND

- BLOWDOWN
- BOG
- LAND CLEARED FOR DEVELOPMENT
- RECENT CLEAR CUTS
- BURN
- DEVELOPMENT
- UNVEGETATED / EXPOSED BEDROCK
- BRUSH / REGENERATING
- GRAVEL PIT
- FORESTED
- BODIES OF WATER

LAND USE 1990

WATERSHED MANAGEMENT PLAN
FOR GANDER LAKE
AND ITS CATCHMENT

GOVERNMENT OF NEWFOUNDLAND
AND LABRADOR
DEPARTMENT OF ENVIRONMENT

EDM
ENVIRONMENTAL
DESIGN AND MANAGEMENT LTD.
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Phone (902) 425-7900

DATE
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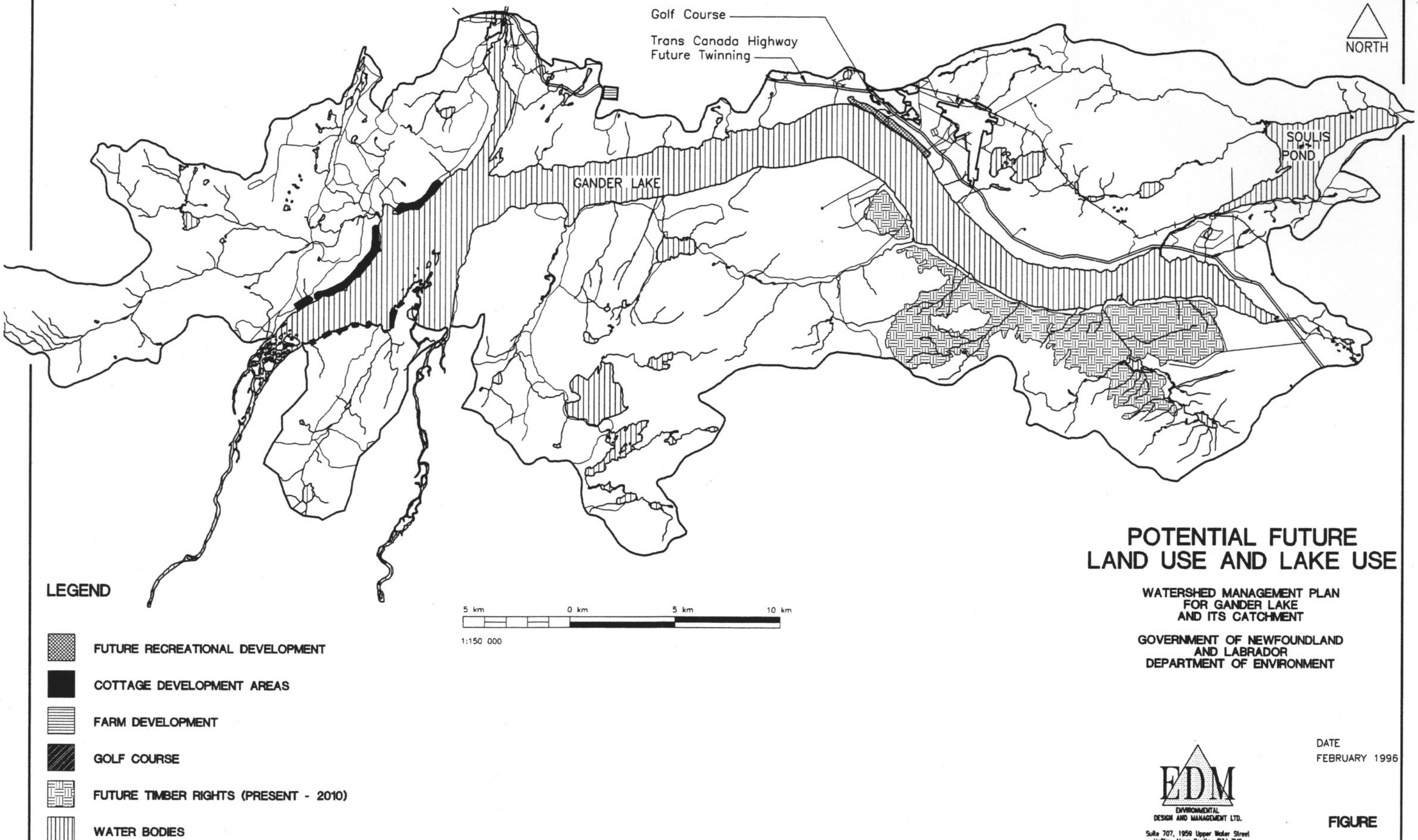
FIGURE
1.8



POTENTIAL FUTURE LAND USE AND LAKE USE

WATERSHED MANAGEMENT PLAN
FOR GANDER LAKE
AND ITS CATCHMENT

GOVERNMENT OF NEWFOUNDLAND
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FIGURE

1.9

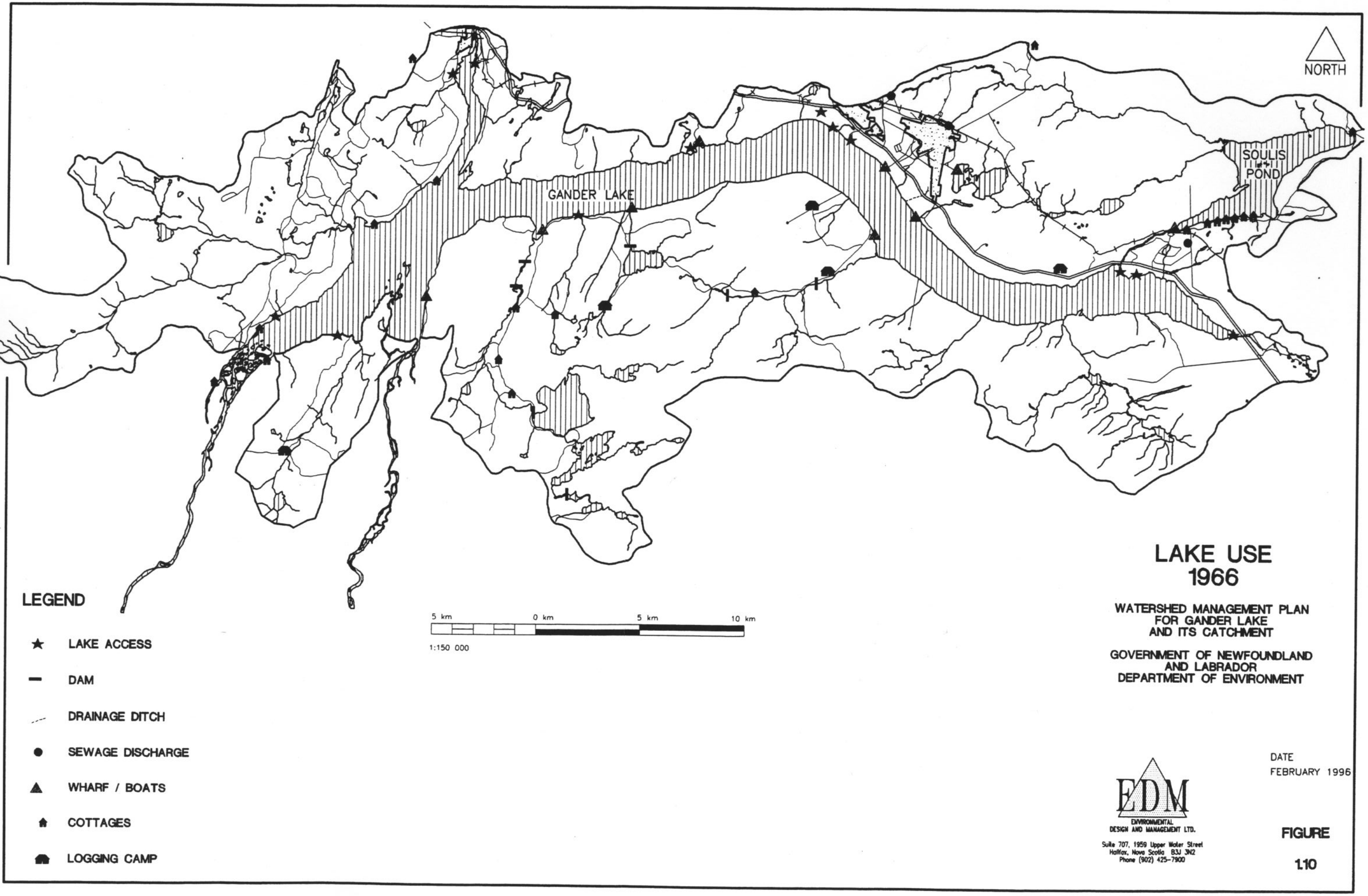
NORTH
GANDER LAKE
SOULIS POND
LEGEND
LAKE ACCESS
DAM
DRAINAGE DITCH
SEWAGE DISCHARGE
WHARF / BOATS
COTTAGES
LOGGING CAMP
5 km
0 km
5 km
10 km
1:150 000
LAKE USE
1966
WATERSHED MANAGEMENT PLAN
FOR GANDER LAKE
AND ITS CATCHMENT
GOVERNMENT OF NEWFOUNDLAND
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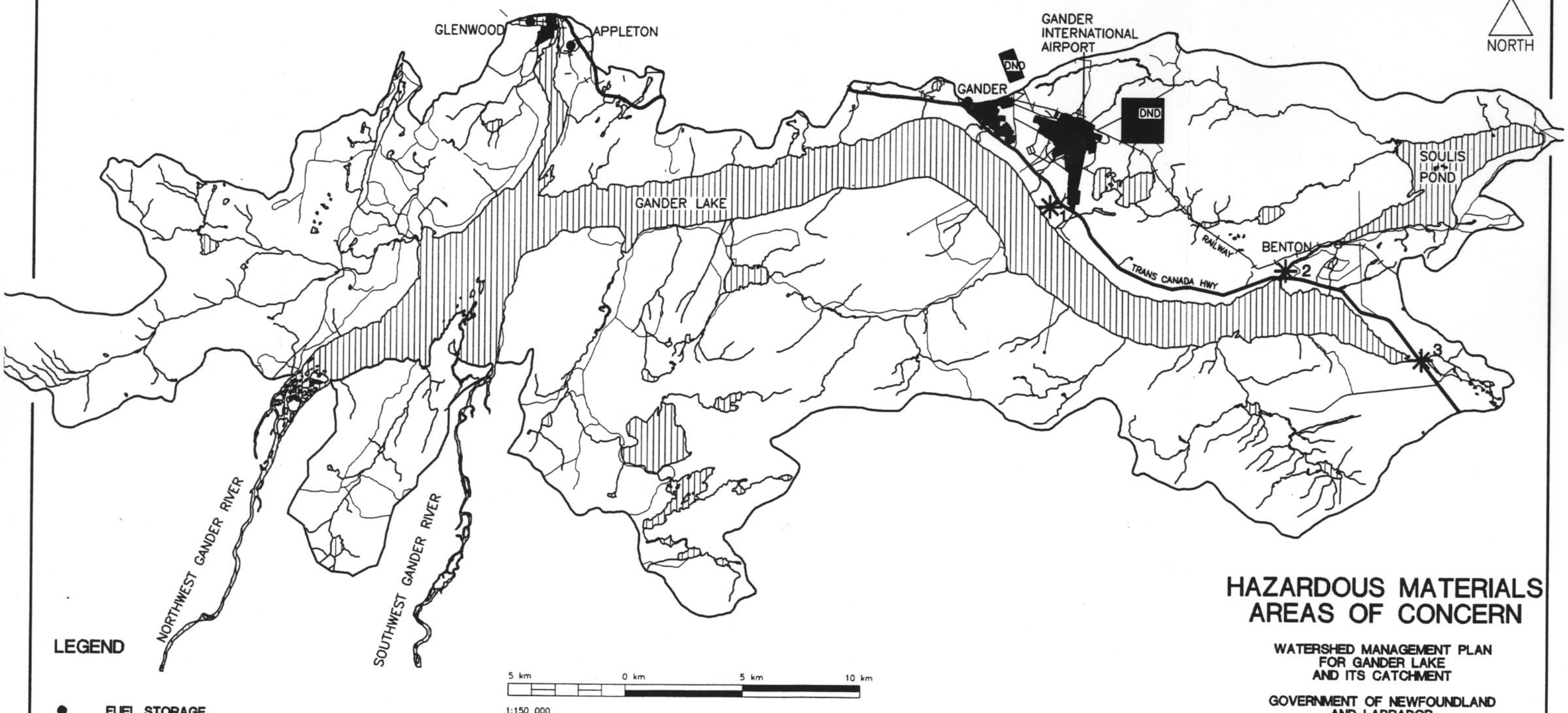
FIGURE
1.10



LEGEND

● FUEL STORAGE

AREAS OF CONCERN

✱1 AIRPORT DRAINAGE DITCH

✱2 SOULIS BROOK BRIDGE

✱3 PROXIMITY TO LAKE

HAZARDOUS MATERIALS AREAS OF CONCERN

WATERSHED MANAGEMENT PLAN FOR GANDER LAKE AND ITS CATCHMENT

GOVERNMENT OF NEWFOUNDLAND AND LABRADOR DEPARTMENT OF ENVIRONMENT

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FIGURE
1.12

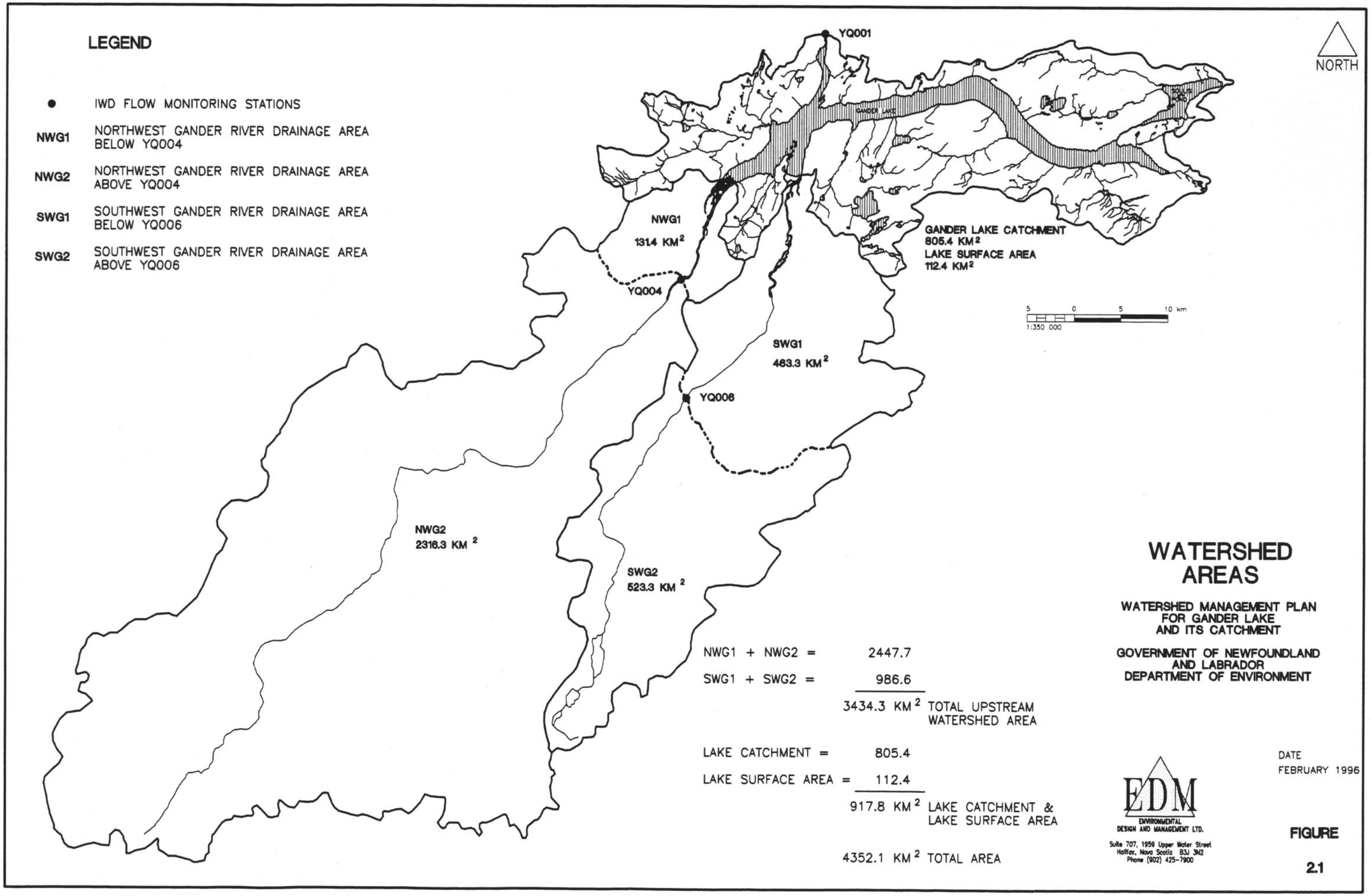
LEGEND
● IWD FLOW MONITORING STATIONS
NWG1 NORTHWEST GANDER RIVER DRAINAGE AREA BELOW YQ004
NWG2 NORTHWEST GANDER RIVER DRAINAGE AREA ABOVE YQ004
SWG1 SOUTHWEST GANDER RIVER DRAINAGE AREA BELOW YQ006
SWG2 SOUTHWEST GANDER RIVER DRAINAGE AREA ABOVE YQ006
YQ001
GANDER LAKE
GANDER LAKE CATCHMENT
805.4 KM²
LAKE SURFACE AREA
112.4 KM²
NWG1
131.4 KM²
YQ004
SWG1
463.3 KM²
YQ006
NWG2
2316.3 KM²
SWG2
523.3 KM²
5 0 5 10 km
1:350 000
NORTH
NWG1 + NWG2 = 2447.7
SWG1 + SWG2 = 986.6
3434.3 KM² TOTAL UPSTREAM WATERSHED AREA
LAKE CATCHMENT = 805.4
LAKE SURFACE AREA = 112.4
917.8 KM² LAKE CATCHMENT & LAKE SURFACE AREA
4352.1 KM² TOTAL AREA
WATERSHED AREAS
WATERSHED MANAGEMENT PLAN FOR GANDER LAKE AND ITS CATCHMENT
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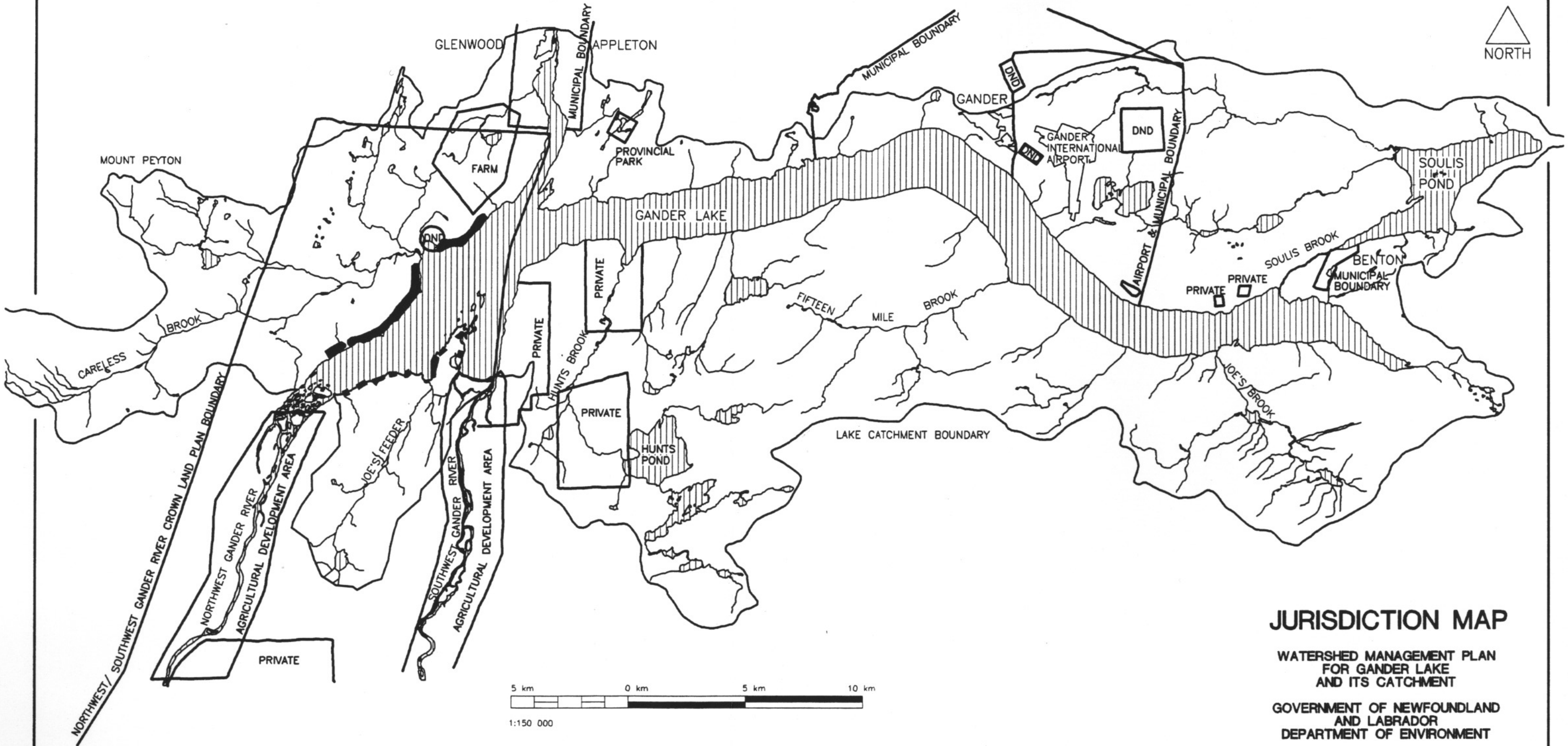
FIGURE
2.1



■ PROPOSED COTTAGE DEVELOPMENT AREAS

JURISDICTION MAP

WATERSHED MANAGEMENT PLAN
FOR GANDER LAKE
AND ITS CATCHMENT

GOVERNMENT OF NEWFOUNDLAND
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FIGURE
3.9

EDM Environmental Design and Management Limited
Watershed Management Plan for Gander Lake and its Catchment
Table 1.3 - Summary of Lake Water Quality Results

Transect	Location	Sample			Chloride t=1	Chloride t=2	Zinc t=1	Zinc t=2	Aluminum t=1	Aluminum t=2	Potassium t=1	Potassium t=2	Silica t=1	Silica t=2	Alkalinity t=1	Alkalinity t=2	pH t=1	pH t=2	TDS t=1	TDS t=2
				Variable	Chloride		Zinc		Aluminum		Potassium		Silica		Alkalinity		pH		TDS	
				Units	mg/l		mg/l		mg/l		mg/l		mg/l		mg/l		Units		mg/l	
				LOQ	.05		.005		.025		0.4		.05		1.0		.01		1	
1	Soulis Brook	1.1	a	Surface	2.06	2.14	N/D	N/D	0.092	0.076	N/D	N/D	N/T	2.06	6	3	6.18	6.97	13	11
			b	60 m.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		1.2	a	Surface	2.11	2.17	N/D	N/D	0.111	0.090	N/D	0.7	N/T	2.07	6	3	6.14	6.96	13	11
			b	60 m.	2.03	2.13	N/D	N/D	0.087	0.090	0.7	0.8	N/T	2.20	6	3	6.15	6.98	14	11
		1.3	a	Surface	2.03	2.33	0.006	N/D	1.100	0.077	1.1	N/D	N/T	2.07	6	3	6.20	7.02	14	11
			b	60 m.	2.04	N/A*	N/D	N/A*	0.900	N/A*	0.9	N/A*	N/T	N/A*	6	N/A*	6.23	N/A*	14	N/A*
2	Fifteen Mile Brook	2.1	a	Surface	2.11	2.21	N/D	N/D	1.200	0.078	1.2	0.6	N/T	2.05	6	3	6.24	6.98	14	11
			b	60 m.	2.04	2.23	0.017	N/D	0.600	0.078	0.6	N/D	N/T	2.19	6	3	6.26	6.89	15	14
		2.2	a	Surface	2.04	2.16	N/D	N/D	1.200	0.086	1.2	N/D	N/T	2.06	5	3	6.08	6.95	14	11
			b	60 m.	2.02	2.17	N/D	N/D	0.500	0.075	0.5	0.6	N/T	2.20	6	3	6.09	6.88	14	11
		2.3	a	Surface	2.07	2.13	N/D	N/D	0.900	0.065	0.9	N/D	N/T	2.06	5	3	6.17	6.33	14	11
			b	60 m.	2.03	N/A*	N/D	N/A*	0.800	N/A*	0.8	N/A*	N/T	N/A*	5	N/A*	6.13	N/A*	13	N/A*
3	Marina	3.1	a	Surface	1.97	2.19	N/D	N/D	N/D	0.083	N/D	N/D	N/T	2.14	5	3	6.15	6.38	13	12
			b	60 m.	2.00	N/A*	N/D	N/A*	N/D	N/A*	N/D	N/A*	N/T	N/A*	5	N/A*	6.00	N/A*	13	N/A*
		3.2	a	Surface	1.99	2.07	0.024	N/D	0.700	0.087	0.7	N/D	N/T	2.08	6	3	6.12	6.42	14	11
			b	60 m.	1.96	2.18	0.008	N/D	0.111	0.097	N/D	N/D	N/T	N/S	6	3	6.08	6.39	13	11
		3.3	a	Surface	1.94	2.10	0.006	N/D	0.105	0.092	0.6	N/D	N/T	N/S	6	3	6.19	6.34	13	12
			b	60 m.	1.99	2.22	0.015	N/D	0.091	0.076	0.7	N/D	N/T	2.10	6	3	6.45	6.30	14	11
4	Hunts Cove	4.1	a	Surface	1.93	2.14	N/D	N/D	0.062	0.089	N/D	N/D	N/T	2.21	6	3	6.16	6.36	13	11
			b	60 m.	1.98	2.27	0.034	N/D	0.119	0.101	N/D	N/D	N/T	2.10	5	3	6.11	6.25	13	11
		4.2	a	Surface	1.92	2.05	N/D	N/D	0.104	0.102	N/D	0.6	N/T	2.20	5	3	6.19	6.62	13	11
			b	60 m.	2.00	2.17	0.018	N/D	0.136	0.086	N/D	0.9	N/T	2.08	5	2	6.13	6.46	13	11
		4.3	a	Surface	1.92	2.10	N/D	N/D	0.120	0.079	1.1	1.0	N/T	2.19	5	3	6.17	6.52	14	12
			b	60 m.	1.93	N/A*	0.015	N/A*	0.117	N/A*	0.5	N/A*	N/T	N/A*	6	N/A*	6.19	N/A*	13	N/A*
5	Lukeman to SW Gander R.	5.1	a	Surface	6.07	2.07	0.025	N/D	0.080	0.094	1.5	0.4	N/T	2.00	5	3	6.28	6.46	21	11
			b	60 m.	5.91	2.11	0.008	N/D	0.110	0.074	0.7	N/D	N/T	2.08	6	3	6.25	6.46	21	11
		5.2	a	Surface	1.97	2.24	0.006	N/D	0.086	0.083	0.8	0.4	N/T	2.19	5	3	6.21	6.47	13	11
			b	60 m.	1.97	2.30	0.009	N/D	0.090	0.075	N/D	0.8	N/T	2.10	6	3	6.15	6.41	13	11
		5.3	a	Surface	2.02	2.15	0.006	N/D	0.155	0.083	N/D	N/D	N/T	2.19	5	3	6.16	6.38	13	11
			b	60 m.	2.01	N/A*	N/D	N/A*	0.151	N/A*	0.6	N/A*	N/T	N/A*	5	N/A*	6.15	N/A*	13	N/A*
6	Joe's Feeder	6.1	a	Surface	5.95	2.22	0.007	N/D	0.101	0.100	N/D	0.5	N/T	2.10	5	3	6.22	6.33	19	12
			b	60 m.	6.05	2.22	0.017	N/D	0.127	0.093	N/D	N/D	N/T	2.14	5	2	6.21	6.36	20	10
		6.2	a	Surface	1.94	2.02	0.012	N/D	0.113	0.084	0.4	N/D	N/T	2.15	5	3	6.27	6.30	13	11
			b	60 m..	6.28	2.17	0.041	N/D	0.119	0.089	1.4	N/D	N/T	2.21	5	3	6.23	6.29	22	11
		6.3	a	Surface	1.95	1.95	0.008	N/D	0.098	0.099	N/D	N/D	N/T	2.02	5	3	6.43	6.30	13	11
			b	60 m.	2.00	N/A*	0.016	N/A*	0.116	N/A*	0.4	N/A*	N/T	N/A*	6	N/A*	6.24	N/A*	14	N/A*
A.	East End	A	a	Surface	2.07	2.45	0.007	N/D	0.110	0.082	N/D	N/D	N/T	2.15	6	3	6.22	6.38	14	12
			b	60 m.	2.03	N/A*	N/D	N/A*	0.099	N/A*	1.2	N/A*	N/T	N/A*	6	N/A*	6.24	N/A*	14	N/A*
B.	Pumping Station	B	a	Surface	2.08	2.11	N/D	N/D	0.115	0.058	1.2	N/D	N/T	2.04	6	3	6.25	7.92	15	11
			b	60 m..	2.00	2.10	N/D	N/D	0.095	0.073	N/D	N/D	N/T	2.09	6	2	6.14	6.89	14	10
C.	The Outflow	C	a	Surface	2.01	2.07	N/D	N/D	0.078	0.076	1.1	0.9	N/T	2.03	6	3	6.20	7.05	14	11
			b	60 m.	1.95	N/A*	N/D	N/A*	0.090	N/A*	N/D	N/A*	N/T	N/A*	6	N/A*	6.19	N/A*	13	N/A*

Transect	Location	Sample			Colour t=1	Colour t=2	Total P t=1	Total P t=2	Nitrate t=1	Nitrate t=2	Total Coliform t=1	Total Coliform t=2	Fecal Coliform t=1	Fecal Coliform t=2	Chlorophyll a. t=1	Chlorophyll a. t=2	Secchi Depth (m) t=1	Secchi Depth (m) t=2	Surface Air Temp t=1	Surface Air Temp t=2
				Variable	Colour		Total P		Nitrate		Total Coliform		Fecal Coliform		Chlorophyll a.		Secchi Depth (m)		Surface Air Temp	
				Units	TCU		mg/l		mg/l		/100ml		/100ml		mg/m3		Meters		Celsius (C)	
				LOQ	1		.004		.02		2		2							
1	Soulis Brook	1.1	a	Surface	N/D	12	N/D	N/D	0.13	0.18	<2	<20	N/D	10	4.2	1.5	N/T	2.5	19.0	15.8
			b	60 m.	N/A	N/A	N/A	N/A	N/A	N/A	N/T	N/T	N/T	N/T	N/T	N/T				
		1.2	a	Surface	5	5	N/D	N/D	0.12	0.28	<2	<20	N/D	10	3.6	1.1	N/T	3.0	19.0	16.1
			b	60 m.	3	12	0.026	N/D	0.24	0.18	N/T	N/T	N/T	N/T	N/T	N/T				
		1.3	a	Surface	N/D	30	0.012	N/D	0.16	0.28	<2	<20	N/D	<10	1.1	1.3	N/T	2.0	19.0	15.8
			b	60 m.	N/D	N/A*	0.010	N/A*	0.17	N/A*	N/T	N/T	N/T	N/T	N/T	N/T				
2	Fifteen Mile Brook	2.1	a	Surface	N/D	26	0.009	N/D	0.12	0.19	<2	<20	N/D	<10	3.8	1.2	N/T	3.0	23.0	16.8
			b	60 m.	N/D	7	0.009	N/D	0.21	0.28	N/T	N/T	N/T	N/T	N/T	N/T				
		2.2	a	Surface	3	13	0.008	N/D	0.23	0.28	<2	<20	N/D	<10	3.8	1.0	N/T	3.0	23.0	18.7
			b	60 m.	N/D	22	0.007	0.006	0.14	0.28	N/T	N/T	N/T	N/T	N/T	N/T				
		2.3	a	Surface	N/D	10	0.006	N/D	0.13	0.28	<2	20	N/D	10	1.7	0.5	N/T	3.0	23.7	17.6
			b	60 m.	N/D	N/A*	0.006	N/A*	0.10	N/A*	N/T	N/T	N/T	N/T	N/T	N/T				
3	Marina	3.1	a	Surface	N/D	24	0.006	N/D	0.14	0.28	<2	<20	N/D	<10	1.7	<.1	N/T	3.5	20.9	16.7
			b	60 m.	N/D	N/A*	0.010	N/A*	0.22	N/A*	N/T	N/T	N/T	N/T	N/T	N/T				
		3.2	a	Surface	N/D	15	0.011	0.008	0.16	0.19	<2	<20	N/D	<10	4.5	1.9	N/T	3.0	22.8	19.3
			b	60 m.	N/D	18	0.005	N/D	0.27	0.28	N/T	N/T	N/T	N/T	N/T	N/T				
		3.3	a	Surface	N/D	26	0.009	N/D	0.21	0.47	<2	<20	N/D	30	1.9	1.0	N/T	3.0	19.3	19.0
			b	60 m.	N/D	3	0.007	N/D	0.26	1.12	N/T	N/T	N/T	N/T	N/T	N/T				
4	Hunts Cove	4.1	a	Surface	N/D	25	0.006	0.004	0.17	0.19	<2	<20	N/D	<10	3.5	2.6	N/T	3.0	17.5	17.8
			b	60 m.	N/D	10	0.006	N/D	0.23	0.23	N/T	N/T	N/T	N/T	N/T	N/T				
		4.2	a	Surface	N/D	26	0.006	N/D	0.08	0.38	<2	<20	N/D	20	4.9	0.1	N/T	2.8	17.5	17.6
			b	60 m.	N/D	26	0.006	N/D	0.03	0.38	N/T	N/T	N/T	N/T	N/T	N/T				
		4.3	a	Surface	N/D	17	0.006	N/D	N/D	0.38	<2	<20	N/D	30	2.0	0.7	N/T	3.0	18.4	18.5
			b	60 m.	N/D	N/A*	0.007	N/A*	0.08	N/A*	N/T	N/T	N/T	N/T	N/T	N/T				
5	Lukeman to SW Gander R.	5.1	a	Surface	N/D	19	N/D	N/D	0.19	0.47	2	20	2	<10	1.0	0.2	N/T	3.5	17.0	15.4
			b	60 m.	N/D	21	N/D	N/D	0.16	0.38	N/T	N/T	N/T	N/T	N/T	N/T				
		5.2	a	Surface	N/D	24	N/D	N/D	0.15	0.28	<2	N/D		20	2.0	<.1	N/T	3.5	16.7	15.0
			b	60 m.	N/D	19	0.004	N/D	0.11	0.28	N/T	N/T	N/T	N/T	N/T	N/T				
		5.3	a	Surface	N/D	11	N/D	N/D	0.29	0.56	<2	<20	N/D	<10	2.4	<.1	N/T	3.5	16.7	17.2
			b	60 m.	N/D	N/A*	N/D	N/A*	0.14	N/A*	N/T	N/T	N/T	N/T	N/T	N/T				
6	Joe's Feeder	6.1	a	Surface	N/D	7	0.012	N/D	0.20	0.56	<2	<20	N/D	<10	0.8	<.1	N/T	2.8	13.3	12.4
			b	60 m.	N/D	26	0.011	N/D	N/D	N/D	N/T	N/T	N/T	N/T	N/T	N/T				
		6.2	a	Surface	N/D	18	N/D	N/D	0.16	N/D	<2	20	N/D	<10	9.2	<.1	N/T	2.5	13.0	12.2
			b	60 m..	N/D	22	N/D	N/D	0.21	N/D	N/T	N/T	N/T	N/T	N/T	N/T				
		6.3	a	Surface	2	15	N/D	N/D	0.24	0.19	13	80	5	50	0.7	<.1	N/T	2.5	13.0	13.0
			b	60 m.	N/D	N/A*	0.020	N/A*	0.10	N/A*	N/T	N/T	N/T	N/T	N/T	N/T				
A.	East End	A	a	Surface	N/D	5	0.009	N/D	0.12	0.28	<2	<20	N/D	<10	3.1	1.6	N/T	3.0	19.0	15.0
			b	60 m.	1	N/A*	0.013	N/A*	0.23	N/A*	N/T	N/T	N/T	N/T	N/T	N/T				
B.	Pumping Station	B	a	Surface	N/D	30	0.006	N/D	0.13	N/D	<2	<20	N/D	<10	0.9	1.5	N/T	3.0	23.0	17.0
			b	60 m..	N/D	38	0.006	0.015	0.25	N/D	N/T	N/T	N/T	N/T	N/T	N/T				
C.	The Outflow	C	a	Surface	N/D	33	0.006	N/D	0.17	0.18	<2	<20	N/D	<10	3.6	1.3	N/T	3.0	N/A	N/A
			b	60 m.	N/D	N/A*	0.006	N/A*	0.02	N/A*	N/T	N/T	N/T	N/T	N/T	N/T				

LEGEND

N/A - Not Applicable (60 Metres Does Not Exist)
N/A* - Sampling Station Moved Closer to Shore
N/D - Not Detected
N/T - Not Taken
N/S - Sample Not Sufficent