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CONSERVATION AND PROTECTION
INLAND WATERS/LANDS DIRECTORATE
WATER PLANNING AND MANAGEMENT BRANCH

A SURVEY OF THE NATURAL SOURCE POLLUTANTS IN THE MEGUMA GROUP AND THEIR IMPACT ON LRTAP STUDIES IN NOVA SCOTIA

FINAL REPORT

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EXECUTIVE SUMMARY

While effects of acidification of natural waters in Nova Scotia from acidic precipitation have been, and continue to be, documented, there is also evidence to indicate acidification from anthropogenic activities occurring in areas underlain by mineralized slate bedrock. The purpose of this study has been to document, for an area of Nova Scotia underlain by bedrock of the Meguma Group, the risk of acidification from anthropogenic activities and to check this risk designation using available water quality information. The defined study region incorporates Queens County, the Municipality of Lunenburg, and the portion of Annapolis County encompassed by Kejimkujik National Park.

The approach to the study, reflected in the content of the report, involves first, the collection of relevant data on geology, hydrology, water quality and anthropogenic activities in the study region. The next step is the development of a qualitative predictive model to delineate the level of risk of acidic drainage. The model is then applied to produce levels of low, medium and high risk, and three watersheds are selected for further study. Two additional watersheds in which the risk of acid drainage is considered nil are used as controls. Each of the five watersheds is evaluated in terms of specific predictive model risks. The water quality database is examined in detail to evaluate the meaning of low, medium and high risk designation. Finally, data gaps are identified and recommendations for further study are presented.

The predictive model developed in this study employs two distinct assessment steps in assigning a low, medium or high potential risk of producing acid drainage. The first assessment step, geological, involves the examination of bedrock lithology, metamorphic grade, proximity to mineral occurrences, presence of imported bedrock fill from high risk area, and buffering

capacity of surficial materials. The second assessment step, anthropogenic, involves the identification of quarry locations (active or abandoned) and the quanitification of existing or potential future land use. Three foldout maps provided with the report illustrate bedrock and surficial geology as well as the potential risk of producing acid drainage for the designed study region.

The application of the model coupled with the knowledge of the existing water quality database (water quality data from NAQUADAT as well as from the Nova Scotia Department of the Environment and the Department of Lands and Forests) allows the selection of three study area watersheds for detailed investigation. These are the West LaHave River, the Grafton Lake and the Mount Tom Brook watersheds.

The West LaHave River watershed falls within the zone of high potential risk of acid drainage. Its watershed area is 211 km^2, of which 12% is lakes and wetlands. It is underlain primarily by Halifax Formation Cunard Member slate with chlorite grade metamorphism. Its surficial geology is complex, with numerous drumlin occurrences of varying composition. There are many deposits of sand and gravel. Anthropogenic activities include quarries, mines, residential and recreational development, and numerous transportation corridors. Water quality data for the West LaHave watershed are extremely limited; water quality for the River is unavailable and only seven lakes in the watershed have comprehensive water quality reports available.

The Grafton Lake watershed falls within the zone of medium/low risk with respect to the potential for producing acid drainage. The mixed designation results from a lack of understanding of the significance of buffering materials in mitigating natural source acid drainage. The area of drainage at the outlet of Grafton Lake is 57.1 km^2, of which lakes and wetlands occupy 14.5%. The bedrock geology of this watershed is dominated by Halifax Formation Cunard Member slate exhibiting biotite grade matamorphism. The surficial geology is primarily slate till ground moraine, with sporadic drumlins. Anthropogenic activities are quite limited, being limited to roads and some residential development. Water quality data for the Grafton watershed are extensive for a point downstream of the lake outlet, however, limited quality data are available for points further upstream in the watershed.

The Mount Tom Brook watershed is designated by the predictive model to be in an area with a low risk of producing acid drainage. The watershed area is 8.7 km^2, two percent of which is occupied by lakes and wetlands. The bedrock geology underlying this watershed is primarily granitoid of Devonian-Carboniferous origin. Surficial geology is dominated by granite till ground moraine, with several areas of bedrock outcropping and no drumlins or sand and gravel deposits. Anthropogenic activities are limited to water quality monitoring, with virtually no development. Water quality data for this watershed are extensive, with long term data collection having been undertaken at Mount Tom Brook near its discharge to Kejimkujik Lake.

The two control watersheds adopted for the purposes of this study are the Beaverskin and Pebbleloggitch Lake watersheds, both of which are in Kejimkujik Park, have small drainage areas, are underlain by Goldenville Formation quartzites, have virtually no anthropogenic activity, and have extensive water quality data available for characterization.

The available water quality data for the five watersheds under consideration are presented in the report through the use of numerous graphs and plots. The quality constituents examined in detail are those which would be expected to illustrate the effects of acid drainage, including pH, sulphate, aluminum, iron, and alkalinity. For the purposes of data interpretation, readings for colour and organic anion are also examined. Long term quality investigations involve the study of quality for data obtained from 1980 to the present. Time series investigations include the study of seasonal quality variations for a two-year period from late 1981 to early 1984.

The water quality data are generally unsuitable for demonstrating conclusively the occurrence of medium or high risk zones for production of acid drainage. The quality data for the West LaHave watershed are inadequate, being limited to seven lakes. The quality data for Grafton Lake are unable to demonstrate acid drainage effects since the lake itself provides a significant buffering effect immediately upstream of the quality sampling point. The quality data for Mount Tom Brook appear to illustrate that the area is not subject to effects from natural source acid drainage.

The study results demonstrate that the area of no and low risk of acid drainage are confidently assigned. Therefore, it is concluded that long Range Transport of Air Pollutants (LRTAP) water quality monitoring stations can be confidently located within these areas without the risk of acid drainage interference in the interpretation of atmospheric deposition effects. Further studies are required to assist in quantifying the suitability of the predictive model's designation of medium and high risk areas.

TABLE OF CONTENTS

LIST OF FIGURES

1.0 INTRODUCTION

Surface waters in Nova Scotia are considered sensitive to acid deposition, particularly in areas underlain by rocks of igneous (granites) or metamorphic (quartzites and slates) origin (Underwood et al, 1986). Effects of acidification on Atlantic salmon populations in rivers of southwestern Nova Scotia and biological and chemical evidence of acidification of lakes in the Halifax area are well documented (Watt et al., 1983; Underwood et al., 1986; Kerekes et al., 1986). Since 1979, Long Range Transport of Air Pollutants (LRTAP) research has attempted to measure the impact of acid deposition on lakes and streams in various locales of the Province. These impacts are now reasonably well understood; for instance, there are data which suggest a pH lowering of 0.017 units per year in some streams (Watt et al., 1983).

Evidence also indicates acidification from anthropogenic activities (quarrying and road building) occurring in mineralized slate bedrock in the Province. Relative to acidification from acid precipitation, acid drainage from mineralized bedrock may have a different and perhaps more significant impact on lakes and streams. Significant local impacts on aquatic resources have been demonstrated at the Halifax Airport and Springfield Lake (Porter Dillon, 1985; Machell and Wiltshire, 1985; Kerekes et al., 1986). For example, fish kills have been documented from acid drainage in the Halifax Airport area and Lunenburg County (Thompson, 1978; Pettipas, 1979).

In order to evaluate the long term impact of continued acid deposition from precipitation, the interference effects from acid drainage must be understood. There is a need to map the distribution of acid drainage in space, determine time variances of formation; and evaluate short and long-term impacts.

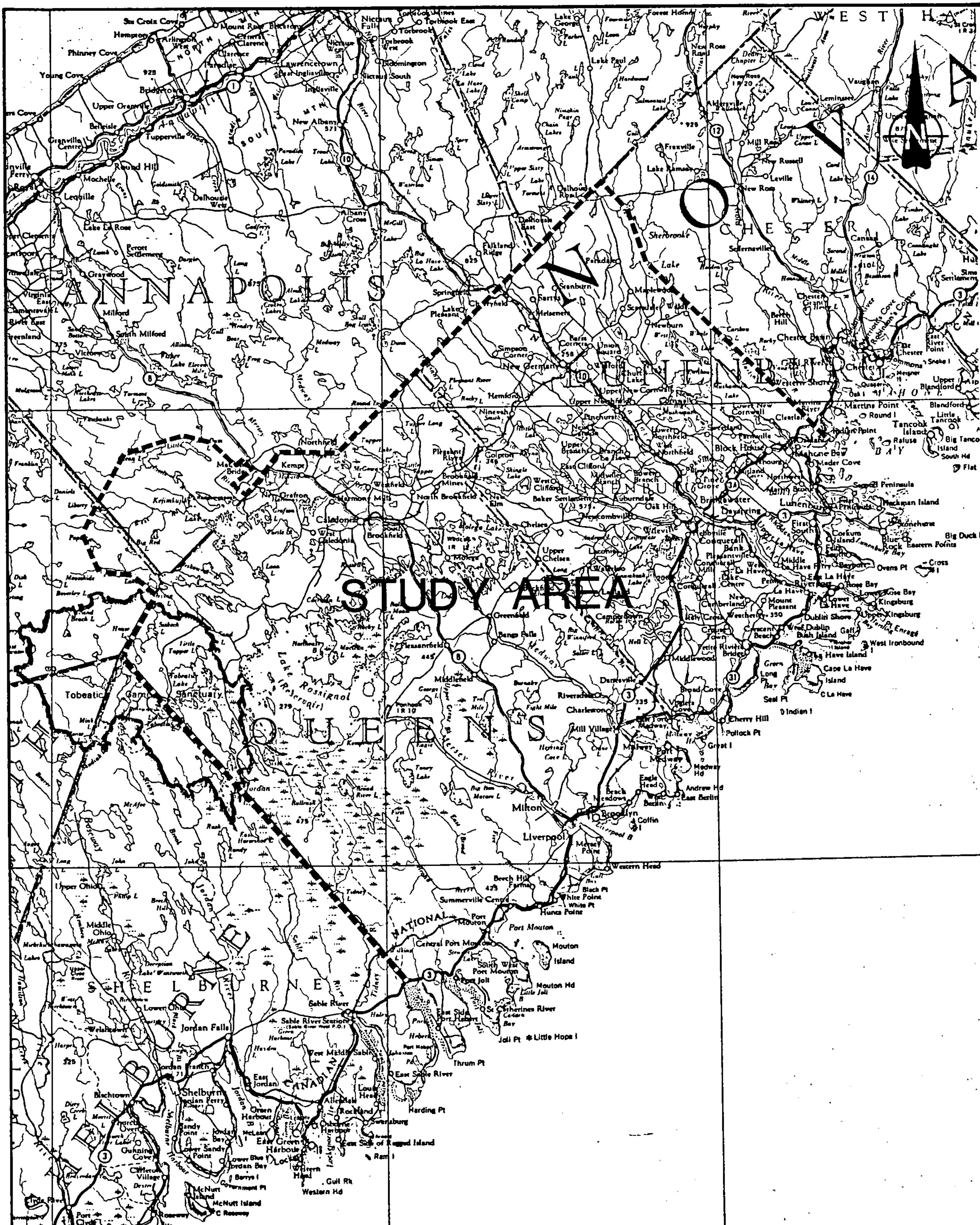
Different from acid precipitation, the occurrence of acid drainage is site specific and is variable in time and space. Consequently, the longer term impacts are poorly understood. It is probable that measurements of acidification attributed to acid precipitation may be related to subtle acid drainage effects.

This study, which was commissioned by the Water Planning and Management Branch of the Inland Waters Directorate, Environment Canada, is a survey of natural source pollutants in the Meguma Group. It is an attempt to assess, comparatively, the physical processes which combine to produce acid drainage. Acid producing areas with varying degrees of defined risk will be compared to other locales known to be little affected by this phenomenon. A corresponding objective of this project is to delineate the effects of acid drainage on LRTAP water quality sampling results.

To satisfy these objectives, a defined region located in southwestern Nova Scotia (see Figure 1.1) has been selected as a study area. This area incorporates Queens County, the Municipality of Lunenburg (i.e. the western portion of Lunenburg County) and a portion of Annapolis County encompassed by Kejimkujik National Park. A substantial data base including geological, hydrological, water quality, and anthropogenic characteristics of the study area has been compiled and evaluated in order to accomplish the following specific work tasks:

1) The development of a predictive model to delineate the level of acid drainage risk.

2) An application of the model in the production of a generalized (i.e. low, medium, high) risk map of the study area.



PORTER DILLON Consulting Engineers • Planners • Environmental Scientists	TITLE STUDY AREA	SCALE 1" = 10 miles
DATE March 1987	PROJECT A SURVEY OF NATURAL SOURCE POLLUTANTS IN THE MEGUMA GROUP	FIGURE No. 1.1

3) Based on the review of the risk map, selection of three (3) watersheds each demonstrating a specific category of risk, for further study .

4) Selection of two watersheds adjacent to the study area, which have been designated through water quality analysis by others, as having "no risk" in terms of the potential to produce acid drainage.

5) Detailed evaluation of each of the five designated watersheds in terms of specific predictive model inputs.

6) Evaluation of the performance of the predictive model and the meaning, in terms of water quality, of low, medium and high risk areas.

7) Establishment of data gaps and recommendations for future study, as required.

2.0 METHODOLOGY

The survey of natural source pollutants in the Meguma Group of southwestern Nova Scotia was undertaken in two distinct phases. Phase I, completed as an interim report and submitted to the client in November 1986, involved the following preliminary aspects of the project:

- The preparation of a flow chart model (i.e. a qualitative rationale scheme) for assigning to areas their potential to produce acid drainage which may result in some level of impact.

- The preparation of a constraint map of the study area which assigns broad-scale levels of risk (i.e. low, medium, high).

- The initial selection of study area watersheds in which a detailed evaluation of predictive model inputs would be undertaken.

- The provision of a preliminary assessment of the potential impact of acid drainage on LRTAP studies.

The Phase I interim report was submitted as a written document only, with the associated flow chart and mapping presented in draft.

Phase II of the study then involved detailed evaluation of the study watersheds. This report is intended to finalize all aspects of Phase I and Phase II, provide an overall summation of the findings of the entire study and present, in final form, all report graphics.

Specifically, Section 3.0, "Predictive Model Development", outlines input criteria and rationale. It is accompanied by the actual flow chart (i.e. Figure 3-1, in text) as well as 1:100,000 scale mapping (in pouch) which details such physical considerations as bedrock and surficial geology, hydrologic information (i.e. flow, water sampling and precipitation stations) and anthropogenic characteristics such as land use, roads and quarries. Section 3.0 concludes with the presentation of a risk map for the study area which delineates areas as having a low, medium or high potential to produce acid drainage.

Section 4.0, "Study Area Watersheds", describes the selection rationale and details the individual physical characteristics of the five drainage areas under consideration. The discussion of each watershed area is accompanied by appropriate scale mapping which illustrates the various inputs of the predictive model. The five watershed areas described are: (1) the West LaHave (high risk), (2) Grafton Lake (medium risk), (3) Mount Tom (low risk), (4) Beaverskin Lake and (5) Pebbleloggitch Lake (no risk).

The report concludes with Section 5.0 which is a detailed discussion of the report findings and Sections 6.0 and 7.0 which give study conclusions and recommendations.

3.0 PREDICTIVE MODEL DEVELOPMENT

The flow chart model (Figure 3-1) as well as the risk map (Map #3, in pouch) should be utilized when referring to this section of the report. The types of information collected and documented for the overall study area are displayed on the extreme left hand side of the flow chart. This information was originally plotted on 1:50,000 scale Nova Scotia Department of the Environment watershed maps and transferred to a reduced (i.e. 1:100,000) scale for report presentation. This data (i.e. Maps #1 and 2, in pouch) forms the basis of the working flow chart model and the associated risk map and is designed to be applicable throughout the study region.

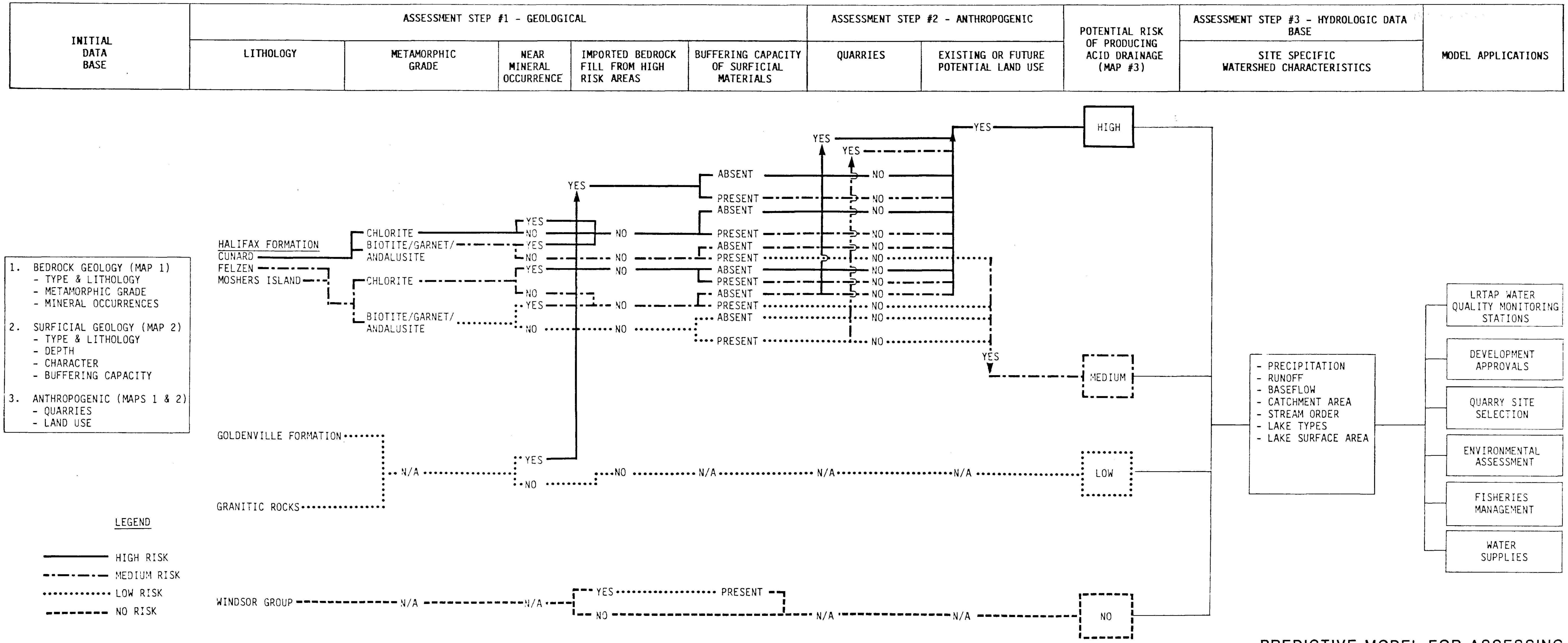
Following the plotting stage, two basic assessment steps have been applied in order to identify areas of probable low, medium and high risk. This information is used for quantification of selected watershed areas for detailed study which are presented in Section 4.0.

3.1 GEOLOGY - ASSESSMENT STEP #1

3.1.1 Bedrock Geology

Map #1 delineates the basic rock types found throughout the study area. It also denotes gradations in metamorphism as well as the locales of disturbed bedrock including mines and quarries.

In general, the study area is underlain by three rock units. These include, in order of increasing geological age, the Windsor Group, the Devonian Granitic rocks and the Meguma Group.



PREDICTIVE MODEL FOR ASSESSING POTENTIAL RISK OF ACID DRAINAGE

FIGURE 3-1

The Windsor Group, which is of Mississipian age, is composed of gypsum, anhydrite, limestone, shale and minor salt. These rocks underlie a small area in the extreme eastern portion of the study area. The Devonian aged Granitic rocks are composed of granite, granodiorite and monzo-granite and underlie small portions of the region primarily to the north, west and south-west. The Cambro-Ordovician Meguma Group is divisible into the lower coarse-grained Goldenville Formation consisting of greywackes and minor argillite, slate and mica schist as well as the finer grained Halifax Formation consisting of slate, siltstone and minor argillite. These two formations underlie the vast majority of the study area, being approximately equal in terms of areal extent.

With respect to the potential of the development of acid drainage, the Windsor Group, due to the composition of the individual rock units, is considered as having no risk. In fact, its evaporite nature indicates a significant buffering capability, however within the defined study area it has little potential in this regard due to its location which corresponds to watersheds draining directly to Mahone Bay.

The Devonian Granitic rocks, which do not exhibit pyrite mineralization, can be generally considered low risk.

Areas which are underlain by rock of the Cambro-Ordovician Meguma Group have, in varying degrees, pyrite mineralization and therefore are considered to have some measure of risk. As noted, the Meguma Group is divisible into the lower coarse-grained Goldenville Formation and the upper finer grained Halifax Formation.

The Goldenville Formation has less pyrite mineralization and has blocky fracturing; therefore this unit may be considered low risk.

The Halifax Formation has been mapped in detail recently south and east of Bridgewater (Map sheets 21A/2 and 21A/8) by the Geological Survey of Canada (O'Brien, 1985, 1986a and 1986b; Waldron and Graves, 1986).

There are three mappable units within the Halifax Formation. The first is a green to grey-green, parallel laminated argillite (Moshers Island Member) which conformably overlies the Goldenville Formation and is referred to as the Goldenville Halifax Transition or the GHT (Zentilli and Graves, 1986). This unit is typically manganiferous, carbonate bearing and often contains sulphide minerals. It is overlain by the Cunard Member of the Halifax Formation which consists of black slate interbedded with thinly bedded pyritiferous metasiltstone. The third overlying unit is the Felzen Member which generally lies in synclines and consists of grey slates with interbedded bioturbated sandstone beds.

Felzen slates have less sulphide and more carbonate than Cunard slates and consequently have less acid producing potential and more buffering capability. Moshers Island argillites, although containing pyrite and anomalous values of many heavy metals, have carbonate which also affords buffering capability. It may be considered therefore that Cunard slates are high risk and that the Moshers Island and the Felzen slates are medium risk. The individual Members of the Halifax Formation are noted on the southeast section of Map 1. Unfortunately in the remainder of the study area north and west of Bridgewater, the Halifax Formation is presently unmapped with respect to these lithologic subdivisions. For the purposes of the exercise regarding the determination of acid drainage risk, we have assumed as a worst case scenario that the Halifax Formation slate in the unmapped area belongs to the Cunard Member.

In addition to the basic bedrock type, the metamorphic geology of the study area has an important effect on the acid producing capacity of the bedrock. The regional metamorphic grade increases systematically from the eastern end of the study area, where the Meguma rocks are low chlorite grade, to the west where the grade increases progressively to biotite, garnet and andalusite grades (Muecke and Keppie, 1979; Purves, 1974). The bulk effect of this gradient is to decrease the amount of CO_2 and increase the relative amount of SiO_2 in the rocks, thus changing carbonate minerals to silicate minerals. The rock becomes less porous and harder and the cations become more tightly bound into coarser-grained metamorphic minerals, therefore, the mobility of rock components is less as the metamorphic grade rises. The quantity and quality of the cleavage also decreases as metamorphic grade rises as plately (mica) minerals are recrystallized into blocking alumino-silicate minerals (garnet, andalusite, cordierite). It has been demonstrated at the Halifax Airport that there is a direct relationship of acid drainage production with amount of cleavage (Lund, 1985).

In view of the relationships between mineral mobility and metamorphic grade, the garnet/andalusite grade may be considered low risk and the chlorite grade high risk. The biotite grade can either be considered medium risk when it occurs in conjunction with the Cunard Member or low risk in conjunction with the Moshers Island Member. The reason for this obvious variation relates to a difference in the mechanical character. In the Moshers Island Member, the high content of manganese inhibits biotite mineral growth and lowers the temperature conditions for the crystallization of garnet. Thus, platy minerals are absent and although the rocks have lost their carbonate, they have less chance of producing acid drainage because of their increased resistance to weathering. With respect to the Felzen Member, this rock type does not occur in association with biotite grade metamorphism so a risk factor is not defined.

In addition to the assessment of regional metamorphic grade, local contact metamorphism must be considered. When assessing geologic causes of acid drainage, there is an aureole of higher grade metamorphic rocks near the contacts of the Meguma Group rocks with the granitic rock. The rock within the aureole of the granites is coarser grained and exhibits less cleavage than equivalent rocks beyond the effect of the granite. This hornfels rock is recognized by these compositional and structural differences 2,000 metres from the contacts (O'Brien, 1986). The coarse grain size, blocky fracturing and hard character along with the decrease in amount of sulphide and carbonate minerals allow these rocks to be considered as low risk regarding the production of acid drainage. The boundary between high and low risk, however, in Cunard slates, for instance is a gradational one. Further work would be required to ascribe levels of risk near the outer edge of this zone.

A further consideration is the distribution and mobility of different sulphide minerals that occur in different proportions in different metamorphic grades and rock units. The dominant sulphide mineral present in these rocks is pyrite (FeS_2). Pyrrhotite ($Fe_{1-x}S$) and arsenopyrite (FeAsS) are more common in the Moshers Island Member and pyrrhotite more common along the granite contact. The behaviour of the different minerals as well as their precise relative abundance and distribution is poorly understood and has not been mapped.

Based on this discussion, rocks demonstrating a high risk potential of producing acid drainage, within the study area, are Halifax Formation slates belonging to the Cunard Member exhibiting chlorite metamorphism. All other rock types in association with the varying grades of metamorphism are considered to be either medium, low or no risk areas. Exceptions to the medium or low risk designation are areas associated with known mineral occurrences and areas which have received imported crushed bedrock from high risk areas. Therefore, mines, mineral occurrences and bedrock fill areas have the potential of producing acid drainage and are designated high risk (see Map 3, enclosed).

3.1.2 Surficial Geology

Map #2 delineates surficial material types found throughout the study area. It also denotes bedrock outcrops and areas of glacial features such as drumlin concentration, outwash/ice contact deposits/eskers and striae.

In general, the bedrock of the study area is overlain by four types of surficial materials which include slate till, quartzite till, granite till and sand and gravel deposits. Isolated areas have been designated as bedrock indicating that 40 percent of the area exhibits rock exposure and boulders.

The Slate till occurs in a significant portion of the study region in the northern and eastern sections. It is described as a light olive brown material with loose angular pebble sized clasts and ranges in depth from 1 to 10 metres (m) with an average depth of 3 m. In addition to this slate ground moraine, the area also contains numerous drumlins composed of either Slate or Lawrencetown till. These features range in depth from 2-20 m and 2-25 m respectively. The Lawrencetown till drumlins are confined to an area north and east of Bridgewater while the Slate till drumlins are numerous throughout the remainder of the sheet.

The Quartzite till also occurs in a significant portion of the study area. It is described as a light bluish grey material with loose angular clasts predominantly cobble sized in a silty matrix. The till sheet ranges in depth from 1 to 10 m with an average of 3 m. Drumlins also occur on this till sheet but are confined to regions immediately north of Lake Rossignol. They are predominantly composed of Quartzite till material, however, there is minor overlap from the Slate till sheet located to the north. These drumlins vary in depth between 2 and 20 m.

The Granite till is of minor significance in the study area overlying the bedrock in isolated localities in the southwest, northwest and northeast. It is described as a greyish orange to yellowish brown material with loose, angular cobble-sized clasts. The till sheet ranges in depth from 1 to 10 m with an average of 3 m. Drumlins are generally absent from this granitic terrain.

Sand and gravel deposits occur throughout the region in small isolated locales and represent a homogenization of local till clasts. They can either take the form of glacial outwash or ice contact deposits (i.e. kames, kame terraces and eskers) with varying depths overlying bedrock or till.

With respect to the buffering capacity of the surficial deposits, three specific factors are of importance. In order of their relative significance, these are grain size, depth and calcium content. Unconsolidated material with high percentages of silt and clay sized particles and relative good depth over bedrock have the greatest capability to buffer acid drainage. Calcium concentration is also a consideration, however, soil/ water contact area and duration appear to be of greater importance. The following table illustrates these features in association with the various surficial materials of the study region.

	FACTOR		
SURFICIAL TYPE	RELATIVE GRAIN SIZE	RELATIVE DEPTH	CALCIUM CONCENTRATION* % (# OF SAMPLES)
Slate Till	Fine	Good	0.08 (27)
Lawrencetown Till	Fine	Good	0.53 (3)
Quartzite Till	Medium	Fair	0.21 (67)
Granite Till	Medium-Coarse	Poor	0.19 (6)
Sand & Gravel	Coarse	Fair	0.09 (7)

*After Stea, 1982

Based upon this qualitative type of analysis, it can be seen that of the unconsolidated materials found in the study area only the Slate and Lawrencetown tills have any significant buffering capacity. The remaining materials because of medium to coarse grain size and shallowness (i.e. lack of drumlin development) have poor or non-existent buffering capability. This aspect of the predictive model requires further definition via site specific field studies.

3.2 ANTHROPOGENIC ACTIVITIES - ASSESSMENT STEP #2

Anthropogenic activities or generalized land use is presented on the accompanying 1:100,000 scale report mapping. Specific parameters under consideration involve various forms of land development including road/rail transport, power transmission corridors as well as forestry, agricultural and human influence. Due to the size of the designated study area, it is beyond the scope of this project to individually map specific land use characteristics such as isolated areas of forest clear cuts or farm fields. However, a general overview of these parameters within the study area indicates that the LaHave watershed is of highest potential risk with respect to anthropogenic activities. The greater population lies within this watershed and results in a larger network of facilities (i.e. roadways, rail and power transmission corridors) with a higher percentage of bedrock exposure originating from construction activities.

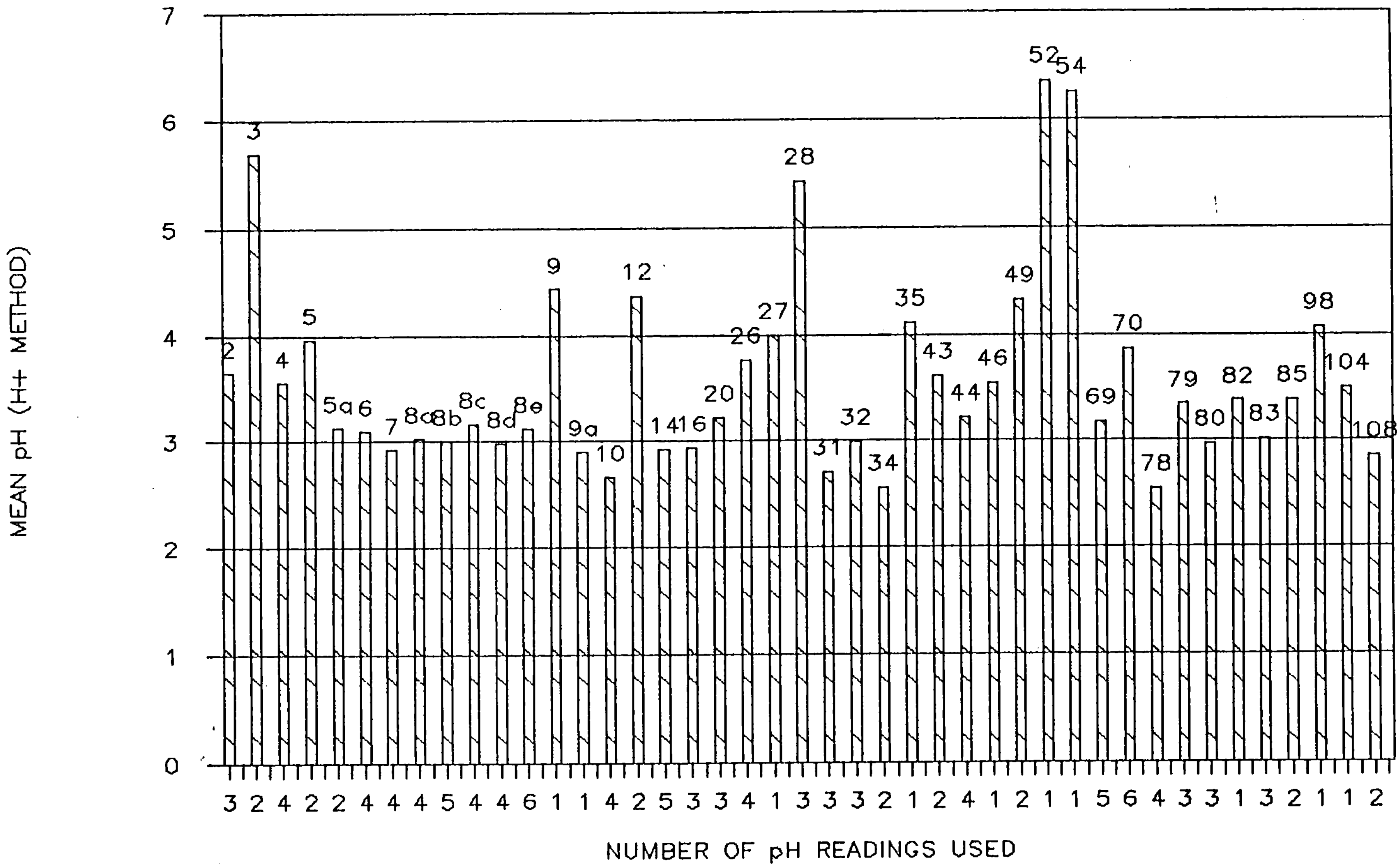
Of greater concern with respect to the development of acid drainage are anthropogenic activities relating to bedrock quarrying. There are an estimated 73 quarries in the study region (see Map #1 or 2), the vast majority of which are located in the LaHave watershed within the Municipality of Lunenburg. Because of ease of excavation, the vast majority of quarries are confined to the Halifax Formation slate (King, 1985). They are predominantly located within the Cunard Member which has been previously identified as the rock type having the highest risk with respect to acid drainage potential. The quarried rock is used locally for road surfacing and many, if not all, secondary dirt and woods roads throughout the study region may be surfaced with this mineralized slate rock.

Assessment of water quality information collected by Environment Canada (Manchester, 1986) in 50 quarries (i.e. those numbered on Maps 1 and 2, enclosed) indicate, in a general sense, that in the north, close to the granite/quartzite/slate contact acid drainage discharge is less than that in quarries located in the Cunard Member. This supports the conclusion that lithological bedrock type and degree of metamorphism are important factors in risk assessment. However, this conclusion is based upon a limited number of samples and therefore requires further clarification. Figure 3-2 illustrates graphically the mean pH of waters from numbered quarries in the LaHave region. It is noted that all these quarries are located in areas underlain by Halifax Formation, Cunard Member black slate exhibiting chlorite grade metamorphism.

FIGURE 3-2

QUARRY pH READINGS IN 1986

DATA FROM MANCHESTER REPORT



With respect to the development of risk areas (i.e. no, low, medium and high) through assessment of anthropogenic activities in the predictive model it is apparent that the location of quarries has the greatest significance. Quarries located in Halifax Formation slate which have not been influenced by either contact metamorphism with the granite or higher metamorphic grade (i.e garnet-andalusite) are considered localized areas of high risk. Quarries in areas subject to higher degrees of metamorphism may present a slightly lower risk, however, they still may adversely effect the surrounding environment and LRTAP water quality monitoring stations. Quarries located in low risk bedrock areas (i.e. quartzite and/or granite) are assumed to be low risk because of a general lack of sulphide mineralization. As noted, there is a general lack of water quality information on quarries in non-slate rock units, therefore further work is required before this aspect can be categorically quantified unless high risk bedrock is to be used in this development.

In general, land use activities in terms of the predictive model risk designation is relatively straightforward. Areas within the Halifax Formation subject to development pressures have a higher risk than areas not subject to development. Land use activities in rock units which have low potential for acid drainage are not considered to affect the overall risk designation unless high risk bedrock is to be used in this development.

3.3 SUMMARY OF INITIAL ASSESSMENT STEPS

Through the utilization of geological and anthropogenic assessments steps in the predictive model, a risk designation has been determined for the study area in terms of geographical extent. The use of the predictive model and associated risk map in this format will be valuable in relation to the isolation of existing areas of acid drainage production as well as for future planning in terms of development. However, in its present format the risk model and map are only an initial step towards the determination of the effect of acid drainage on watershed sampling programs (i.e. specifically LRTAP). The overall effect on LRTAP studies must consider the geological and anthropogenic considerations in association with the specific watershed characteristics in which they are located. This aspect is introduced in the following assessment step and is addressed fully in the detailed evaluation of the three study area watersheds presented in Section 4.0.

3.4 WATERSHED CONSIDERATIONS - ASSESSMENT STEP #3

In order to determine the effect of the geographical distribution of risk areas on water quality monitoring stations an evaluation of individual watershed characteristics must be undertaken. The variability of these site specific characteristics makes the assessment of each individual watershed within the study area beyond the scope of this project. However to provide examples, we have applied the individual assessment components to the three selected watersheds under consideration. These components include precipitation, runoff, baseflow, catchment area, type (i.e. brown or clear water), lake surface area and stream order.

Precipitation, runoff, baseflow, catchment area and stream order all have a definite effect on site-specific water quality in terms of a natural source pollutant such as acid drainage. For example, first and second order streams* may lack both

* Stream order as defined herein is taken from Chow (1964) and provides an indication of location within the watershed. The lowest orders combine to produce higher orders as one proceeds downstream from headwaters.

buffering capacity and dilution potential because of their relative location in the watershed. This is supported by the location of the Patten Brook fish kill which resulted from surfacing the Union Square Road with transported mineralized slate (Pettipas, 1979). It can also be assumed that as acid drainage moves to the lower reaches of a watershed, dilution and buffering mechanisms reduce impact. Therefore, in terms of the area effect of acid drainage, higher order watersheds and associated water quality monitoring stations would be expected to suffer less impact.

Another important consideration is the effect of lake and wetland surface area within an individual watershed. These surface water bodies act as sinks for metal complexing and other chemical reactions thereby preventing acid drainage from continuing downstream. Therefore, the wetlands may be considered as buffers, however, these areas may be impacted over the long term via sediment movement and associated chemical release or via acid deposition from precipitation. At present, these relationships are poorly understood and their role in the overall assessment of acid waters requires further definition.

Another watershed characteristic which plays a role in the evaluation of water quality involves lake type. There are two basic type of lakes in this regard, either clear water or brown water lakes. Clear water lakes are in general those water bodies which do not receive drainage from organic soils in swamps or boggy areas. In this respect they have low colour, low humic and tannic acid concentrations and generally higher pH levels. On the other hand, brown water lakes do receive drainage from sources high in allochthonous organic matter and therefore exhibit high colour, high humic and tannic acid concentrations and relatively lower pH readings. The systems of buffering which influence pH levels are different in each lake type (Machell, et. al., 1985; Howell, 1986).

The importance of characterizing lake type and relative distribution is obvious in terms of quantifying the effect on overall drainage basin water quality in association with both acid drainage and precipitation.

In summary, the predictive model via the application of the three assessment steps can be utilized for a variety of applications. These include the evaluation of LRTAP Water quality monitoring stations, development approvals, quarry site selection, environmental assessment, fisheries management and water supplies.

4.0 STUDY AREA WATERSHEDS

Using the rationale outlined in the predictive model and the subsequently derived risk map (i.e. #3), we have chosen three basins for further detailed evaluation:

1) West LaHave watershed, the LaHave system in Lunenburg County.

2) Grafton Lake watershed, the Mersey system, Kejimkujik Park in Queens and Annapolis Counties.

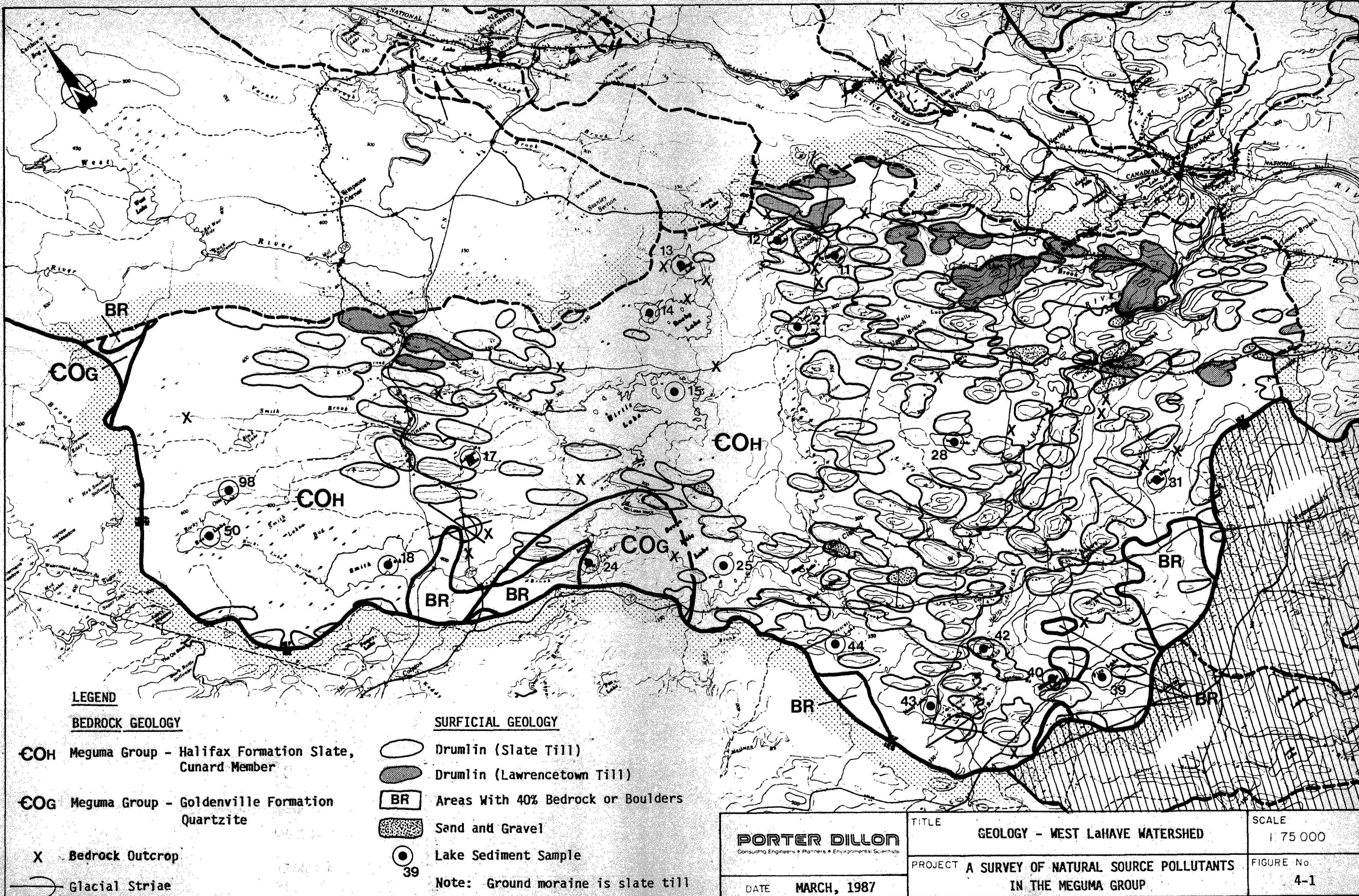
3) Mount Tom watershed, the Mersey system, Kejimkujik Park in Annapolis County.

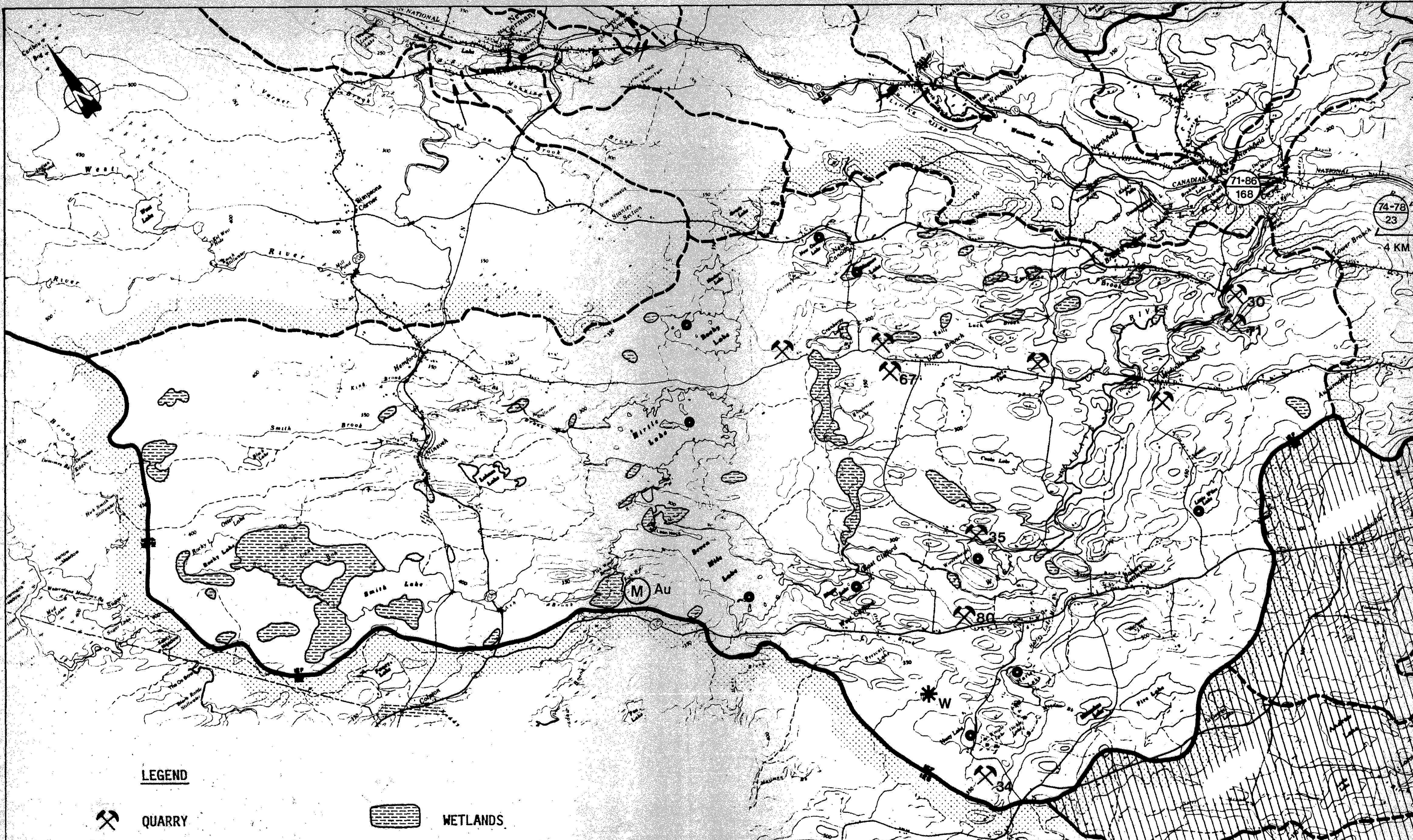
These three watershed areas correspond to the various levels of risk (i.e. high, medium/low and low) developed by the predictive model. The Grafton system originally designated as medium risk has been redefined as medium/low on the risk assessment map. The reason for this alteration relates to the lack of quantification of the effect of buffering by local surficial materials. For reasons of association, these watersheds will be compared to two watersheds which have been determined through detailed evaluation of water quality (Kerekes, 1986a and 1986b) to have "no risk" in terms of acid drainage production. The "no risk" watersheds include Pebbleloggitch and Beaverskin Lakes and are located in the Shelburne river system, Kejimkujik Park, in Queens and Digby Counties respectively.

4.1 PHYSICAL CHARACTERTISTICS

4.1.1 West LaHave Watershed

The West LaHave drainage basin has been designated by the predictive model as having a high risk with respect to the


BR
COG
COH
COG
BR
BR
BR
BR
BR
13
14
15
17
98
50
18
24
25
12
11
27
28
31
44
42
40
39
43
LEGEND
BEDROCK GEOLOGY
COH Meguma Group - Halifax Formation Slate, Cunard Member
COG Meguma Group - Goldenville Formation Quartzite
X Bedrock Outcrop
Glacial Striae
SURFICIAL GEOLOGY
Drumlin (Slate Till)
Drumlin (Lawrencetown Till)
BR Areas With 40% Bedrock or Boulders
Sand and Gravel
39 Lake Sediment Sample
Note: Ground moraine is slate till
PORTER DILLON
Consulting Engineers • Planners • Environmental Scientists
DATE MARCH, 1987
TITLE GEOLOGY - WEST LaHAVE WATERSHED
PROJECT A SURVEY OF NATURAL SOURCE POLLUTANTS IN THE MEGUMA GROUP
SCALE 1:75 000
FIGURE No. 4-1



LEGEND

⚒	QUARRY		WETLANDS
(M)	MINE	(71 86 / 168)	WATER QUALITY MONITORING STATION (long term)
✱	MINERAL OCCURRENCE	●	SINGLE LAKE SOURCE WATER SAMPLE

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Consulting Engineers • Planners • Environmental Scientists

DATE MARCH, 1987

TITLE ANTHROPOGENIC CHARACTERISTICS - WEST LaHAVE WATERSHED

PROJECT A SURVEY OF NATURAL SOURCE POLLUTANTS IN THE MEGUMA GROUP

SCALE 1:75 000

FIGURE No. 4-2

potential to produce acid drainage. This designation is based upon the following components of the assessment process which are depicted on Figures 4-1 and 4-2.

In terms of bedrock geology, the watershed is primarily underlain by Halifax Formation Cunard Member slate which exhibits chlorite grade metamorphism. A small area in the westernmost portion, around Seven Mile and Fish Weir Lakes, is underlain by Goldenville Formation greywackes or quartzites (see Figure 4-1).

The surficial geology of the West LaHave watershed is quite complex in terms of glacial landforms. The area is basically overlain by slate till with a minor occurrence of quartzite till in the extreme northwestern section of the watershed. In the south and southeast, the slate till sheet contains numerous drumlins dominated by material from the Halifax Formation. However, in the eastern section of the drainage basin the drumlins are composed of Lawrencetown till which has been transported from areas underlain by Carboniferous bedrock.

The watershed also contains several deposits of sand and gravel and areas of bedrock outcrop. Figure 4-1 which depicts bedrock and surficial geology also denotes lakes within the watershed which have had sediment samples collected and analyzed (Nova Scotia Department of Mines and Energy, 1985). A total of 17 lakes were sampled in the LaHave system. This information is summarized in Appendix A together with the data from other study area watersheds (Grafton and Mount Tom).

Figure 4-2 depicts anthropogenic characteristics of the West LaHave watershed. These include quarries, mines, mineral occurrences and water monitoring stations. In addition, wetlands are noted. In general, this watershed is extensively developed with a total of 9 quarries and numerous transportation corridors.

4.1.2 Grafton Lake Watershed

The Grafton Lake drainage basin has been designated by the predictive model as having a medium/low risk with respect to the potential to produce acid drainage. This assessment is based upon the geological and anthropogenic characteristics depicted in Figures 4-3 and 4-4, respectively.

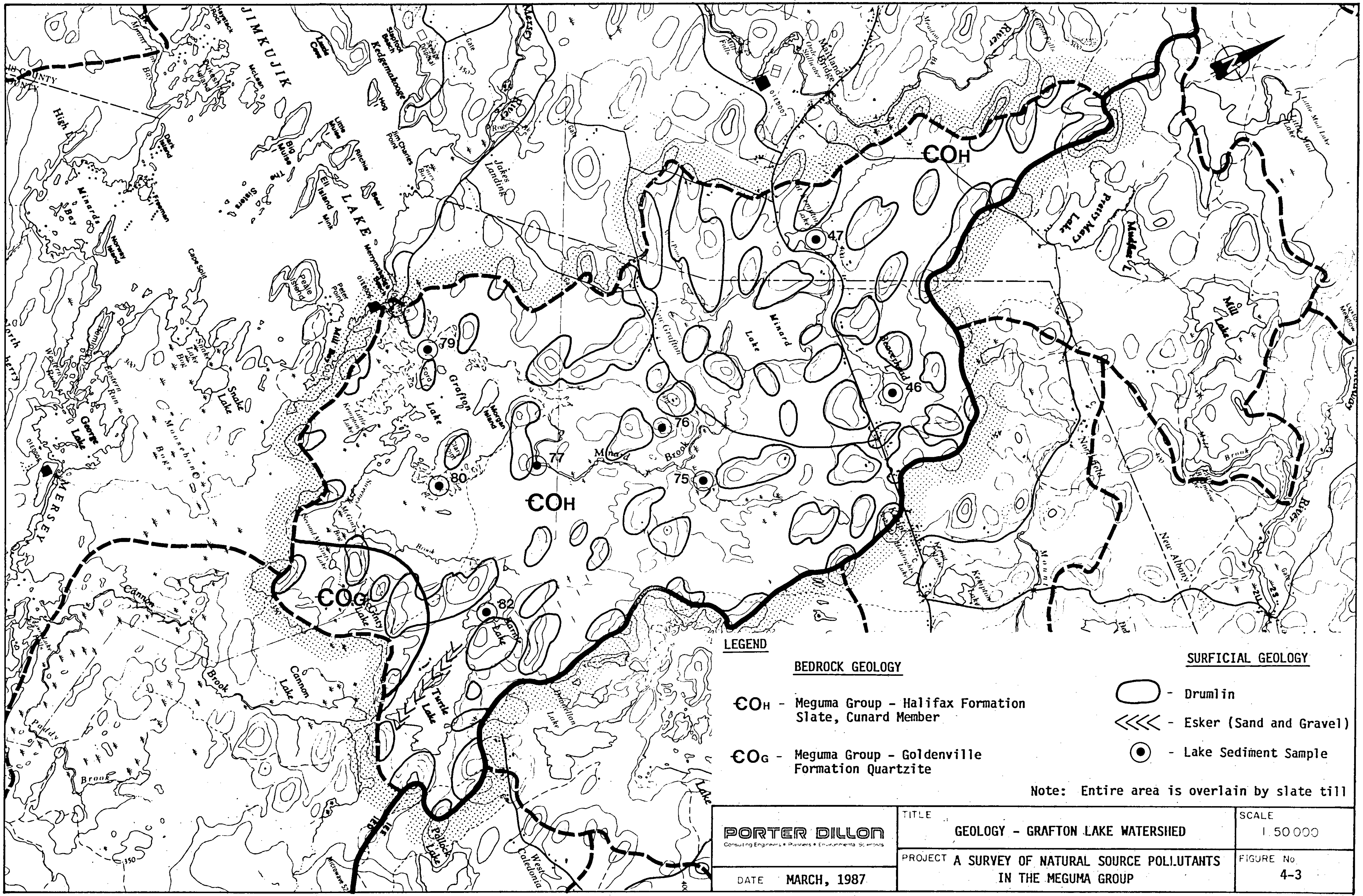
The bedrock geology of this watershed is dominated by Halifax Formation, Cunard Member slate exhibiting biotite grade metamorphism. A small area in the extreme southern section of the drainage basin is underlain by Goldenville Formation quartzite.

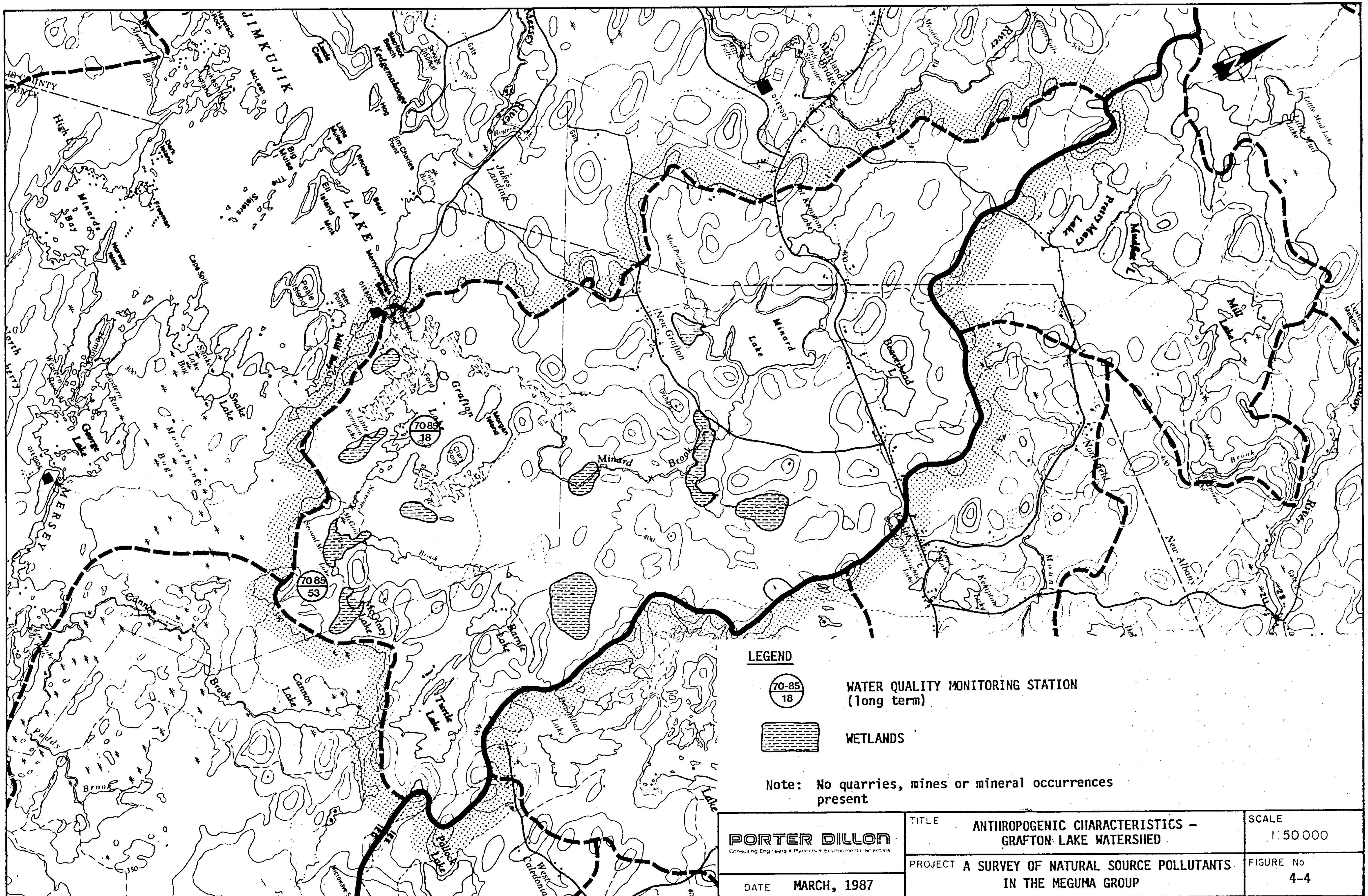
The surficial geology of the Grafton Lake watershed is dominated by slate till ground moraine. Drumlins, composed of similar material, occur sporadically throughout. Sand and gravel occurrences are limited, being confined to an esker located in the southeast adjacent to Turtle Lake. Figure 4-3 also denotes lake sediment sample locations (8 in total), the results of which are presented in Appendix A.

Figure 4-4 depicts anthropogenic characteristics and the location of wetlands. The anthropogenic detail is limited to water quality monitoring stations, roads and residential development. This area is, at the present time, devoid of other man-made disturbances such as quarries and mines.

4.1.3 Mount Tom Watershed

The Mount Tom drainage basin has been designated by the predictive model as having a low risk with respect to the potential to produce acid drainage. The geological and anthropogenic characteristics which support this assessment are depicted in Figures 4-5 and 4-6 respectively.


LEGEND
BEDROCK GEOLOGY
ЄOH - Meguma Group - Halifax Formation Slate, Cunard Member
ЄOG - Meguma Group - Goldenville Formation Quartzite
SURFICIAL GEOLOGY
- Drumlin
- Esker (Sand and Gravel)
- Lake Sediment Sample
Note: Entire area is overlain by slate till
PORTER DILLON
Consulting Engineers • Planners • Environmental Scientists
DATE MARCH, 1987
TITLE GEOLOGY - GRAFTON LAKE WATERSHED
PROJECT A SURVEY OF NATURAL SOURCE POLLUTANTS IN THE MEGUMA GROUP
SCALE 1:50 000
FIGURE No. 4-3
ЄOH
ЄOG
JIMKUJIK
LAKE
Grafton Lake
Minard Lake
Minard Brook
Mill Lake
Cannon Lake
Turtle Lake
Pollock Lake
George Lake
Snake Lake
Kedgemakooge
Jakes Landing
Peskowesk
MERSEY
New Albany
West Caledonia
47
46
76
77
75
79
80
82



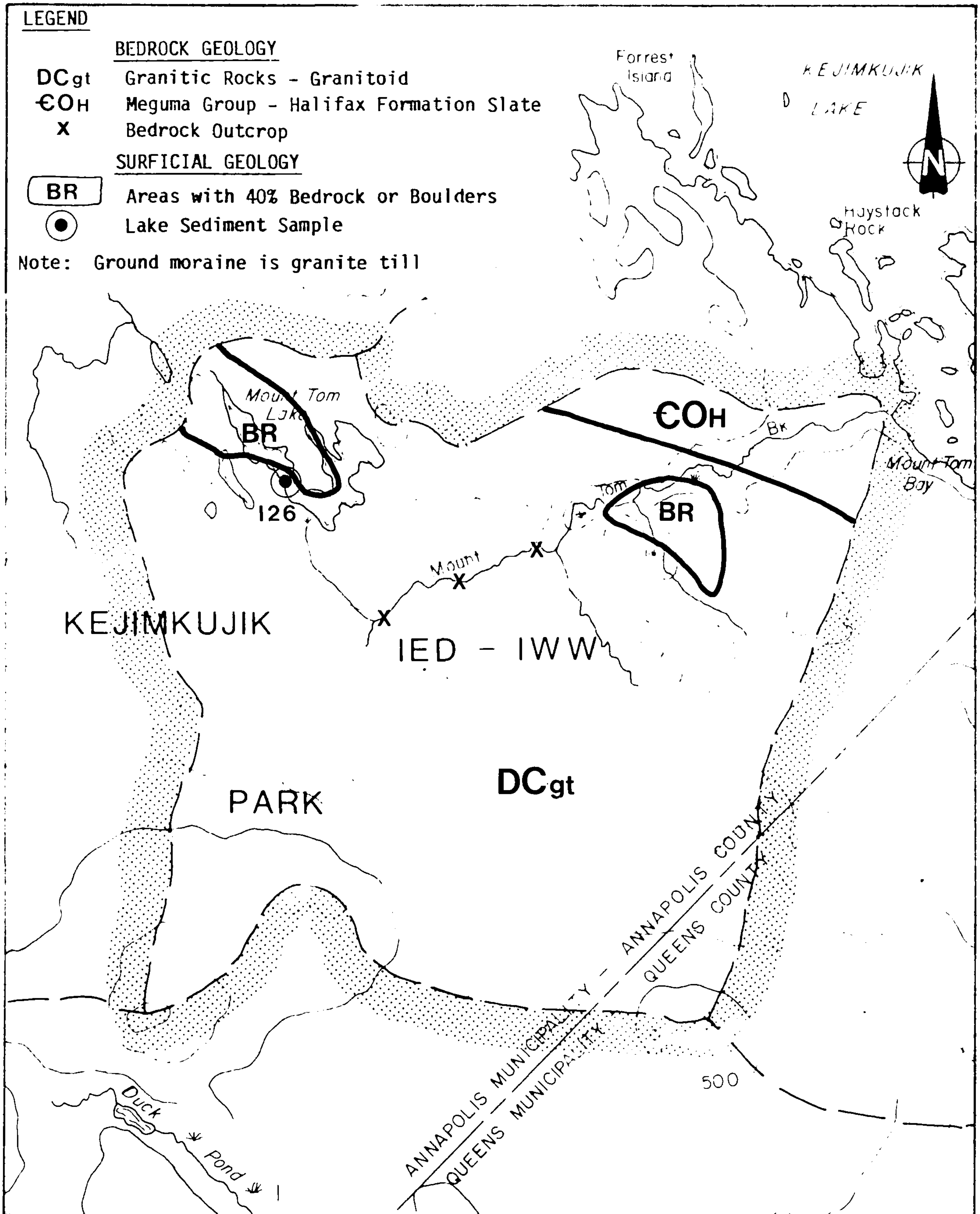
LEGEND

(70-85 / 18) WATER QUALITY MONITORING STATION (long term)

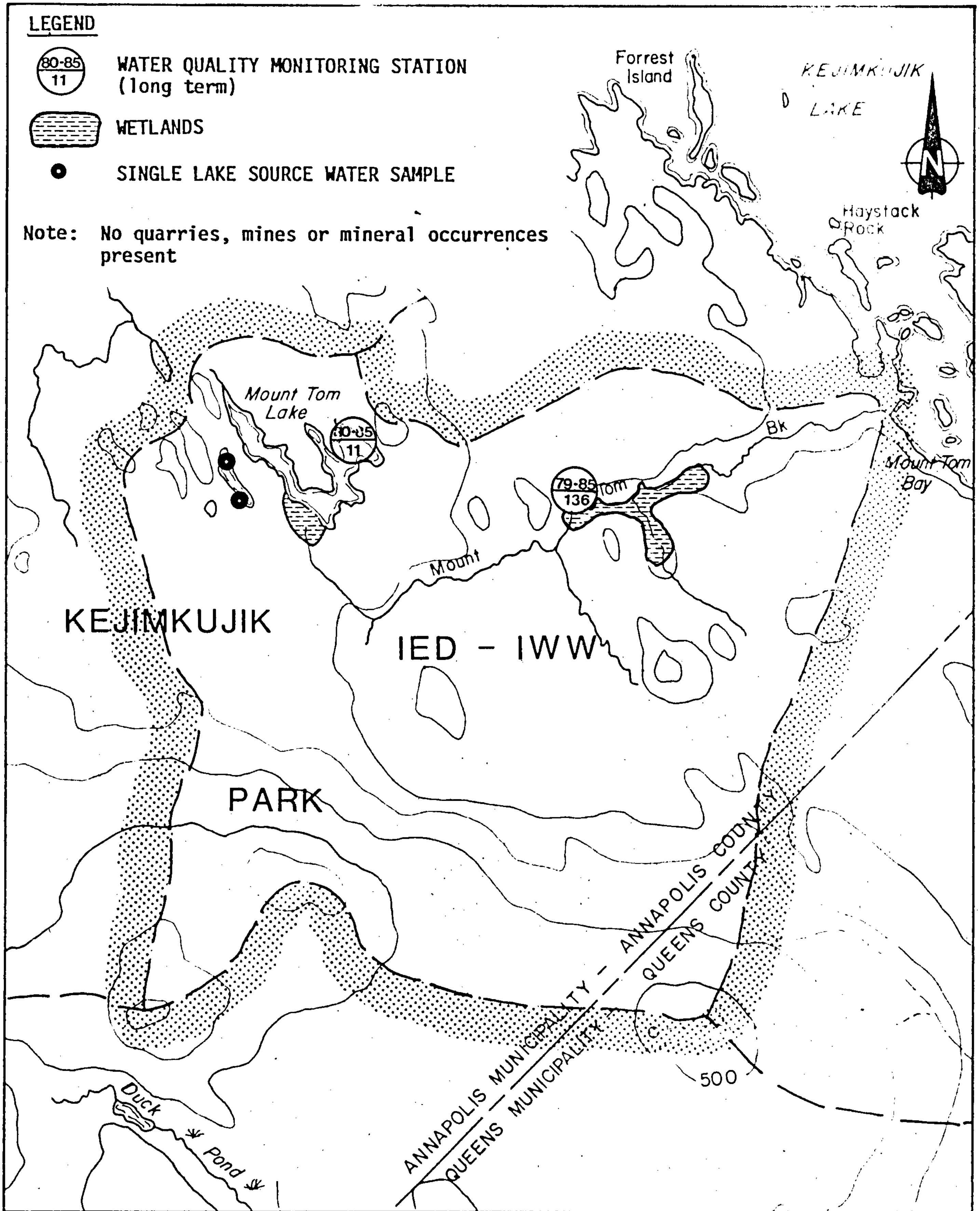
WETLANDS

Note: No quarries, mines or mineral occurrences present

PORTER DILLON Consulting Engineers • Planners • Environmental Scientists	TITLE ANTHROPOGENIC CHARACTERISTICS – GRAFTON LAKE WATERSHED	SCALE 1:50 000
DATE MARCH, 1987	PROJECT A SURVEY OF NATURAL SOURCE POLLUTANTS IN THE MEGUMA GROUP	FIGURE No 4-4



PORTER DILLON	GEOLOGY - MOUNT TOM WATERSHED	SCALE 25 000
MARCH, 1987	PROJECT A SURVEY OF NATURAL SOURCE POLLUTANTS IN THE MEGUMA GROUP	4-5



PORTER DILLON

TITLE ANTHROPOGENIC CHARACTERISTICS - MOUNT TOM WATERSHED

SCALE 25 000

PROJECT A SURVEY OF NATURAL SOURCE POLLUTANTS IN THE MEGUMA GROUP

DATE MARCH, 1987

4-6

The bedrock geology underlying this watershed is primarily composed of Devonian-Carboniferous granitoid which denotes low risk. In the northern section, a small area adjacent to Kejimkujik Lake is underlain by Halifax Formation, Cunard Member slate exhibiting biotite grade metamorphism. This slate area, however, is also designated low risk in that it falls within the 2000 m region affected by contact metamorphism from the nearby granite.

The surficial geology of the Mount Tom watershed is dominated by granite till ground moraine, however, several areas of bedrock outcropping do occur. Both drumlins and sand and gravel deposits are entirely absent. Figure 4-5 also denotes the presence of a single lake sediment sample (#126 - Mount Tom Lake), the results of which are included in Appendix A.

Anthropogenic characteristics are depicted in Figure 4-6 and are confined to water quality monitoring stations and the location of single lake source samples. The watershed is generally devoid of other manmade disturbances such as quarries and mines. This diagram also notes the location and extent of wetlands within the drainage basin.

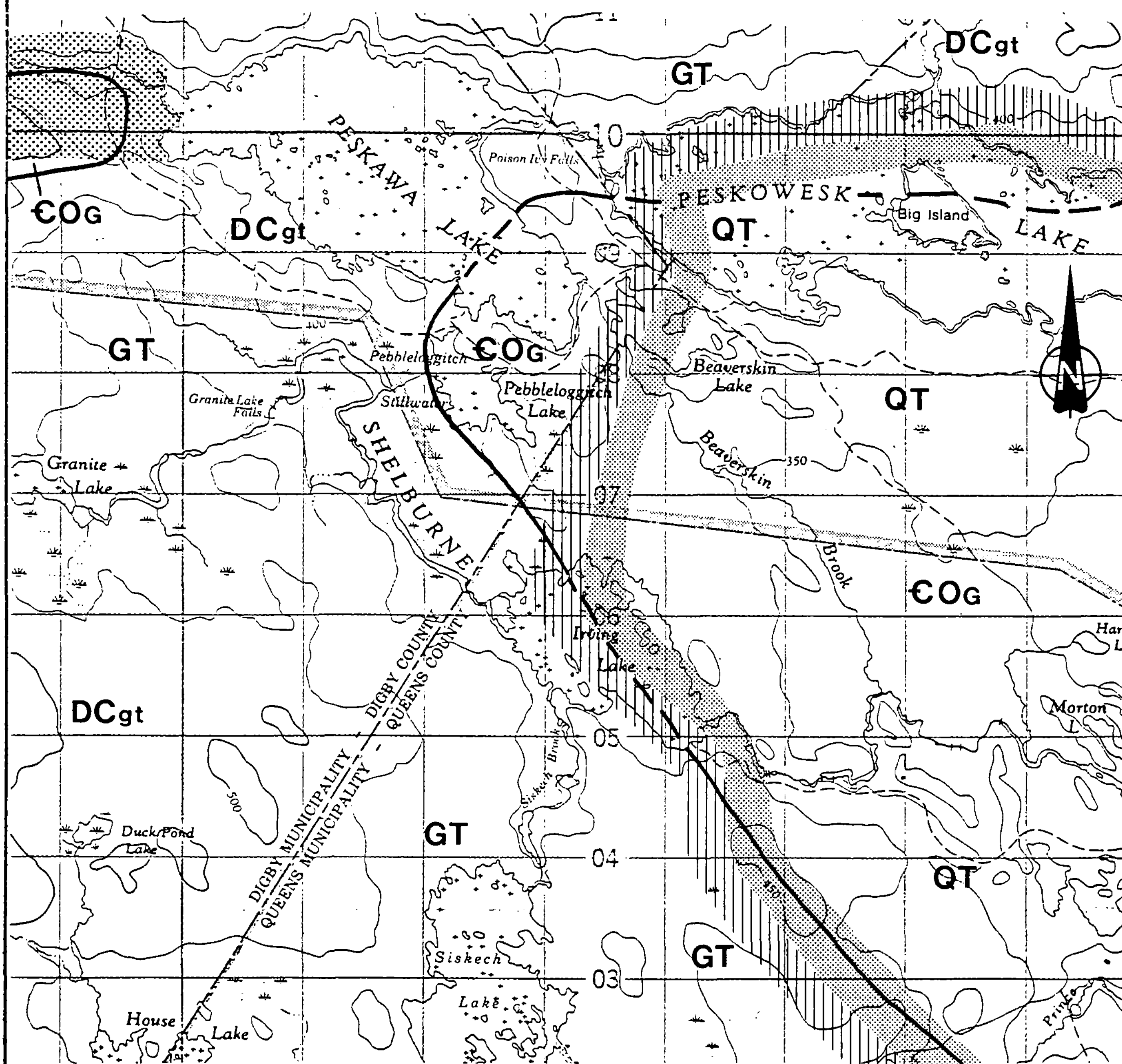
4.1.4 Pebbleloggitch and Beaverskin Lake Watersheds

The Pebbleloggitch and Beaverskin Lake drainage basins have been designated through water quality work by others (Kerekes, et. al., 1986a and 1986b) to have no risk with respect to the potential to produce acid drainage. To compare these watersheds with the three study area watersheds, Figures 4-7 and 4-8 depict the geological and anthropogenic characteristics of the Pebbleloggitch-Beaverskin lake areas.

The bedrock geology of these watersheds is dominated by Goldenville Formation quartzites. In the southwestern section, a

LEGEND

	SURFICIAL GEOLOGY DESIGNATION	———	BEDROCK GEOLOGY BOUNDARY
QT	Quartzite Till	DCgt	Granitic Rock - Granitoid
GT	Granite Till	ЄOG	Meguma Group - Goldenville Formation Quartzite
	Sand and Gravel		



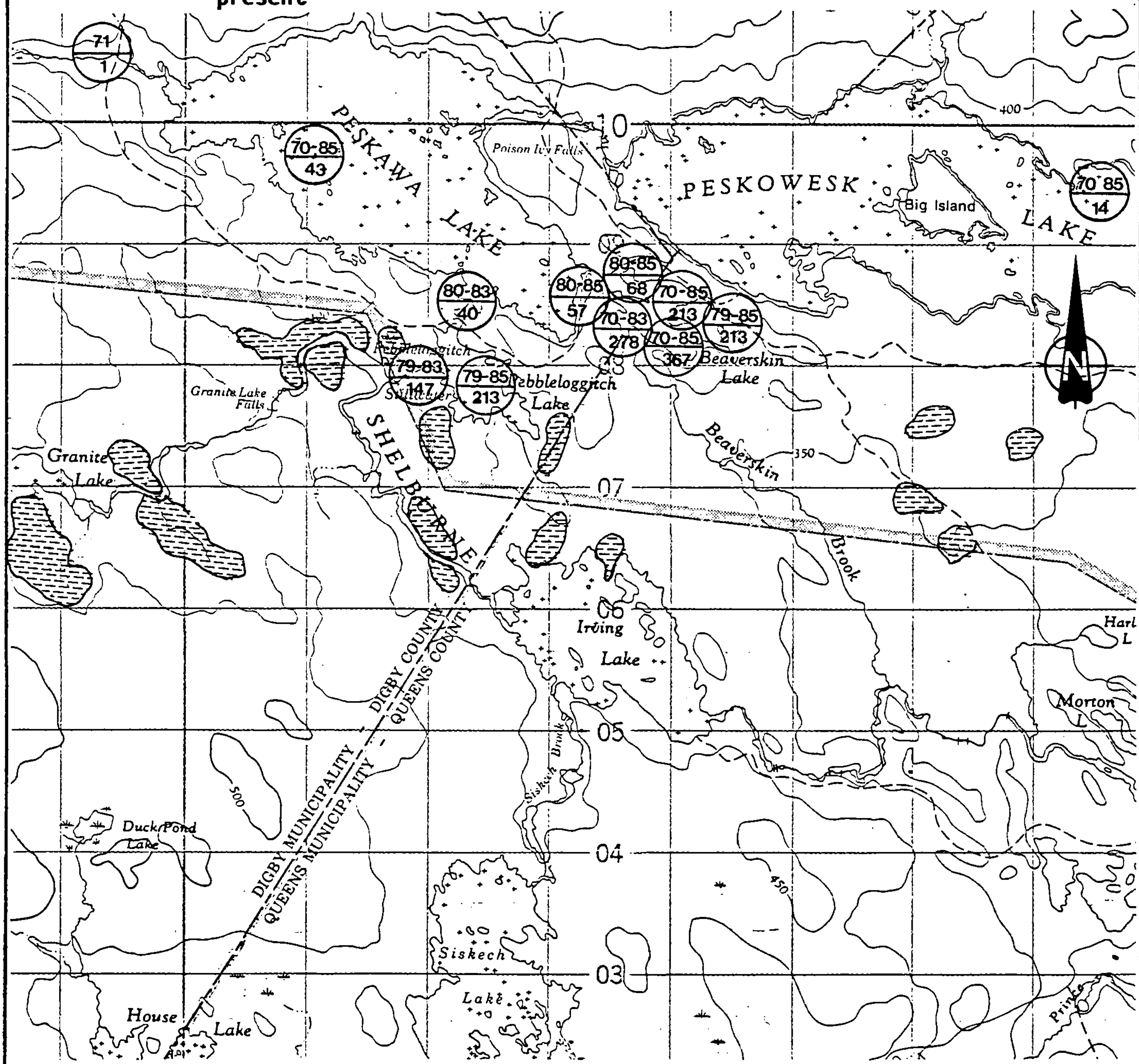
PORTER DILLON Consulting Engineers • Planners • Environmental Scientists	TITLE GEOLOGY - PEBBLELOGGITCH/ BEAVERSKIN LAKE WATERSHEDS	SCALE 1:50,000
DATE MARCH, 1987	PROJECT A SURVEY OF NATURAL SOURCE POLLUTANTS IN THE MEGUMA GROUP	FIGURE No. 4-7

LEGEND

70 85 / 14 — WATER QUALITY MONITORING STATION (long term)

WETLANDS

Note: No quarries, mines or mineral occurrences present



PORTER DILLON Consulting Engineers • Planners • Environmental Scientists	TITLE ANTHROPOGENIC CHARACTERISTICS - PEBBLELOGGITCH/BEAVERSKIN LAKE WATERSHEDS	SCALE 1:50,000
DATE MARCH, 1987	PROJECT A SURVEY OF NATURAL SOURCE POLLUTANTS IN THE MEGUMA GROUP	FIGURE No. 4-8

small area adjacent to Pebbleloggitch Lake is underlain by Devonian-Carboniferous granitoid. Both watersheds are of high regional metamorphic grade (garnet/biotite) and contact metamorphic grade (<2000 m from granite).

The surficial geology of these watersheds is composed of two specific till units. The drainage basins are dominated by granite till with quartzite till being secondary and located in the extreme eastern section of the watersheds adjacent to Beaverskin Lake. Other surficial features such as drumlins, sand/gravel deposits and lake sediment sample locations are generally absent.

Anthropogenic characteristics depicted in Figure 4-8 are confined to water quality monitoring stations in and adjacent to the specific watersheds. Wetlands have also been noted, however, the area is devoid of man-made disturbances such as mines and quarries.

4.2 WATER QUALITY

4.2.1 Information Sources

The present study has made use of currently available information in developing the predictive model and the risk mapping. With respect to water quality data, no field data collection has been undertaken, but all available sources of comprehensive surface water chemistry data have been identified and relevant data have been compiled and interpreted.

The water sampling locations within the five study area watersheds are shown on the individual map sheets. Data sources for all watersheds are primarily the water samples collected by federal agencies, the results of which are stored on the NAQUADAT database system. Supplementary lake chemistry data collected by the Nova Scotia Departments of the Environment and Lands & Forests have also been examined.

Various authors have examined water chemistry in southwestern Nova Scotia rivers and lakes (see for example, Howell 1986; Kerekes et. al., 1986a and 1986b; Underwood et. al., in press). Some of these studies reported on water chemistry in study watersheds examined herein. Consequently, the following discussion of water chemistry is presented in a manner consistent with the presentation formats in the work of other authors.

4.2.2 Comparative Water Quality Profile

In order to examine possible influences of natural source acidic drainage on the watersheds being investigated, several water quality parameters have been examined in detail. These are pH, alkalinity, excess sulphate, calcium and magnesium, iron, aluminum and organic anion. Some parameters would be expected to reflect directly the influences of acidic drainage, while others would be used in the interpretation of baseline quality.

For purposes of comparison, quality of runoff from disturbed pyritic bedrock, as measured at the Halifax International Airport (Lund, 1987), is compared below to natural ranges measured in the five watersheds under consideration in the study region:

	Ranges Reported in ueq/L	
Parameters	Disturbed Bedrock	Five Study Watersheds
pH	2.95-3.35 units	3.70-6.90 units
Fe	12 300-79 600	1-36
Al	14 200-49 400	1-56
SO4	3 100-151 700	1-640

A general profile of water chemistry in the five watersheds is presented in Figures 4-9 through 4-12, showing "box and whisker" plots* of various parameters. Data sources for all watercourses except West LaHave are NAQUADAT river/lake quality data for 1980 to 1986 inclusive. West LaHave data include quality analyses for seven individual lakes sampled by the Nova Scotia Department of Lands and Forests.

The main LaHave water quality data are from the station at West Northfield, upstream of the confluence with the West LaHave River; nonetheless these data are included for the sake of completeness and comparison with the other watersheds. Data for Grafton, Mount Tom, Pebbleloggitch and Beaverskin are from the single long-term monitoring stations in each watershed.

Figure 4-9 shows pH and colour levels. Median pH levels in main LaHave, West LaHave and Grafton watersheds are similar. Median pH in Mount Tom and Pebbleloggitch is considerably lower, but Beaverskin pH is closer to that of the LaHave and Grafton watersheds. Median colour is highest in Pebbleloggitch and Mount Tom watersheds, and lowest in Beaverskin. Median colour in the main LaHave, at 50 colour units, is considerably higher than that observed in the seven lakes in the West LaHave watershed.

Figure 4-10 illustrates the hardness and buffering capacities of the waters in the five study area watersheds. Median sea salt corrected Calcium levels (Ca*)+ show a decreasing trend from east to west. The highest median Ca* concentration is

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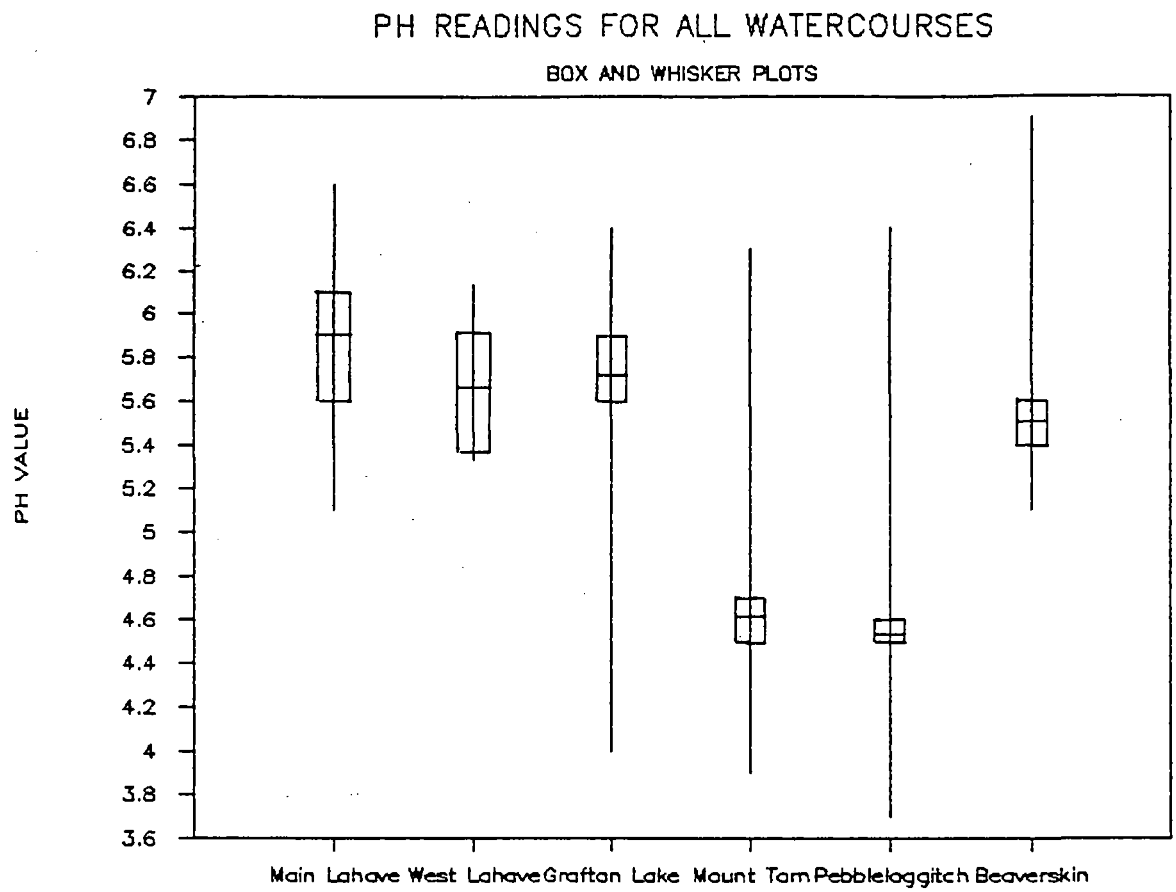
* The box and whisker format illustrates maximum, minimum, 75%-ile, 25%-ile and median readings.

+ The * indicates a correction for sea salt influence on the noted parameter.

FIGURE 4-9


PH READINGS FOR ALL WATERCOURSES
BOX AND WHISKER PLOTS
PH VALUE
7
6.8
6.6
6.4
6.2
6
5.8
5.6
5.4
5.2
5
4.8
4.6
4.4
4.2
4
3.8
3.6
Main Lahave
West Lahave
Grafton Lake
Mount Tom
Pebbleloggitch
Beaverskin

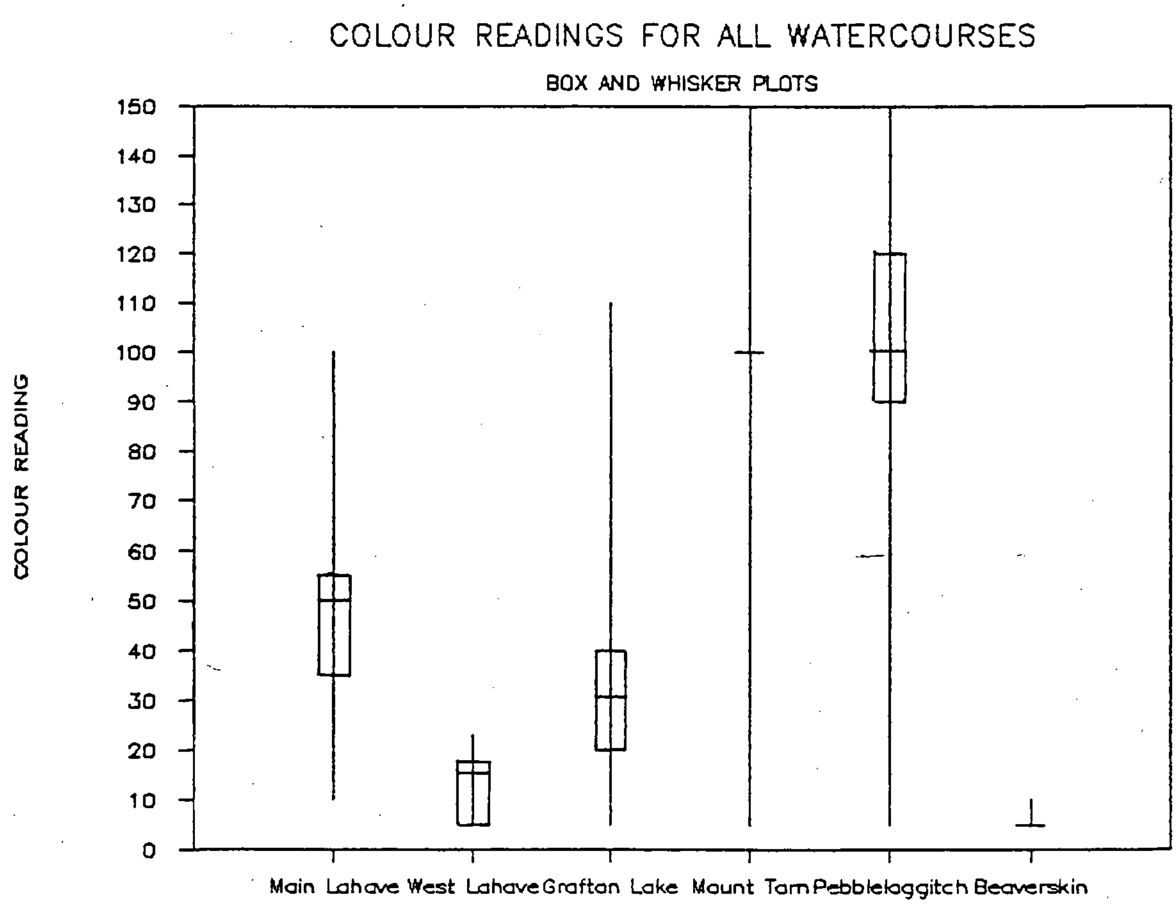
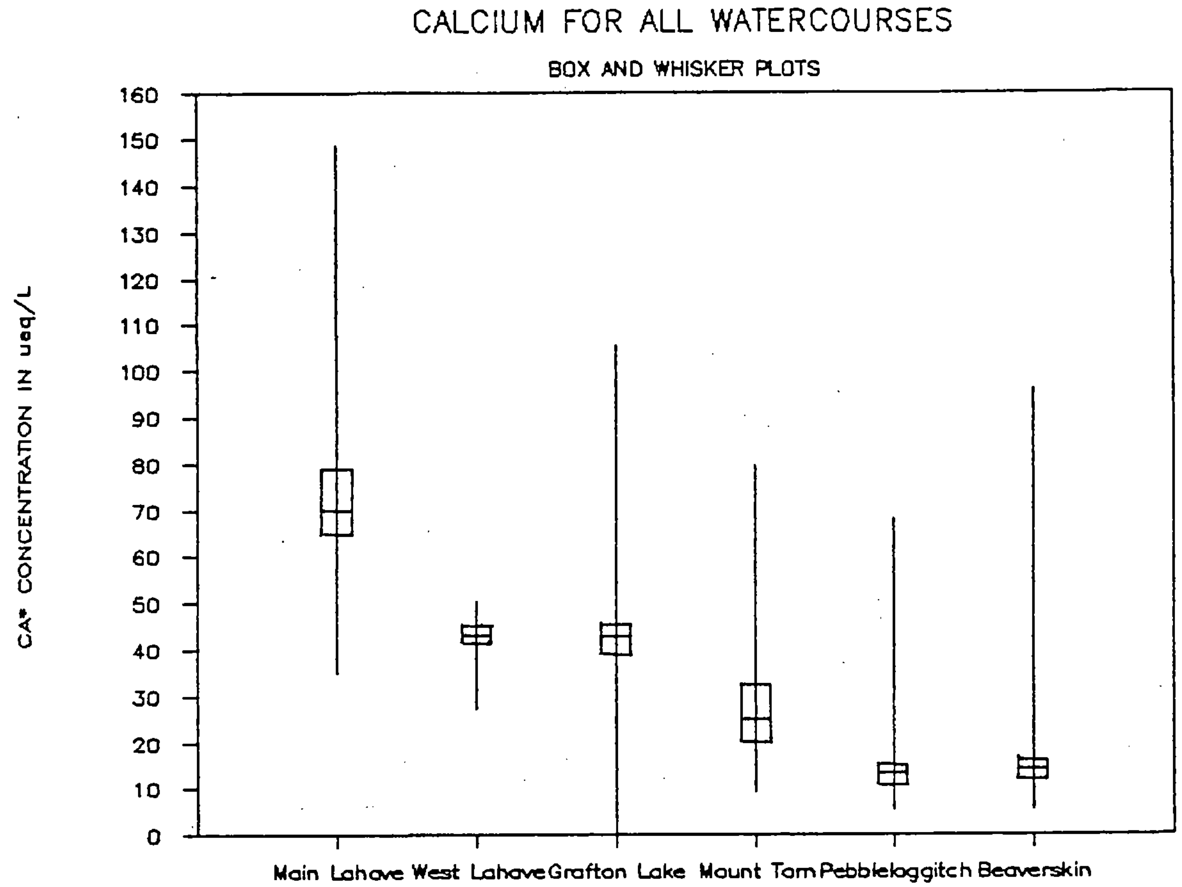

COLOUR READINGS FOR ALL WATERCOURSES
BOX AND WHISKER PLOTS
COLOUR READING
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
Main Lahave
West Lahave
Grafton Lake
Mount Tom
Pebbleloggitch
Beaverskin

FIGURE 4-10


CALCIUM FOR ALL WATERCOURSES
BOX AND WHISKER PLOTS
CA* CONCENTRATION IN ueq/L
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
Main Lahave
West Lahave
Grafton Lake
Mount Tom
Pebbleloggitch
Beaverskin

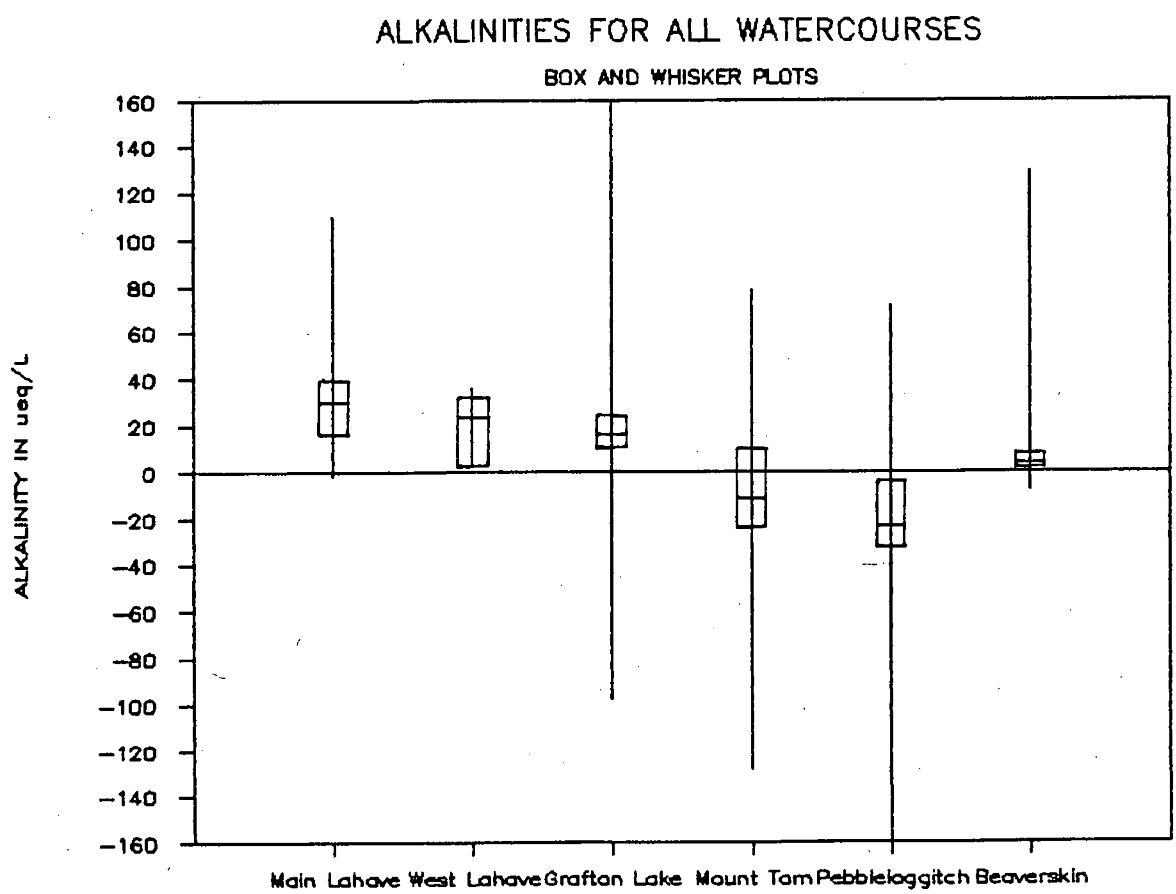
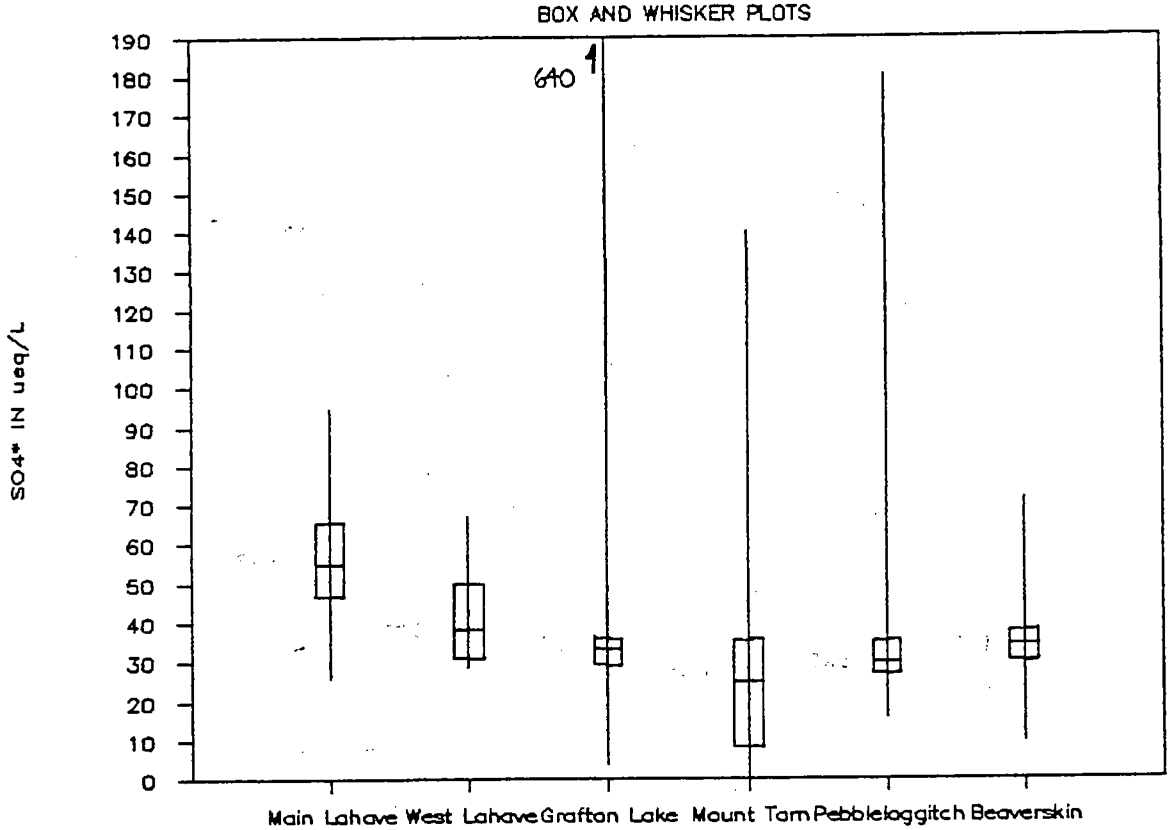

ALKALINITIES FOR ALL WATERCOURSES
BOX AND WHISKER PLOTS
ALKALINITY IN ueq/L
160
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
-140
-160
Main Lahave
West Lahave
Grafton Lake
Mount Tom
Pebbleloggitch
Beaverskin

FIGURE 4-11

SO4* READINGS FOR ALL WATERCOURSES

BOX AND WHISKER PLOTS



ORGANIC ANION FOR ALL WATERCOURSES

BOX AND WHISKER PLOTS

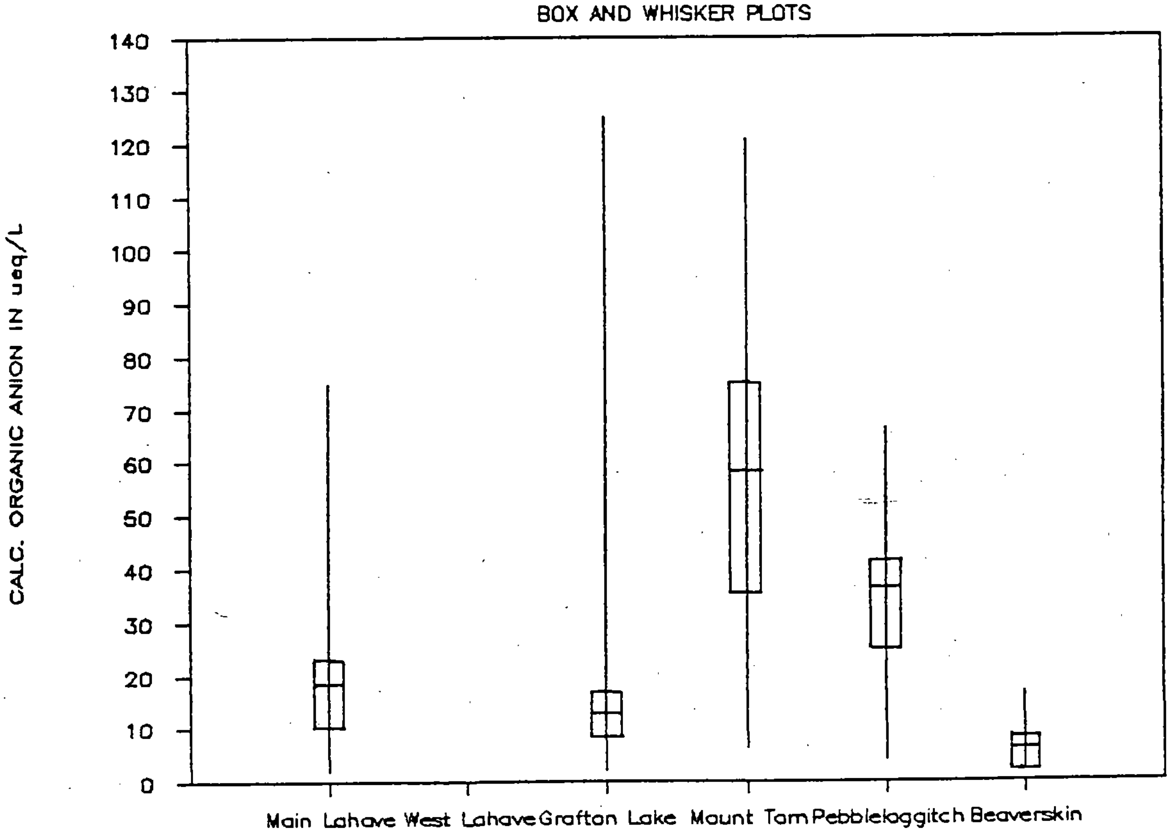
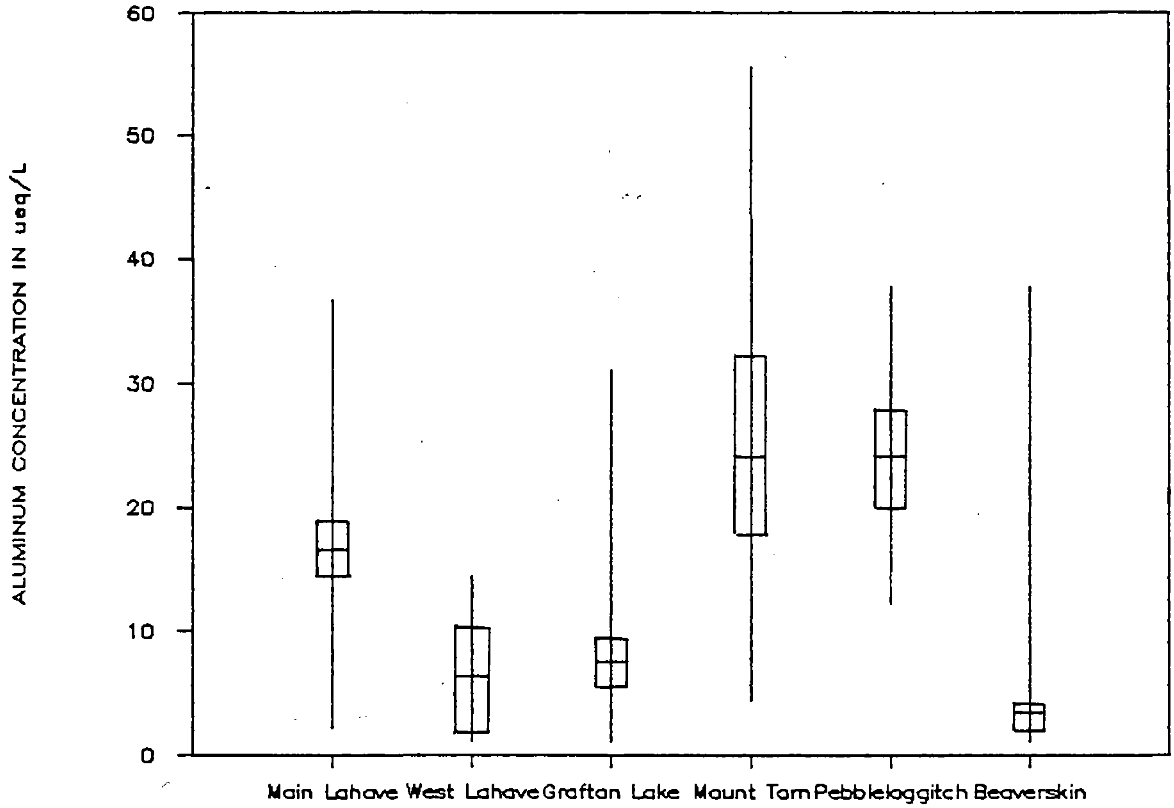


FIGURE 4-12

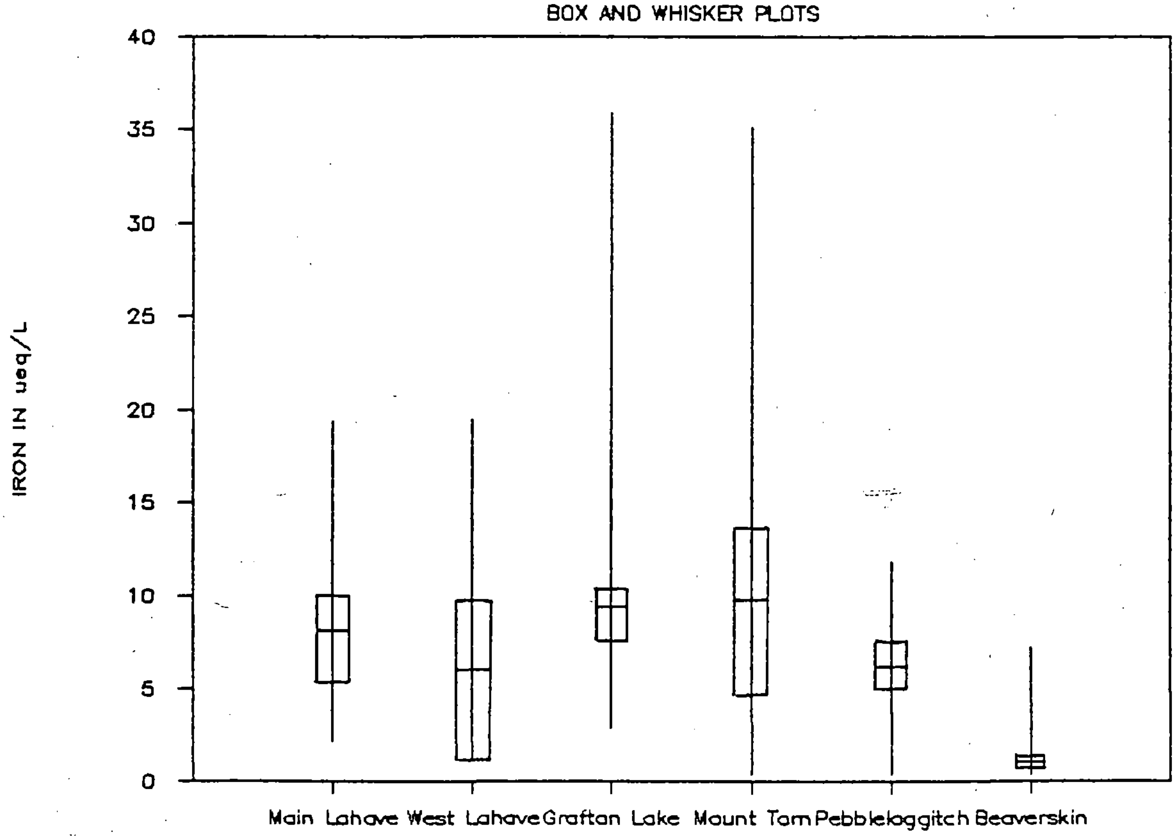
ALUMINUM READINGS FOR ALL WATERCOURSES

BOX AND WHISKER PLOTS



IRON CONCENTRATION FOR ALL WATERCOURSES

BOX AND WHISKER PLOTS



observed in the main LaHave at 70.3 ueq/L (1.4 mg/L) while the lowest is in Pebbleloggitch at 12 ueq/L (0.24 mg/L). On this basis, the waters in the study areas are considered dilute.

Total and Gran alkalinities have been combined to produce the second plot in Figure 4-10. While such a combination may not be scientifically rigorous, it does illustrate that buffering capacity shows a decreasing trend from east to west. Median alkalinities are positive in the LaHave, Grafton and Beaverskin watersheds and negative in Mount Tom and Pebbleloggitch. Even in those watersheds with positive values, median buffering capacity is extremely limited being 25 ueq/L (1.25 mg/L) in the main LaHave and decreasing to the west.

Figure 4-11 shows sea salt corrected Sulphate (SO_4*) and calculated organic anion (A^-) concentrations. Sulphate in all watersheds except the West LaHave is reported with the ion chromatograph (IC) method which is not subject to interference from humic materials (Kerekes and Pollock, 1983; Howell, 1986). Sulphate readings in the West LaHave lakes are also corrected for humic interference but are not obtained with the IC method (Underwood, personal communication).

Median SO_4* concentrations are relatively low in all watersheds and show a slight decreasing trend from east to west. The highest median SO_4* is in the main LaHave at 54.4 ueq/L (2.6 mg/L). This level is considerably lower than the levels considered to be representative of lakes which may be affected by pyrite rock drainage (Kerekes et al, 1986a, b). According to these authors, SO_4* concentrations in drainages over pyrite bearing rocks may be 200 to 700 ueq/L. Data from the Department of Lands and Forests' lake survey program also illustrate high SO_4* values (130 to 150 ueq/L) in lakes known to be affected by acid drainage (such as Soldier and Miller Lakes) but they are somewhat lower than values reported by Kerekes.

Median levels do not illustrate the extremes, also shown on Figure 4-11, which may suggest seasonal or rainfall-induced changes in SO_4* levels. These are discussed more fully later.

Calculated organic anion is based on the assumption that the difference between the methyl-thymol blue (MTB) and IC methods of measuring SO_4 is a reasonably good estimate of A^- concentration (Howell, 1986). Because of analytical techniques, therefore, the A^- estimates are not available for the West LaHave lakes, but are available for the other study area watersheds.

Median A^- concentrations, shown in the second part of Figure 4-11, are seen to be highest in the Mount Tom watershed, second highest in Pebbleloggitch and much lower in the Main LaHave, Grafton and Beaverskin watersheds. As expected, these results display qualitative similarity with the median colour readings in Figure 4-9.

The concentrations of aluminum (Al) and iron (Fe) measured in the study area watersheds are shown in Figure 4-12. The highest median Al concentrations, at 23.3 ueq/L (0.21 mg/L) are observed in the Mount Tom and Pebbleloggitch watersheds, while the lowest median concentration of 3.3 ueq/L (0.03 mg/L) is reported for Beaverskin. The highest median values are well in excess of the limit of 0.1 mg/L suggested for protection of the aquatic environment (McNeely et al, 1979). As shown on Figure 4-9, the lowest pH waters in the study area are also in the Mount Tom and Pebbleloggitch watersheds. However, while it is recognized that lower pH levels may result in greater mobilization of Al, it is also known that the speciation of aluminum is very important in assessing environmental significance. Clair and Komadina (1984) report that in some organic-rich waters of Nova Scotia, Al may be complexed to organic compounds and be essentially unharmful to aquatic biota. This may well occur in some of the study area watersheds under consideration.

Median iron (Fe) concentrations are between 5.9 and 9.3 ueq/L (0.16 and 0.26 mg/L) in all watersheds except Beaverskin, where the concentration is only 1.0 ueq/L (0.03 mg/L). It is probable that the presence of Fe is also related to the presence of high molecular weight organics. Median concentrations are lower than the 0.3 mg/L level suggested for protection of the aquatic environment (McNeely et al, 1979).

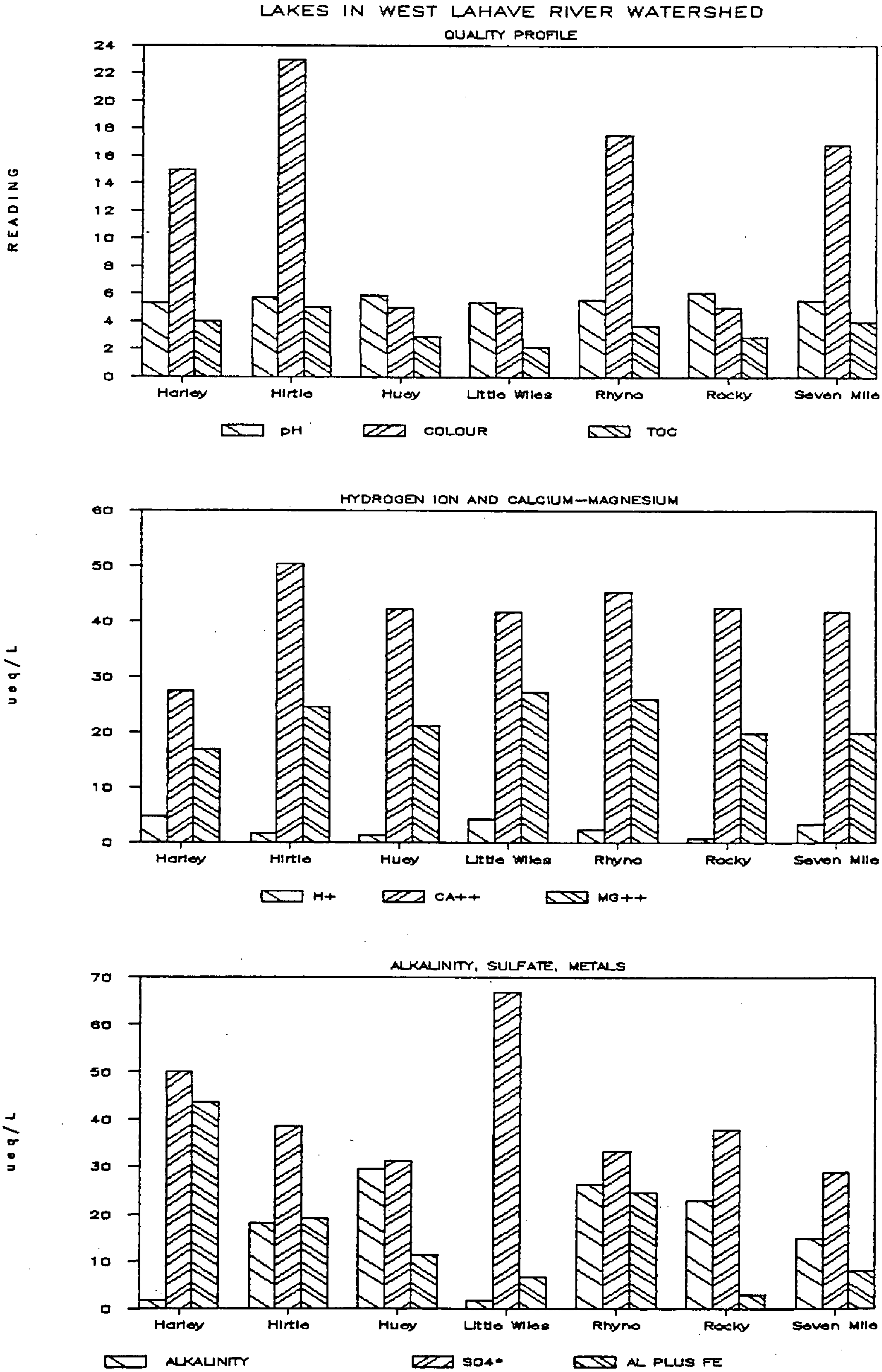
Greater detail on the seven individual lakes in the West LaHave River watershed is provided on Figure 4-13. Generally, the bar plots illustrate similarity in pH and hardness levels but variations in colour, alkalinity, sulphate and metals. Colour varies from less than 5 in Little Wiles Lake to over 23 units in Hirtle Lake. Alkalinity varies from close to nil to about 30 ueq/L. The highest SO_4* reading is observed in Little Wiles Lake at 67 ueq/L (3.22 mg/L). None of these data suggest gross contamination of waters from pyritic slate runoff, however it must be recognized that the data provide no indication of temporal variabilities.

4.2.3 Seasonal Water Quality Variations

Recognizing that the influences on water quality from pyritic slate runoff may be highly limited in time, it is essential to examine seasonal water quality variations in the study area watersheds. The following presentation examines seasonal trends in the main LaHave, Grafton, Mount Tom and Pebbleloggitch watersheds. The Beaverskin Lake system is not examined further because its quality is not representative of the other watersheds being examined herein. Figures 4-14 to 4-18 illustrate the data examined.

Figure 4-14 illustrates stream discharge (November 1981 to January 1984) and selected water quality parameters for the main LaHave River at West Northfield. Seasonal variations in

FIGURE 4-13



LAKES IN WEST LAHAVE RIVER WATERSHED
QUALITY PROFILE
READING
0
2
4
6
8
10
12
14
16
18
20
22
24
Harley
Hirtle
Huey
Little Wiles
Rhyno
Rocky
Seven Mile
pH
COLOUR
TOC
HYDROGEN ION AND CALCIUM—MAGNESIUM
ueq/L
0
10
20
30
40
50
60
Harley
Hirtle
Huey
Little Wiles
Rhyno
Rocky
Seven Mile
H+
CA++
MG++
ALKALINITY, SULFATE, METALS
ueq/L
0
10
20
30
40
50
60
70
Harley
Hirtle
Huey
Little Wiles
Rhyno
Rocky
Seven Mile
ALKALINITY
SO4*
AL PLUS FE

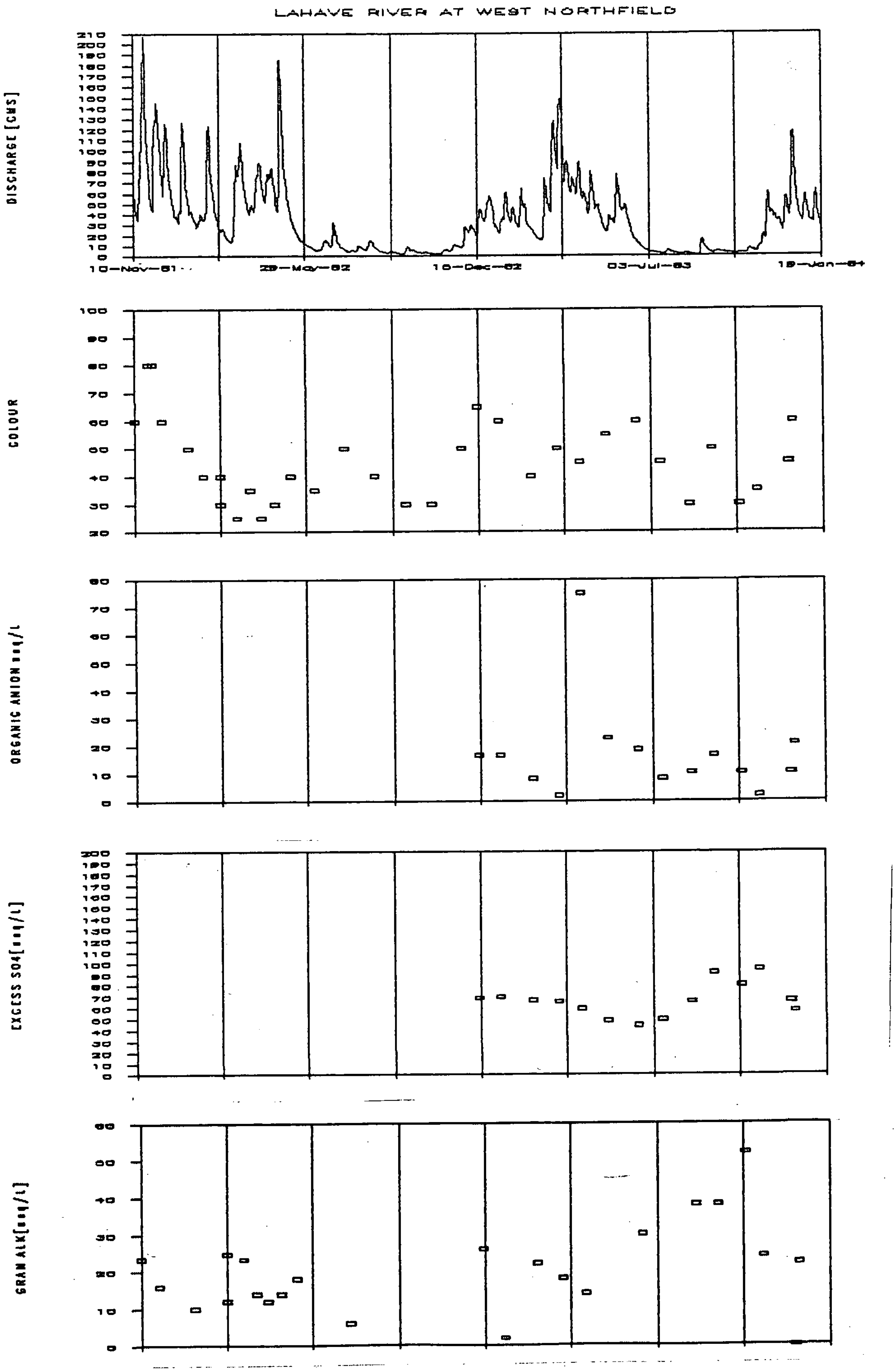


Figure 4-14 - Seasonal Quality in LaHave River, 1981-1984

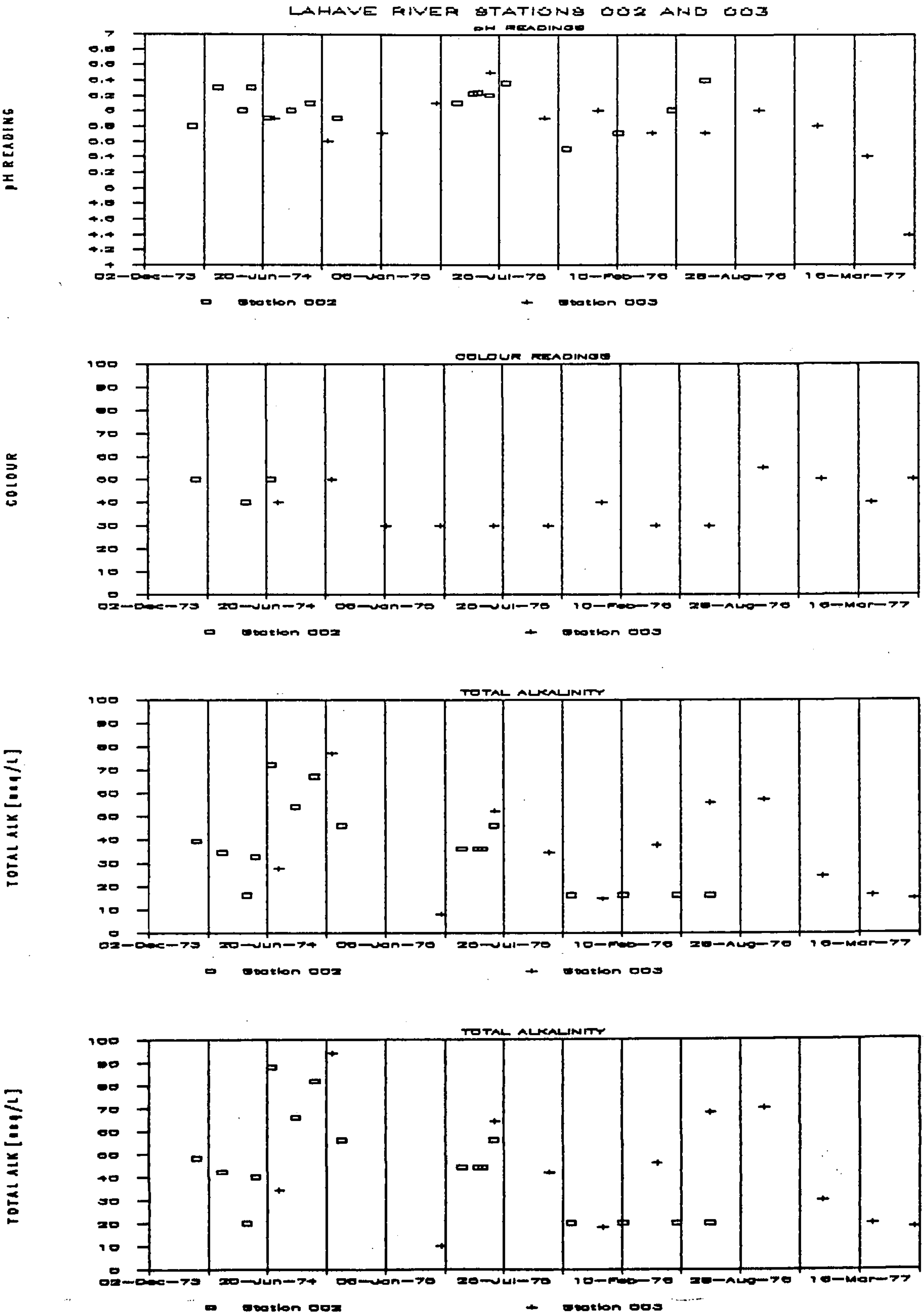


Figure 4-15 - Seasonal Quality in LaHave River, 1973-1977

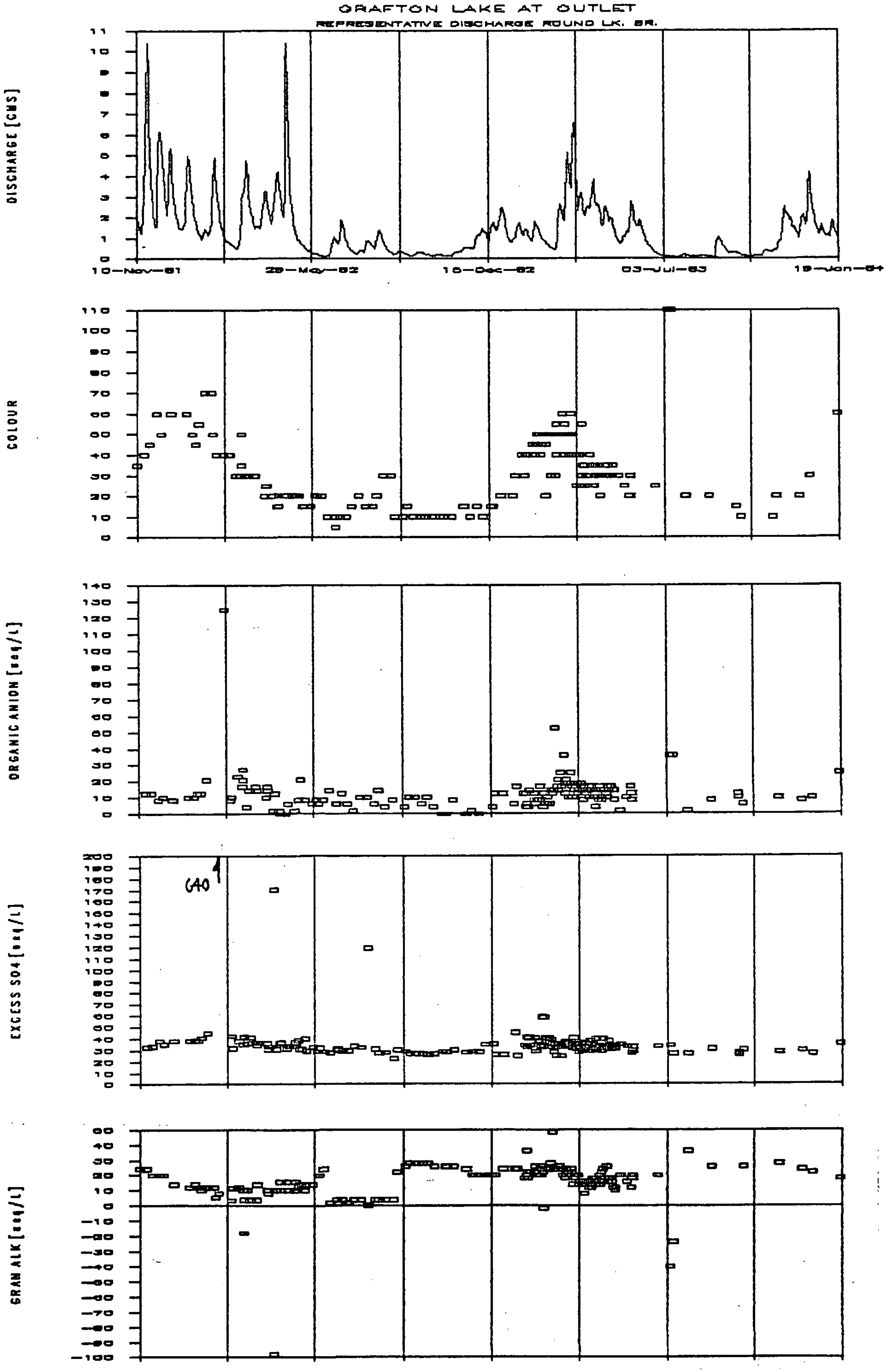


Figure 4-16 - Seasonal Quality in Grafton Lake, 1981-1984

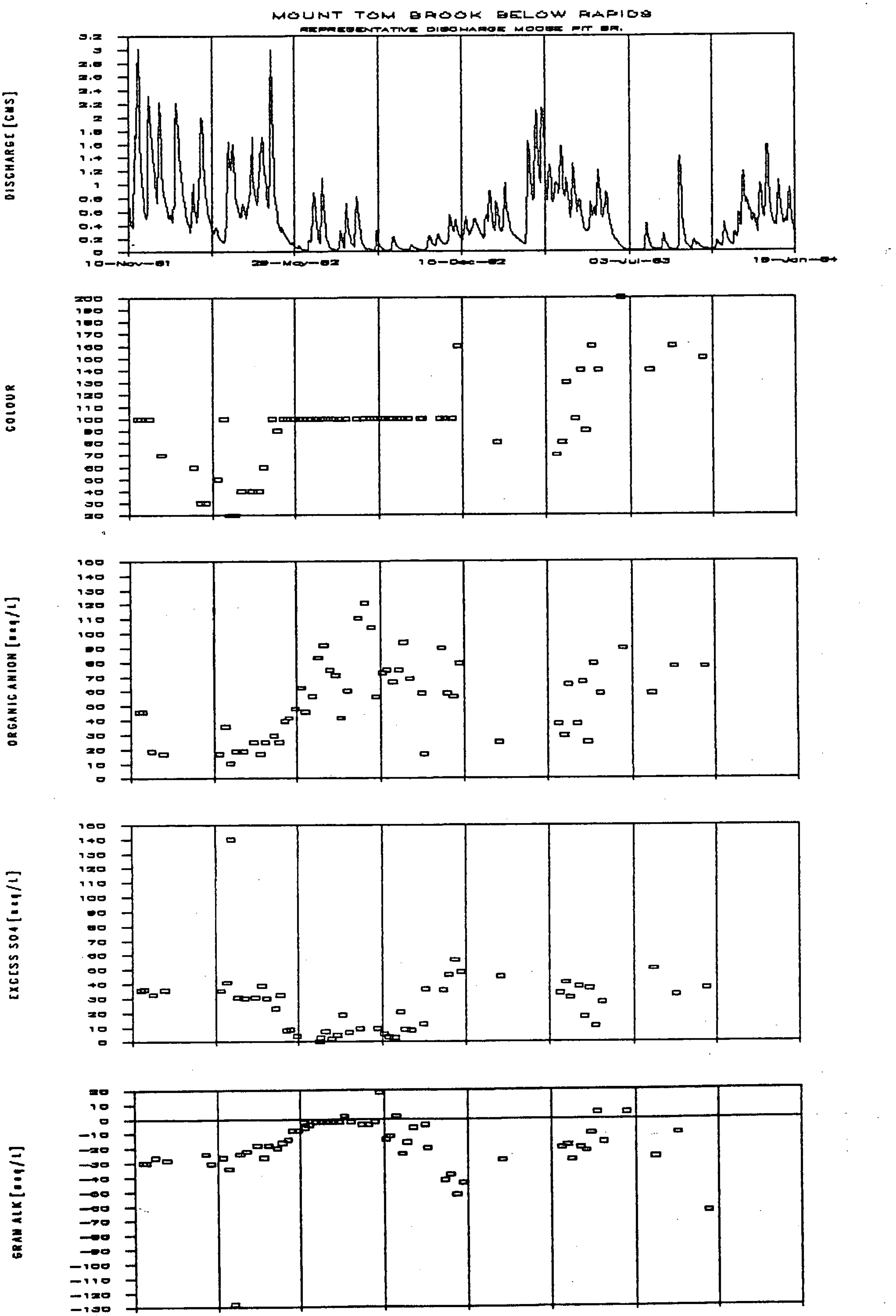


Figure 4-17 - Seasonal Quality in Mount Tom Brook, 1981-1984

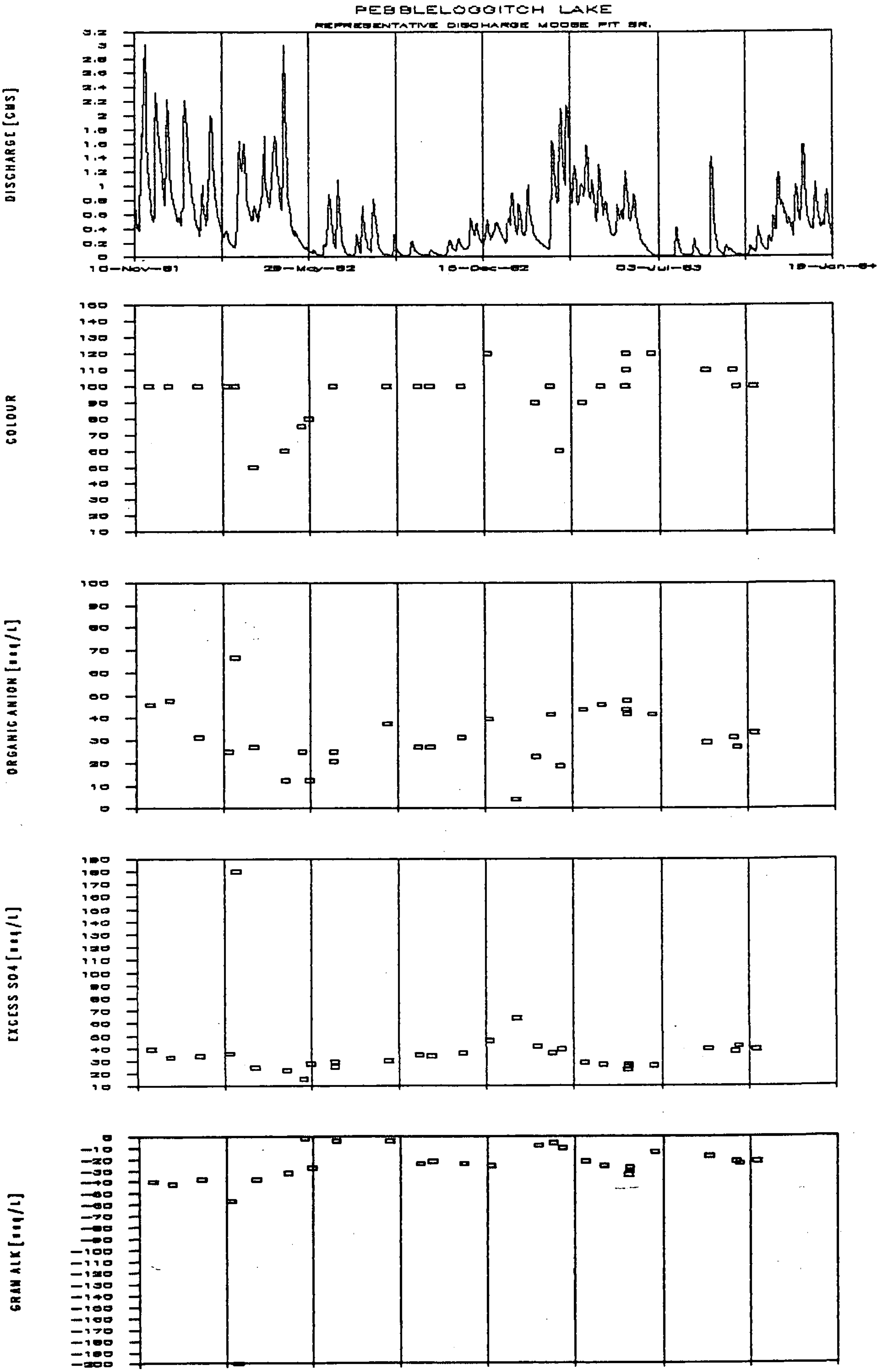


Figure 4-18 - Seasonal Quality in Pebbleloggitch Lake, 1981-1984 colour are evident, however no clear trend is observable. Variations in A^- and SO_4* are shown for the portion of the period where these data are available. Maximum SO_4* readings appear to occur during the fall period, at the same time that A^- readings are dropping. However, very limited data are available with which to confirm these apparent seasonal fluctuations.

A temporal illustration of selected water quality parameters in the main LaHave River at two stations (one upstream and the other downstream of the confluence with the West LaHave River) is shown in Figure 4-15. These plots provide data for the 1974 to 1976 period, the only time during which both quality stations were operating simultaneously. Based on these plots, there appears to be no substantial difference in pH and colour in the main LaHave River between the two monitoring stations. Sulphate (MTB analysis method, not corrected for colour interference or for sea salt contribution) readings appear dissimilar between the two stations, but the variations are not consistent. Based on this information, it is not possible to conclude whether drainage from the West LaHave River has a significant effect on Main LaHave River water quality.

Figure 4-16 shows water quality variations at the Grafton Lake outflow monitoring station for the November 1981 to January 1984 period. Discharge for Round Lake Brook, near McGowan Lake, is also shown as a representative flow rate for the same period. Temporal variations in colour are evident with the highest readings occurring during the spring runoff period and the lowest during summers. Concentrations of SO_4* and A^- appear to be quite constant throughout the year, however. Sulphate is quite constant seasonally at between 30 and 40 ueq/L (1.4 and 1.9 mg/L). Review of the raw data records shows that, for the period of time examined, three SO_4* readings above 100 ueq/L were measured:

DATE	SO_4*	pH	FOLLOWING RAINFALL
16 February 1982	640	6.1	No
12 April 1982	170	4.0	Yes (14 mm)
28 July 1982	119	4.8	Yes (36 mm)

These events correspond with rainfall events based on AES data from the Kejimkujik Park Climate Station. These data points are of interest but are of such limited number as to be inconclusive.

Gran-alkalinity variations in the Grafton watershed are shown in the lower plot on Figure 4-16. These variations are not suggestive of seasonal trends.

Figure 4-17 illustrates water quality variations at the Mount Tom Brook monitoring station. Discharge for Moose Pit Brook, near McGowan Lake, is also shown as a representative flow rate for Mount Tom Brook for the period being examined. Temporal variations in colour are somewhat masked by the 100 unit limit on the measurement method which was applied until December 1982. However, it can fairly readily be inferred that the maximum colour levels (and the maximum organic anion concentrations) occur during the summer low flow season. In fact, the A^- concentration rises rapidly during the late spring-early summer period. At the same time, the SO_4* concentrations appear to drop to their lowest levels, remaining low during the summer, then rising during the fall-winter runoff period.

The bottom plot on Figure 4-17 shows variations in Gran alkalinity. It is seen that the negative Gran alkalinity is the near mirror image of SO_4* concentration. These seasonal variations in water quality correspond well with the patterns reported by Kerekes et al (1986a, b) for other coloured water tributaries of the Kejimkujik watershed.

The highest SO_4^* readings at the Mount Tom station are:

DATE	SO_4^*	pH	FOLLOWING RAINFALL
9 March 1982	140	3.9	Yes (37 mm)
11 October 1984	93.8	4.6	No

Figure 4-18 provides graphs showing water quality variations at the Pebbleloggitch Lake monitoring station. As with Mount Tom Brook, discharge for Moose Pit Brook is shown as a representative flow rate. The seasonal fluctuations in colour, SO_4^*, A^- and Gran alkalinity are similar to those observed in the Mount Tom watershed, though not as convincing because of fewer data points. Nonetheless, the variations in Pebbleloggitch Lake are considered by Kerekes et al (1986a, b) to be similar to those in other watersheds with peaty, organic drainages.

The highest SO_4^* reading at the Pebbleloggitch Lake Station is:

DATE	SO_4^*	pH	FOLLOWING RAINFALL
3 March 1982	180	3.7	No

Figures 4-19 and 4-20 illustrate, respectively, seasonal variations in SO_4^* and A^- for each of the four watersheds discussed previously. In comparing SO_4^* variations between Grafton, Mount Tom and Pebbleloggitch watersheds, it appears that the Grafton and Pebbleloggitch may be more similar to each other in that SO_4^* readings do not drop to zero in the summer months as they do in the Mount Tom watershed. This suggests that the hydrologic storage in the Mount Tom system may be dampening the SO_4^* variations through the year.

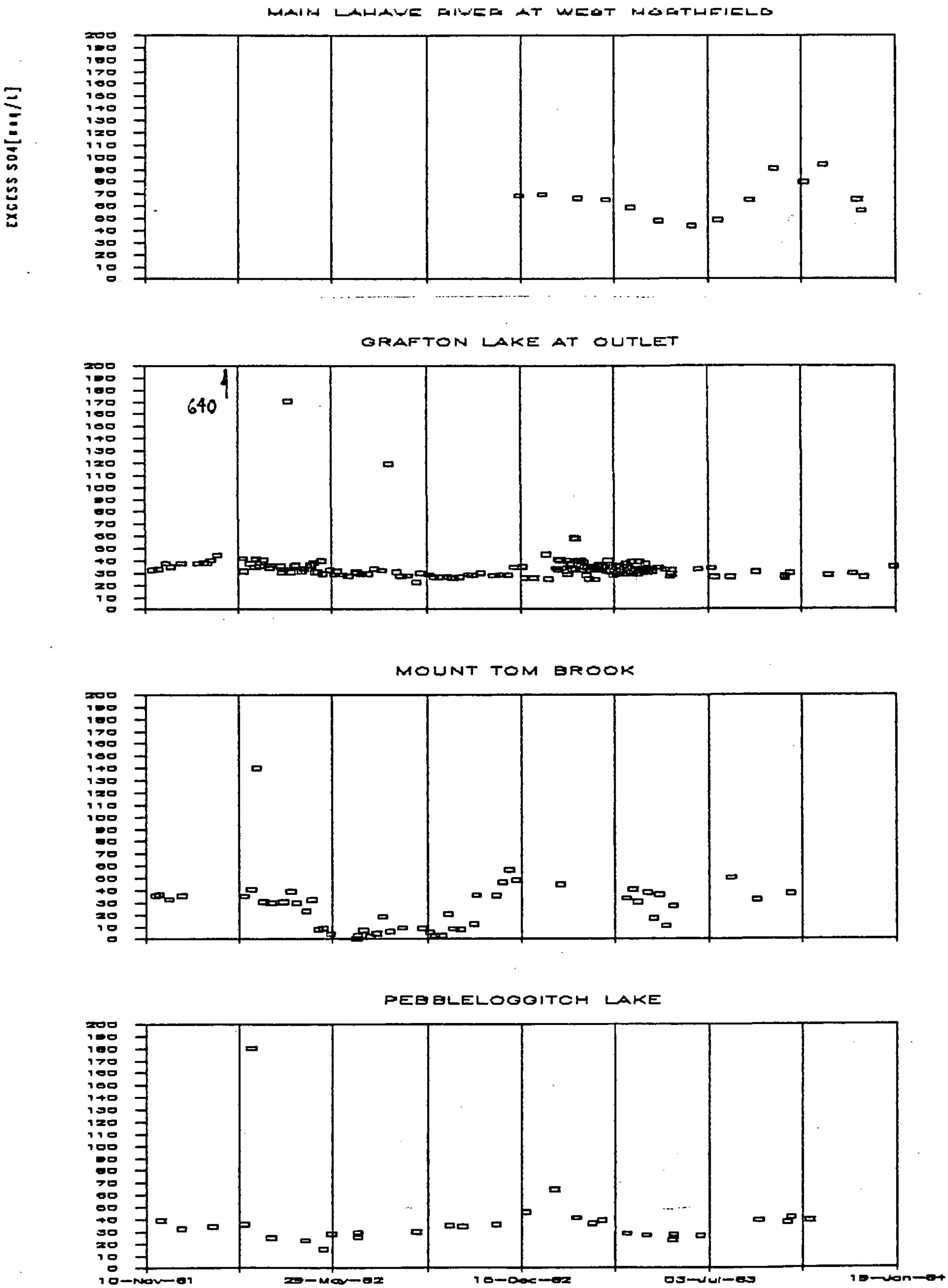


Figure 4-19 - Comparison of Seasonal Sulphate in Four Watersheds

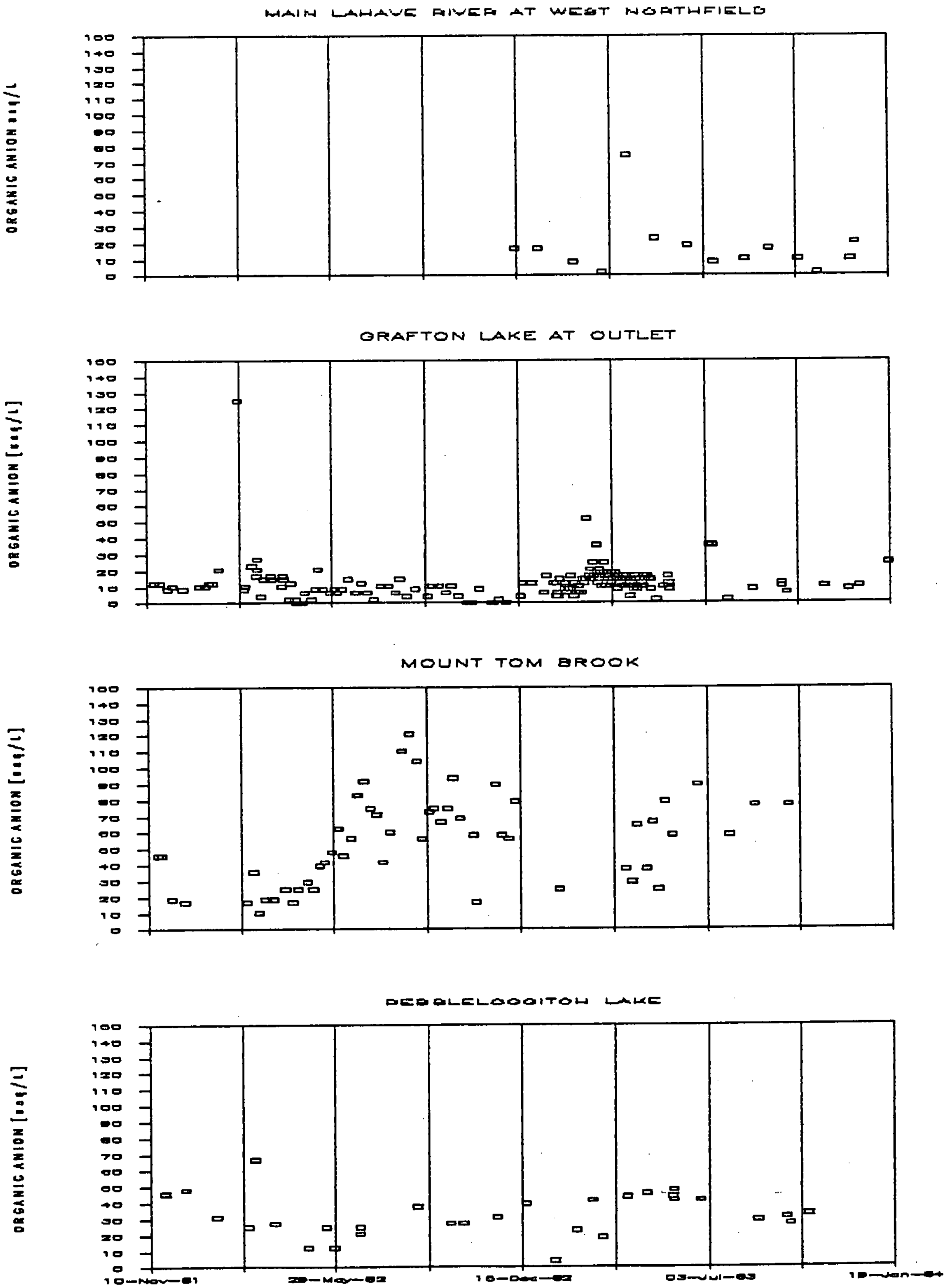


Figure 4-20 - Comparison of Seasonal Organic Anion in Four Watersheds

5.0 FINDINGS

5.1 RESULTS OF WATER QUALITY INVESTIGATIONS

The risk model assessment steps, when applied to the study region for this project, indicate that the West LaHave watershed area is high, the Grafton watershed area is medium/low, and the Mount Tom watershed area is low with respect to the potential for production of natural source acid drainage. The purpose of water quality data interpretations has been to determine whether or not the available quality data suggest that these risk designations are properly applied. Each of the three watershed areas is addressed separately below.

5.1.1 West LaHave Watershed Area

The West LaHave River watershed has a drainage area of 211 km^2, 7% of which is lakes and 5% of which is wetlands. Despite its size, no comprehensive water quality data are available for the West Lahave, and of the many lakes in the watershed, only seven have comprehensive water quality data reports. The water quality results from these lakes are not indicative of water systems which may be suffering from natural source acid drainage. Excess sulphate (SO_4*) readings are in the 30 to 70 ueq/L range, well below levels which may suggest effects from pyritic slate runoff.

The limited comparative data for the main LaHave River for points upstream and downstream of its junction with the West LaHave, obtained during the mid-1970's, are inconclusive. They do not suggest substantial changes in quality in the main LaHave upstream and downstream of the West LaHave confluence, but it is not possible to confirm whether or not natural source acid drainage is presently influencing water quality in the West LaHave River.

It has been noted (Section 3) that a number of quarries present in the West LaHave watershed area have waters with very low pH levels. It is clear that these acid-affected waters may have localized influences on first and second-order streams within the West LaHave watershed.

5.1.2 Grafton Lake Watershed Area

The drainage area of the Grafton watershed area as measured at its point of discharge to Kejimkujik Lake is 57.1 km^2. Within this area, lakes occupy 11% and wetlands occupy a further 3.5%, suggesting a potentially signficant dampening effect of rainfall and natural source contaminants.

Water quality data interpretation for the Grafton watershed focused on the extensive data base for the monitoring station below the Grafton Lake outlet. Some data are also available for McGinty Lake but questions have been raised as to the accuracy of some of the reported parameters, including pH (Howell, pers. comm.). (The period of record water quality for selected quality parameters in McGinty Lake is provided in two figures in Appendix B)

Summary quality data for Grafton Lake at the outlet do not provide clear evidence of contamination from natural source acid drainage. Period of record median SO_4* concentration is 32.7 ueq/L (1.6 mg/L), in a range to be expected for lakes in the area with undisturbed (or minimally disturbed) drainage basins (Underwood et al, in press). Alkalinity is typically slightly positive. Aluminum and iron concentrations are not particularly elevated.

Seasonal variations in quality in the Grafton watershed, as measured at the Grafton Lake outlet, are clearly dampened by the storage/buffering action of the lake iteself. Sulphate shows steady readings over the year. Organic anion and colour show some seasonal fluctuations with the higher readings occurring during high flow periods. Generally the seasonal fluctuations in water quality demonstrate no clear evidence of contamination from natural source pollutants.

According to NAQUADAT data, some high readings of SO_4* have been measured at the Grafton outlet. These data are assumed to be correct indicators of quality at the time of sampling. Two of these readings were associated with a low pH, and the third with high pH readings. They may be suggestive of potential contamination from acid drainage, but in the absence of further supporting data, it is difficult to ascribe significance to these readings. The buffering capacity of Grafton Lake calls into question the appearance of a high reading of SO_4* (Kerekes, personal communication). Insufficient data are available at the Grafton Lake quality monitoring station with which to determine the time variance around these reported peak SO_4* readings.

5.1.3 Mount Tom Watershed Area

Mount Tom Brook, at its point of discharge to Kejimkujik Lake, has a drainage area of 8.7 km^2, two percent of which is occupied by lakes (primarily Mount Tom Lake, in the extreme headwater) and a further two percent by wetlands. Given the prevailing geology and the position of storages within the watershed, it is to be expected that discharge and runoff quality would respond quickly to rainfall events. The Mount Tom Brook quality monitoring station is therefore considered to be in a suitable location for identifying seasonal variations in quality and possible influences.

Long term summary quality data for the Mount Tom station (1980 to present) show a similar median profile to the control watershed with coloured water (Pebbleloggitch). Median pH, colour Ca*, alkalinity, aluminum, and SO_4* are similar between the two watersheds. Median calculated organic anion appears to be slightly higher in the Mount Tom watershed, suggesting a potentially greater influence of drainage from organic soils. Extreme high readings for SO_4* are not higher than in the Pebbleloggitch watershed area. In general, the summary data show no evidence of influence from natural source pollutants.

Seasonal variations in quality in the Mount Tom waterhsed area are quite significant, particularly with respect to SO_4*, A^- and Alkalinity. The seasonal trends illustrate that the particular behaviour of sulphate and organic anion is similar to that reported for other highly coloured, dilute, organic-rich waters of southwestern Nova Scotia.

Based on available data, only one high SO_4* reading is observed at the Mount Tom quality monitoring station. This reading was associated with a low pH value, but insufficient data points are available to demonstrate the temporal behaviour of SO_4* concentration around the time that this reading was obtained.

6.0 CONCLUSIONS

The following is a summary of the conclusions arising from the study of natural source pollutants in the Meguma Group of southwestern Nova Scotia:

- Based on bedrock geology, areas which demonstrate potential of producing acid drainage are Halifax Formation slates belonging to the Cunard Member exhibiting chlorite grade metamorphism.

- The designation of individual Members of the Halifax Formation (i.e. Cunard, Felzen and Moshers Island) are important with respect to potential acid drainage risk, however, these units have not, to date, been mapped north and west of Bridgewater.

- A further consideration with respect to acid producing potential of individual rock units is the distribution and potential for release of different sulphide bearing minerals (i.e. pyrrhotite and arsenopyrite). The behaviour of the different minerals as well as their precise relative abundance and distribution is poorly understood and has not been mapped.

- All other rock types (i.e. Granitic, Goldenville Formation and Windsor Group) in association with varying grades of metamorphism are considered to be either medium, low or no risk areas with respect to potential for producing acid drainage.

- Exceptions to the medium or low risk designation are areas associated with known mineral occurrences and areas which have received imported crushed bedrock from high risk areas.

- The relative characteristics (i.e. grain size, depth and calcium content) of surficial materials are of importance with respect to buffering capacity, however, this aspect requires further definition for realistic quantification.

- Anthropogenic activities including quarrying, road construction and general development in designated high risk areas will significantly increase the potential for production of acid drainage.

- Following risk designation via assessment of geological and anthropogenic characteristics, an assessment of individual watershed considerations must be undertaken in order to apply the model to the location of existing or future LRTAP water quality monitoring stations, development approvals, quarry site selection, environmental assessment studies, fisheries management and local water supplies.

- In terms of predictive model application, study area watersheds (i.e. West LaHave, Grafton, Mount Tom and Pebbleloggitch/Beaverskin) have been chosen to demonstrate high, medium/low, low and no risk. Pebbleloggitch and Beaverskin watersheds have been used as controls for coloured-water and clear-water system comparisons.

- Evaluation of the available water quality data base for the study area watersheds has shown that in the West LaHave and Grafton watersheds the information is insufficient for quantifying the extent and duration of natural source acid drainage. This is largely because the West LaHave data provide no indication of short-term temporal variabilities in quality, while the Grafton data are indicators of quality at a point in the watershed immediately downstream of a significant hydrologic buffer. The Mount Tom water quality data, however, are not subject to these interpretative limitations, and therefore are generally more suited to assessing acid drainage production.

- Comprehensive water quality data in the West LaHave watershed are limited to seven lakes, none of which demonstrate contamination from natural source acid drainage. These data, however, provide no indication of temporal variations in quality, the quantification of which is necessary for assessing acid drainage.

- Comprehensive water quality data in the Grafton watershed are relatively extensive at a point downstream of the Grafton Lake outlet. These data provide no clear evidence of contamination from natural source acid drainage, even though data on temporal variations are available. The extensive buffering and quality modification which is provided by water passage through Grafton Lake is likely to be so extensive as to make the Grafton outlet quality monitoring station unsuitable for assessment of acid drainage. Limited quality data available for McGinty Lake, in the headwaters of the Grafton system, do not display clear evidence of natural source contamination.

- Comprehensive water quality data in the Mount Tom watershed demonstrate relatively well that contamination from natural source acid drainage is not occurring in this system.

- The behaviour of SO_4* versus time in areas of potential acid drainage is poorly understood and median SO_4* levels are not expected to serve as suitable indicators of acid drainage influence. Extreme value readings are only expected to be conclusive if they are substantial with other readings from adjacent watersheds.

- The areas of no and low risk are confidently assigned, therefore the use and application of water quality data from LRTAP stations in these areas is considered appropriate for examining long term atmospheric deposition of SO_4^*.

- The designation of Halifax Formation, Cunard Member slates exhibiting chlorite grade metamorphism as having high risk potential is consistent with known adverse acid drainage events such as the Patten Brook fish kill (Lunenburg County) and studies at the Halifax International Airport and Little Springfield Lake (Halifax County).

7.0 RECOMMENDATIONS

The analysis of existing information for the study of natural source pollutants in the Meguma Group of southwestern Nova Scotia has identified specific data gaps as well as particular areas which require further study, as follows:

- The individual sub-units (i.e. Members) of the Halifax Formation should be mapped for the portion of the study area north and west of Bridgewater.

- The distribution and mobility of different sulphide bearing minerals within bedrock units and sub-units throughout the study area is poorly understood and therefore should be quantified and mapped.

- The processes of buffering through surficial materials, groundwater contributions, high order streams and on-channel storage is poorly understood and should be addressed via further study.

- Anthropogenic activities, especially those involving quarrying and road building contribute significantly to risk and therefore should be eliminated or mitigated where possible.

- The use of crushed bedrock from high risk areas as fill material should be replaced via increased utilization of relatively inert sand and gravel deposits.

- For observed SO_4* peaks, water quality and precipitation data should be examined for all watersheds in southwestern Nova Scotia in order to evaluate and potentially identify significant trends.

- Further studies should be initiated in a small sub-watershed (i.e. similar to Mount Tom) demonstrating high potential risk in order to identify Halifax Formation sub-unit bedrock type, sulphide distribution and specifics concerning water quality versus time (i.e. summer through fall). Indicator parameters should include SO_4, A^-, pH, Ca, Mg, Cl, Fe and Al.

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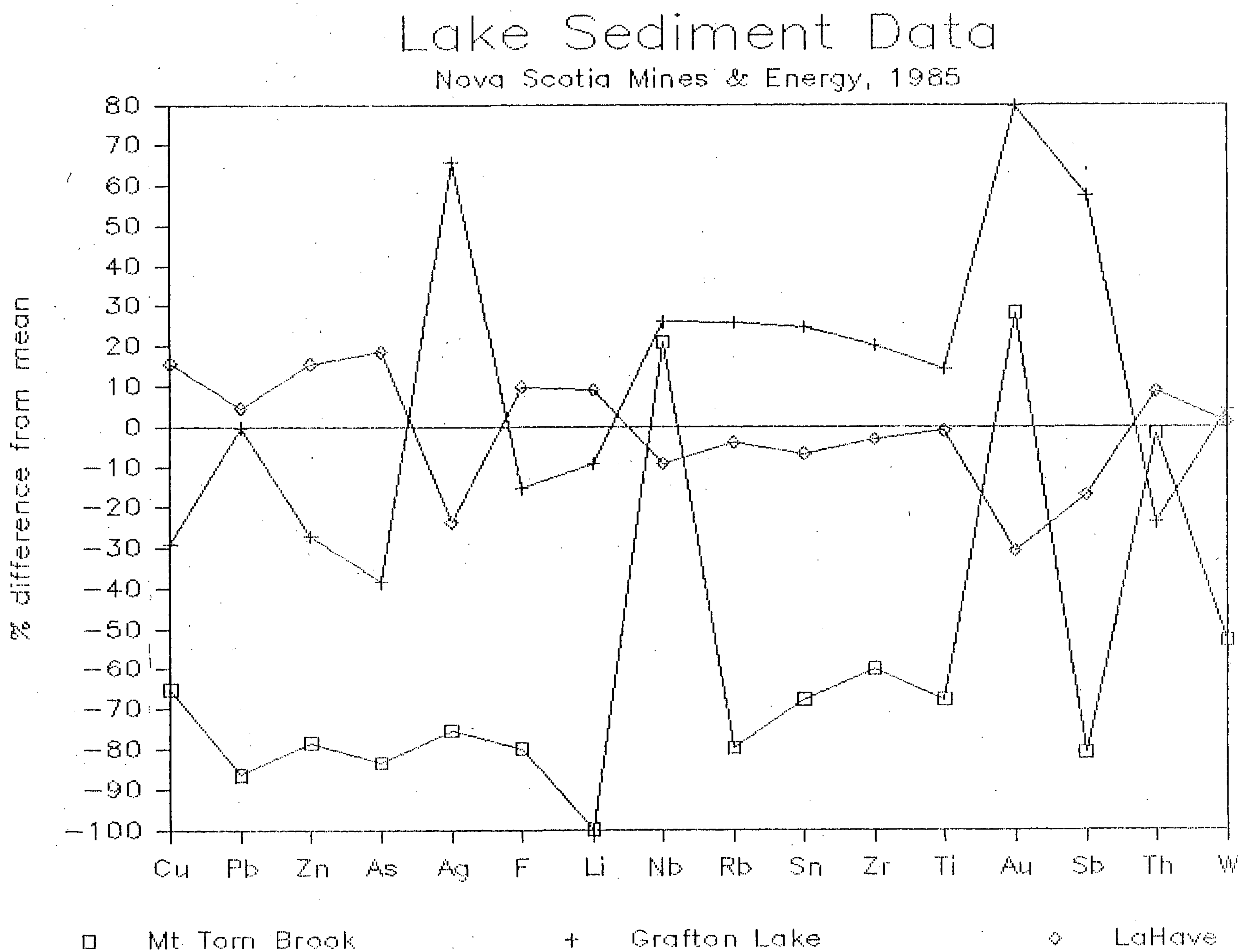
APPENDIX A

RESULTS OF CHEMICAL ANALYSIS FROM STUDY AREA LAKE SEDIMENT SAMPLES

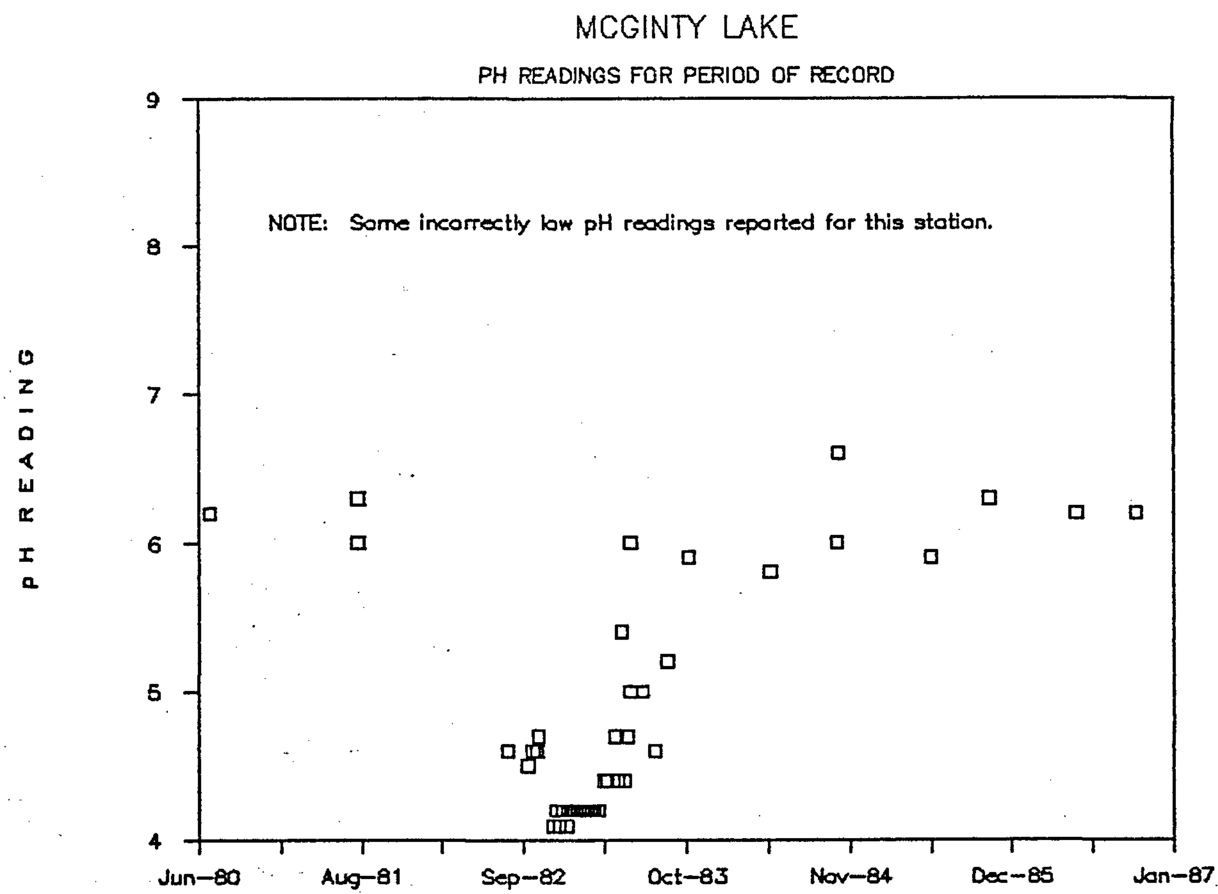

Lake Sediment Data
Nova Scotia Mines & Energy, 1985
% difference from mean
80
70
60
50
40
30
20
10
0
−10
−20
−30
−40
−50
−60
−70
−80
−90
−100
Cu
Pb
Zn
As
Ag
F
Li
Nb
Rb
Sn
Zr
Ti
Au
Sb
Th
W
Mt Tom Brook
Grafton Lake
LaHave

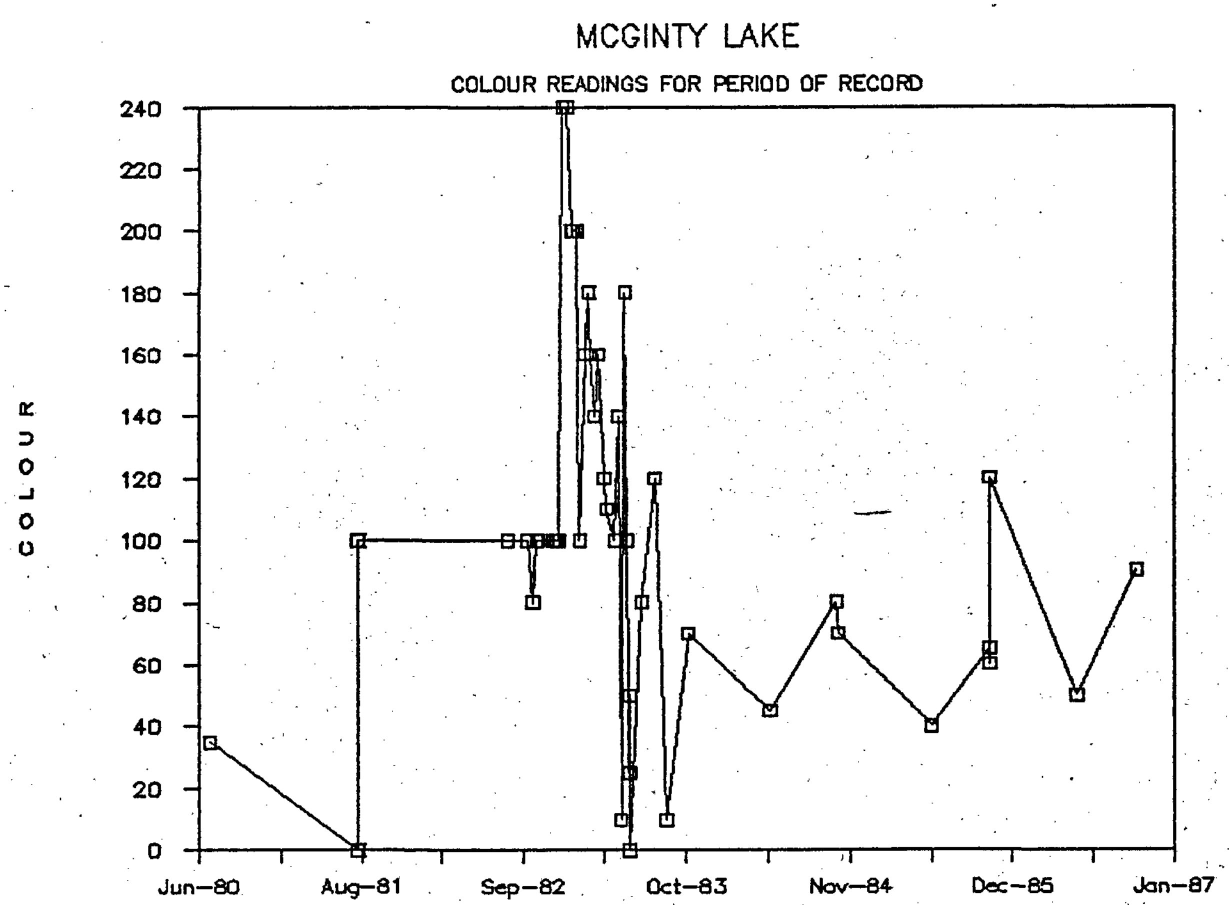
basin	NTS	#	lake	Cu	Pb	Zn	As	Ag	F	Li	Nb	Rb	Sn	Zr	Ti	Au	Sb	Th	W
Mt Tom	21A6	126	Mount Tom	6	2	18	3.4	0.05	28	0.5	2.0	8	0.5	27	0.06	8.0	0.1	4.4	0.40
Grafton	21A6	46	Beaverhead	8	12	69	9.8	0.10	240	39.0	2.0	118	5.0	163	0.42	56.0	1.3	6.0	1.90
Grafton	21A6	47	Pat Kempton	12	7	27	2.3	0.05	100	9.0	4.0	52	0.5	70	0.24	2.0	0.2	2.8	1.20
Grafton	21A6	75		11	13	30		0.05		2.0			1.0						
Grafton	21A6	76		16	19	84	21.4	1.60	70	7.0	0.5	21	3.0	47	0.08	5.0	1.2	2.0	0.50
Grafton	21A6	77		11	18	37	9.0	0.05	120	9.0			0.5			7.0	0.6	2.7	0.35
Grafton	21A6	79	Grafton	13	21	160	11.1	0.50	140	21.0	5.0	64	4.0	129	0.27	2.5	1.2	6.2	1.40
Grafton	21A6	80	Grafton	17	10	36	8.7	0.05	75	2.0	0.5	8	0.5	39	0.21	4.0	1.0	1.6	0.35
Grafton	21A6	82	Barnie	10	18	45	26.0	0.30	80	7.0	0.5	35	1.0	39	0.06	2.0	0.3	2.6	0.50
LaHave	21A10	98	Otter	10	15	47	5.5	0.20	83	6.0	0.5	27	2.0	48	0.10	1.5	0.4	2.4	0.85
LaHave	21A10	50	Rocky	14	3	53	39.0	0.10	66	4.0	0.5	12	0.5	31	0.08	4.0	0.4	2.0	0.80
LaHave	21A7	11		15	11	80	8.0	0.05	165	20.0	5.0	49	0.5	71	0.25	4.0	0.3	3.9	0.55
LaHave	21A7	12	New Canada	14	10	70	4.2	0.05	200	20.0	1.0	44	1.0	68	0.21	2.0	0.3	4.4	1.80
LaHave	21A7	13		22	18	89	15.7	0.40	80	4.0	0.5	15	0.5	38	0.06	12.0	0.3	4.5	0.60
LaHave	21A7	14	Rocky	43	17	168	27.6	0.10	130	13.0	1.0	31	0.5	79	0.14	7.0	0.4	9.2	1.50
LaHave	21A7	15	Hirtle	13	13	80	12.4	0.20	60	4.0	0.5	16	0.5	35	0.07	4.0	0.2	2.9	0.50
LaHave	21A7	17		8	15	84	22.6	0.05	180	23.0	4.0	51	2.0	101	0.23	11.0	0.5	5.1	1.40
LaHave	21A7	18	Smith	60	16	70	14.7	0.20	250	29.0	8.0	92	1.0	142	0.45	6.0	0.6	4.9	2.00
LaHave	21A7	24		13	2	48	9.3	0.05	103	4.0	0.5	37	6.0	56	0.12	1.5	0.3	2.8	0.55
LaHave	21A7	25	Seven Mile	21	21	131	24.4	0.05	100	7.0	0.5	25	2.0	53	0.09	6.0	0.3	4.3	0.55
LaHave	21A7	27	Cranberry	11	7	51	4.3	0.05	155	9.0	0.5	28	2.0	55	0.13	1.5	0.3	2.1	0.55
LaHave	21A7	28		12	20	125	12.2	0.20	200	33.0	3.0	79	0.5	114	0.41	1.5	0.6	6.6	0.60
LaHave	21A7	31		21	18	131	41.5	0.10	165	22.0	0.5	43	6.0	60	0.28	2.0	0.6	6.2	0.70
LaHave	21A7	39	Fire	30	19	213	58.4	0.30	230	24.0	0.5	47	0.5	78	0.31	7.0	0.6	9.2	0.80
LaHave	21A7	40		22	19	86	26.4	0.10	280	14.0	0.5	28	0.5	47	0.14	2.0	0.5	6.2	0.70
LaHave	21A7	42	Harley	25	21	145	49.8	0.05	230	22.0	0.5	56	0.5	80	0.27	2.0	0.8	8.8	0.70
LaHave	21A7	43	Huey	13	28	51	30.6	0.20	85	7.0	0.5	9	0.5	30	0.05	2.0	0.5	2.1	0.65
LaHave	21A7	44		12	21	116	24.7	0.50	140	9.0	0.5	31	0.5	56	0.12	5.0	0.4	5.0	0.55
Total mean				17.3	14.6	83.7	20.4	0.2	139.1	13.2	1.7	39.5	1.6	67.5	0.2	6.2	0.5	4.5	0.9
Mt Tom mean				6.0	2.0	18.0	3.4	0.1	28.0	0.0	2.0	8.0	0.5	27.0	0.1	8.0	0.1	4.4	0.4
Grafton mean				12.3	14.8	61.0	12.6	0.3	117.9	12.0	2.1	49.7	1.9	81.2	0.2	11.2	0.8	3.4	0.9
LaHave mean				19.9	15.5	96.7	24.2	0.2	152.7	14.4	1.5	37.9	1.4	65.4	0.2	4.3	0.4	4.9	0.9
Mt Tom mean as % total				-65.2	-86.5	-78.5	-83.4	-73.4	-79.9	-100	20.9	-79.7	-67.8	-60.0	-67.3	28.2	-81.0	-1.7	-52.9
Grafton mean				-29.0	-0.2	-27.1	-38.3	65.9	-15.3	-9.2	26.0	25.9	24.7	20.2	14.4	79.7	57.5	-23.8	4.2
LaHave mean				15.6	4.7	15.6	18.5	-23.7	9.8	9.1	-9.3	-4.0	-6.8	-3.2	-1.0	-30.8	-16.9	8.8	1.2

APPENDIX B

GRAPHICAL REPRESENTATION OF
SELECTED CHEMICAL PARAMETERS - McGINTY LAKE

APPENDIX B

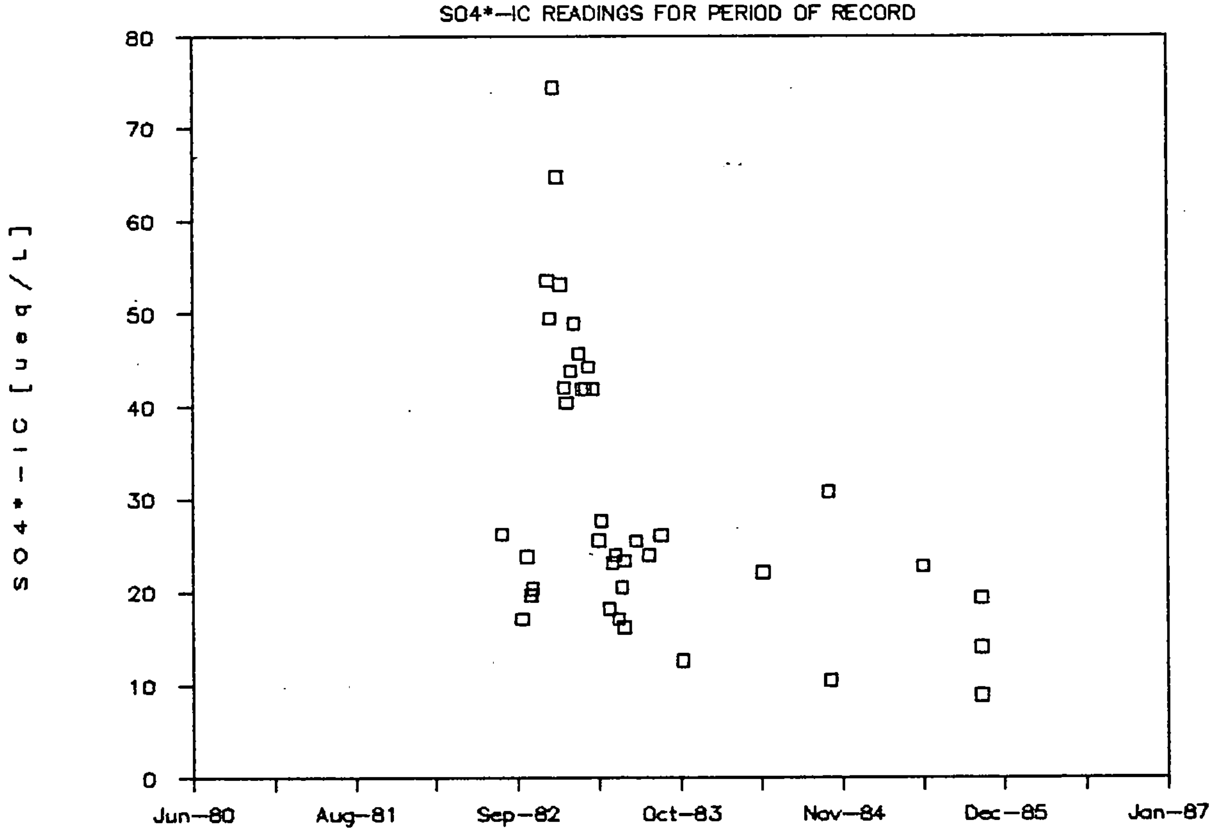

MCGINTY LAKE
PH READINGS FOR PERIOD OF RECORD
NOTE: Some incorrectly low pH readings reported for this station.
pH READING
9
8
7
6
5
4
Jun-80
Aug-81
Sep-82
Oct-83
Nov-84
Dec-85
Jan-87


MCGINTY LAKE
COLOUR READINGS FOR PERIOD OF RECORD
COLOUR
240
220
200
180
160
140
120
100
80
60
40
20
0
Jun-80
Aug-81
Sep-82
Oct-83
Nov-84
Dec-85
Jan-87

APPENDIX B

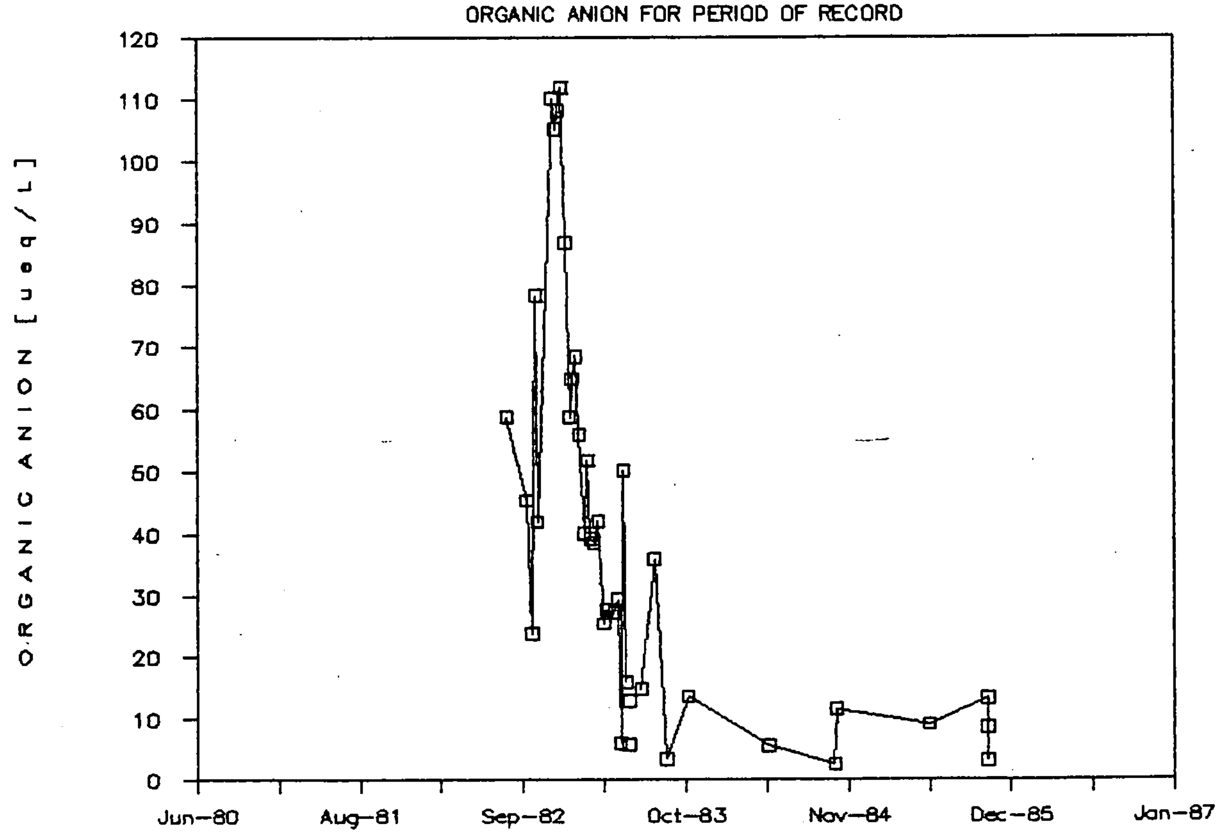
MCGINTY LAKE

SO4*-IC READINGS FOR PERIOD OF RECORD

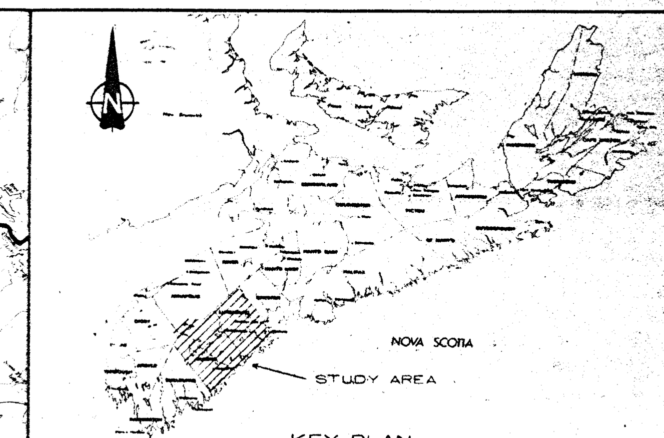


MCGINTY LAKE

ORGANIC ANION FOR PERIOD OF RECORD




NOVA SCOTIA
STUDY AREA
KEY PLAN
LEGEND
STUDY AREA BOUNDARY
STUDY AREA DESIGNATED WATERSHED
Au MINERAL OCCURRANCE (GOLD)
(M) Au MINES (GOLD)
QUARRIES
WATER SUPPLY AREA
GAUGING STATIONS
FLOW DIRECTION
IEF PRIMARY DIVISION NUMBER, BOUNDARY
IEF-2 SECONDARY DIVISION NUMBER, BOUNDARY
IEF-2A TERTIARY DIVISION NUMBER, BOUNDARY
SD SHORELINE DIRECT INFLOW TO SALT WATER
8 *NOTE: NUMBERING SYSTEM IS DIRECTLY RELATED TO QUARRY INVENTORY PROGRAM, KING (1985) & MANCHESTER (1986), ENVIRONMENT CANADA, INLAND WATERS DIRECTORATE.
AREA TO THE NORTH & WEST OF BRIDGEWATER HAS NOT BEEN MAPPED WITH RESPECT TO SUB-DIVISIONS OF THE HALIFAX FORMATION AND IS THEREFORE ASSUMED TO BE CUNARD MEMBER SLATE
ECw WINDSOR GROUP - SANDSTONE, SILTSTONE, LIMESTONE, DOLOSTONE, ANHYDRITE AND GYPSUM.
DC GRANITIC ROCKS -
gt - GRANITOID
mg - MONZO - GRANITE
gd - GRANODIORITE
€OH MEGUMA GROUP, HALIFAX FORMATION SLATE
(F) - FELZEN MEMBER; GREY SLATE WITH INTERBEDDED METASANDSTONE
(C) - CUNARD MEMBER; BLACK PYRITE-BEARING SLATE AND SILTSTONE
(MI) - MOSHER'S ISLAND MEMBER; LAMINATED MANGANIFEROUS ARGILLITE
€OG MEGUMA GROUP, GOLDENVILLE FORMATION QUARTZITES OR QUARTZ WACKES
AREA OF CONTACT METAMORPHISM IN THE HALIFAX FORMATION
NOTE MAPPING REDUCED FROM NOVA SCOTIA DEPARTMENT OF THE ENVIRONMENT 1:50,000 PROVINCIAL WATERSHED MAPPING
BEDROCK GEOLOGY AFTER O'BRIEN, 1985, MUECKE AND KEPPIE, 1979 AND KEPPIE, 1979.
NO
REVISIONS
DATE
BY
ENVIRONMENT CANADA
INLAND WATERS DIRECTORATE
PORTER DILLON
Consulting Engineers • Planners • Environmental Scientists
A SURVEY OF NATURAL SOURCE POLLUTANTS IN THE MEGUMA GROUP OF SOUTHWESTERN NOVA SCOTIA
BEDROCK GEOLOGY
MAP No.
1
DESIGN
DRAWN
CHECKED
APPROVED
DATE
SCALE
1:100,000
PROJECT NO
2145
DCgt
DCgd
DCmg
€OG
€OH
€OH(C)
€OH(F)
€OH(MI)
ECw



KEY PLAN

LEGEND

- STUDY AREA BOUNDARY
- STUDY AREA DESIGNATED WATERSHED
- Au — MINERAL OCCURRANCE (GOLD)
- (M) Au — MINES (GOLD)
- QUARRIES
- WATER SUPPLY AREA
- GAUGING STATIONS
- FLOW DIRECTION
- IEF — PRIMARY DIVISION NUMBER, BOUNDARY
- IEF-2 — SECONDARY DIVISION NUMBER, BOUNDARY
- IEF-2A — TERTIARY DIVISION NUMBER, BOUNDARY
- SD — SHORELINE DIRECT INFLOW TO SALT WATER

8 *NOTE: NUMBERING SYSTEM IS DIRECTLY RELATED TO QUARRY INVENTORY PROGRAM, KING (1985) & MANCHESTER (1986), ENVIRONMENT CANADA, INLAND WATERS DIRECTORATE.

- 71-86 / 168 — DURATION (YEARS) / No. OF SAMPLES — WATER QUALITY MONITORING STATION
- PRECIPITATION STATION

- ST — SLATE TILL
- QT — QUARTZITE TILL
- GT — GRANITE TILL
- BR — BEDROCK (40% OF AREA IS BEDROCK EXPOSURE OR BOULDERS)
- SAND / GRAVEL (EITHER OUTWASH OR ICE CONTACT STRATIFIED DRIFT)
- STRIAE
- ESKER (SAND / GRAVEL)
- DRUMLIN FIELD AREA

NOTE: MAPPING REDUCED FROM NOVA SCOTIA DEPARTMENT OF THE ENVIRONMENT 1:50,000 PROVINCIAL WATERSHED MAPPING

SURFICIAL GEOLOGY AFTER STEA, 1982 AND CANN AND HILCHEY, 1958 & 1959.

No.	REVISIONS	DATE	BY

ENVIRONMENT CANADA
INLAND WATERS DIRECTORATE

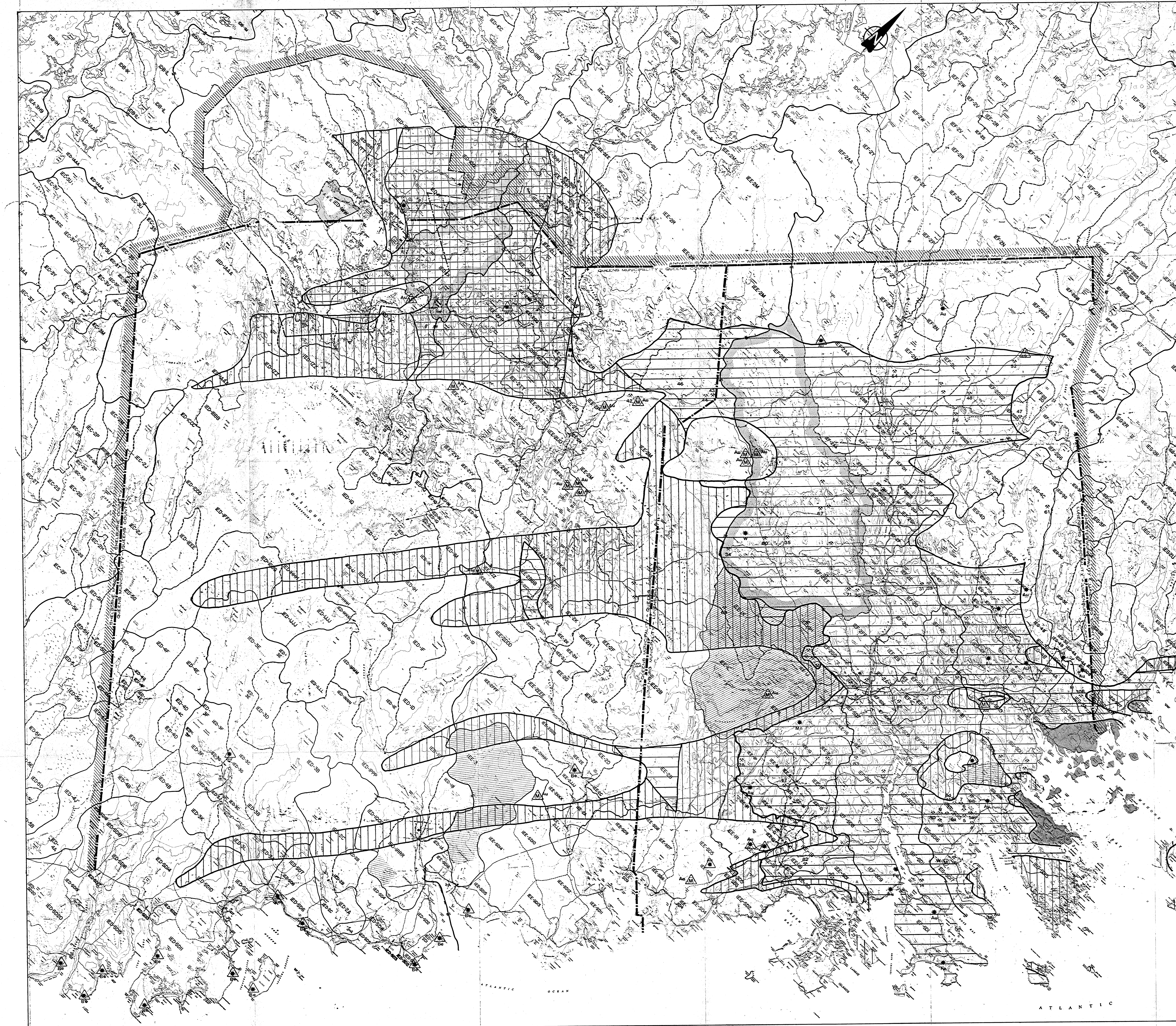
PORTER DILLON
Consulting Engineers • Planners • Environmental Scientists

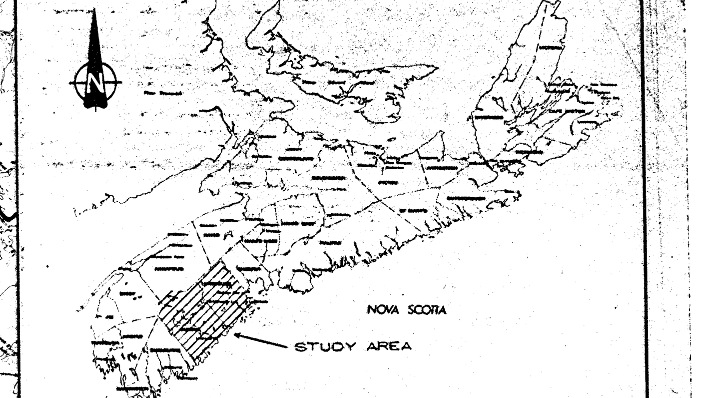
A SURVEY OF NATURAL SOURCE POLLUTANTS IN THE MEGUMA GROUP OF SOUTHWESTERN NOVA SCOTIA

SURFICIAL GEOLOGY

MAP No. **2**

DESIGN	PROJECT NO. 2145
DRAWN	
CHECKED	
APPROVED	
DATE	
SCALE 1:100,000	





KEY PLAN

LEGEND

- STUDY AREA BOUNDARY
- STUDY AREA DESIGNATED WATERSHED
- Au — MINERAL OCCURRANCE (GOLD)
- (M) Au — MINES (GOLD)
- 8*/ — QUARRIES
- WATER SUPPLY AREA
- GAUGING STATIONS
- FLOW DIRECTION
- IEF — PRIMARY DIVISION NUMBER, BOUNDARY
- IEF-2 — SECONDARY DIVISION NUMBER, BOUNDARY
- IEF-2A — TERTIARY DIVISION NUMBER, BOUNDARY
- SD — SHORELINE DIRECT INFLOW TO SALT WATER

8 *NOTE: NUMBERING SYSTEM IS DIRECTLY RELATED TO QUARRY INVENTORY PROGRAM, KING (1985) & MANCHESTER (1986), ENVIRONMENT CANADA, INLAND WATERS DIRECTORATE.

RISK DESIGNATIONS

- NO
- LOW
- LOW – MEDIUM
- MEDIUM
- HIGH

DESCRIPTIVE NOTES

High Risk - Includes areas underlain by Halifax Formation Cunard Member, slate exhibiting chlorite grade metamorphism which have significant existing land use and/or do not have potential buffering from overlying surficial materials.

Medium Risk - Includes areas underlain by Halifax Formation Cunard Member slate exhibiting chlorite grade metamorphism with no or low existing land use; Halifax Formation Felzen and Moshers Island Members exhibiting chlorite grade metamorphism and Halifax Formation Cunard Member exhibiting biotite, garnet and andalusite grade metamorphism.

Low/Medium Risk - Includes areas underlain by Halifax Formation Cunard Member slate exhibiting biotite grade metamorphism in association with significant but unquantified buffering capacity from overlying surficial materials.

Low Risk - Includes areas underlain by Goldenville Formation quartzites and Granitic Rocks (i.e. granitoid, monzo-granite and granodiorite) in addition to Halifax Formation, Cunard, Felzen and Mosher's Island Members, in areas of contact metamorphism (i.e. hornfels).

No Risk - Includes areas underlain by Windsor Group rocks.

NOTE: MAPPING REDUCED FROM NOVA SCOTIA DEPARTMENT OF THE ENVIRONMENT 1:50,000 PROVINCIAL WATERSHED MAPPING.

NO	REVISIONS	DATE	BY

ENVIRONMENT CANADA
INLAND WATERS DIRECTORATE

PORTER DILLON
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A SURVEY OF NATURAL SOURCE POLLUTANTS IN THE MEGUMA GROUP OF SOUTHWESTERN NOVA SCOTIA

POTENTIAL RISK OF PRODUCING ACID DRAINAGE

MAP No.		
3	DESIGN	PROJECT NO. 2145
	DRAWN	
	CHECKED	
	APPROVED	
	DATE	
	SCALE 1:100,000	