REGIONAL WATER RESOURCES CUMBERLAND COUNTY NOVA SCOTIA

by James G. Vaughan
and George H. Somers

NOVA SCOTIA
DEPARTMENT Of The ENVIRONMENT

A joint project with
Canada Department of
Regional Economic Expansion and
Nova Scotia Department of Development

Halifax 1980

Province of Nova Scotia
Department of the Environment

Water Planning and Management Division

Regional Water Resources
Cumberland County, Nova Scotia

by

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Halifax, Nova Scotia
1980

Canadian Cataloguing in Publication Data
Vaughan, James G.
Regional water resources, Cumberland County, Nova Scotia

ISBN 0-88871-021-6

1. Water-supply--Nova Scotia--Cumberland County. 2. Water quality management--Nova Scotia--Cumberland County. 3. Hydrology--Nova Scotia--Cumberland County. I. Somers, George H. II. Nova Scotia. Water Planning and Management Division. III. Title.

GB708.N6V38 333.91'009716'11 C81-096005-2

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EXECUTIVE SUMMARY

Objectives

The objectives of the study were 1) to evaluate the occurrence, quality and quantity of surface and groundwater in Cumberland County and 2) to assess the probability of contamination of the water resources by human activities and to advise on measures to alleviate such problems.

Funding Agencies

This project, conducted from April 1977 to November 1979, was co-funded by the Nova Scotia Department of Development and Department of Regional Economic Expansion, and was implemented by the Nova Scotia Department of the Environment. This project consists of two concurrent water resources evaluation and inventory programs. One program investigated the Amherst-Oxford-Springhill triangle in Cumberland County and the other concentrated in the Pictou-New Glasgow-Trenton areas in Pictou County.

Scope

This report presents the findings of a hydrological investigation conducted on the surface and groundwater resources of six major drainage basins located in Cumberland County: River Philip, Maccan, Nappan, Tidnish, Shinimikas and LaPlanche. The study consisted of the collection and analysis of meteorological, hydrological and geological data through the installation of 7 meteorological recording stations and 5 streamflow recording stations, the drilling of 16 test wells, well log location, surficial mapping, basin analysis and surface and groundwater sampling.

Results

Surface Water Potential

Investigations of streamflow and climatic records reveal significant surface water resources discharging from the Cobequid Mountains within the Maccan and River Philip watersheds. These watershed lands, covering 249 km^2 (96 mi^2) of the study area, represent a minimum yield in the order of 1.3 x 10^{5}m^3/day (28 MIGD).

Surface Water Quality

Results indicate that the water qualities of Maccan River to Southampton and River Philip to Oxford are of similar good chemical quality, and consistent throughout each river system, with a few minor exceptions. Overall, waters of both rivers are slightly alkaline, and are low in color, turbidity and suspended solids. Minor treatment may be required for municipal use.

Groundwater Potential

Test drilling operations have identified major hydrostratigraphic units within Pictou and Cumberland Group sandstones near Amherst, Springhill and Oxford. Pleistocene surficial sand and gravel aquifers have been delineated at Rodney, south of Springhill and at Collingwood Corner. Test results have shown that individual, properly constructed wells drilled into these aquifers produce yields of 19 l/s to 27 l/s (250 to 350 igpm) and may exceed 38 l/s (500 igpm) at some localities.

Preliminary investigations have identified a surficial sand and gravel aquifer at Collingwood Corner extending south toward the Cobequid Mountains and covering an area of 3.6 km^2 (2.2 mi^2). Conservative estimates indicate a minimum potential yield of 4.5 x 10^3 m^3/day (1 MIGD) and may exceed 22.5 x 10^3 m^3/day (5 MIGD). Agriculture, Forestry and other industrial and commercial interests could rely on this water resource given a future demand for these activities.

The estimated minimum renewable groundwater resource potential, determined from base flow and water balance calculations, approximates 130 mm (5 in.) over the drainage area. In effect a northern watershed area equivalent in size to the Tidnish River Basin (to head of tide, 40 km^2 or 15 mi^2) receives annual groundwater recharge of 5 x 10^6 m^3/yr (1 billion gallons per year). Although the lowland watersheds in this region do not offer any significant surface water resource, the watersheds of the LaPlanche, Tidnish and Shinimikas Rivers for example are vital groundwater recharge areas.

Groundwater Quality

The important sedimentary hydrostratigraphic sandstone units of Pictou and Cumberland Group and the interbedded sequences of Riversdale and Cumberland Group produce a chemical water quality characterized by calcium, magnesium carbonate and bicarbonate alkalinity. Generally low in hardness, total dissolved solids and high in pH, these groundwaters are considered to be of good quality. Surficial sand and gravel aquifers sampled at Springhill also produce good quality groundwater, low in TDS, hardness, iron and manganese. There are some instances of excess iron and manganese concentrations, but generally the water supplies drawn from these aquifers for municipal use would require only filtration and chlorination.

Environmental Survey

Each of six river basins were surveyed to locate activities that might have an adverse effect on water quality and the site of each recorded. The survey included activities and operations as: forestry, agricultural feedlots, industrial and municipal sewage outfalls; solid waste disposal sites; and mining including quarry and gravel pit operations. In general, the survey indicates that at the present time, none of the river basins has activities which present a serious threat to the water quality of the study area.

Water Resources Data Base Inventory

In conjunction with the preparation and publication of the Water Resources Evaluation Project, a Data Base Inventory System has been developed. This subject file and map index incorporates all reference material in this report, along with information considered useful for any subsequent investigations. Included are such subjects as:

1) well log data
2) bedrock geologic information
3) surface geological information
4) aquifer analysis
5) water quality data
6) hydrological information
7) meteorological information
8) basin analysis

This information resource is unique. For the first time, a comprehensive water resources data file for regions of Cumberland County are organized and easily accessible in one place.

This information will serve to encourage the rational development of an industrial base. It will assist in reaching decisions regarding municipal and domestic water supply and waste disposal services; and to define measures which will ensure protection of this region's water resources.

Implications and Recommendations

Town of Amherst

The Town of Amherst will rely primarily on the sandstone aquifers of the Pictou Group. Specifically, analyses of well data from test wells No. 1 at Tyndle Road, No. 4 at Mansfield, No. 2 at Beecham Road and No. 6 at Fort Lawrence (east) and review of town well data indicate that individual well yields may range from 2 to 38 l/s (25 to 500 igpm).

The Town of Amherst should implement a detailed groundwater exploration project specifically designed (a) to provide information regarding the capabilities of its existing well field, (b) to determine the extent and yield capabilities of Pictou Group aquifers north and east of the Town and (c) to define significant groundwater recharge areas.

Town of Springhill

The Town of Springhill has a number of potential water supplies available. The Cobequid Mountains offer an excellent resource. The Leamington Brook sub-watershed of the Maccan River is capable of long term sustained low flow equivalent to 14 x 10^3 m^3/day (3.4 MIGD) or 3 times the current requirement without storage. Alternatively, investigations indicated that Pleistocene sand and gravel aquifers and Cumberland Group sandstone aquifers located south of the Town near Rodney are capable of producing groundwater supplies of approximately 4.5 to 7 x 10^3 m^3/day (1 to 1.5 MIGD).

The Town has chosen Leamington Brook watershed as the Town's future water supply. It is important that the Nova Scotia Department of the Environment, the Department of Health, the Federal Department of Fisheries, and the Municipal Governments and landowners concerned, all work together to achieve long-term water resources security and to maintain the existing good quality water of the Leamington Brook watershed.

Town of Oxford

In the Oxford region, groundwater exploratory drilling in Cumberland and Pictou Group sediments has identified sandstone aquifer sequences north of Oxford at Black Subdivision and Mount Pleasant with excellent potential for the future development of additional water supply. Test well No.14 drilled at Mount Pleasant will produce a long term sustained pumping rate of 5.6 to 7.6 l/s (75 to 100 igpm). Test results from a well drilled by the Town (OX-8B-76) indicate the area north of Oxford may produce additional sustained yields of 7.6 l/s (100 igpm) or more from individual drilled wells. The full potential of this area has yet to be realized.

Detailed analyses of the Town of Oxford existing wells drilled in Riversdale interbedded sandstone and shale aquifers indicate a total well field potential of approximately 1.6 x 10^3 m^3/day (0.36 MIGD).

During 1978, streamflow analysis of West River Philip at Collingwood Corner indicates a minimum low flow yield of 4.5 x 10^3 m^3/day (1.0 MIGD). This translates to long term low flow capabilities of River Philip at Oxford exceeding 4.5 x 10^3 m^3/day (1 MIGD).

The Town of Oxford should implement water resource investigations designed (a) to explore and assess long term yield capabilities and water quality of Pictou and Cumberland Group aquifers extending over a wide area from Oxford to Mount Pleasant, (b) to re-evaluate the yield capabilities of the Town's existing well field, and (c) to review costs and treatment requirements associated with the integration of River Philip as part of the Town's water works system.

CHAPTER 1
Introduction

1.1 Purpose and Scope

Utilization of our provincial water resources continues to accelerate to meet the needs for irrigation, industrial, urban and suburban water supplies. Competition for our available resources has brought about an awareness that one of the principal concerns confronting primary and secondary industry, recreational activity and municipal requirements is water resource management. Before water resources can be managed they must first be quantitatively appraised.

As part of a continuing provincial program the Nova Scotia Department of the Environment initiated a two and one-half year project beginning in 1977, designed to evaluate the regional surface and groundwater resources in areas of Cumberland and Pictou Counties, Nova Scotia. The project was funded jointly by the Canada Department of Regional Economic Expansion and the Nova Scotia Department of Development. The project terms of reference are outlined in the original G.D.A. Agreement (Appendix A). The prime objectives of the project were (a) to evaluate the occurrence, quality, and quantity of surface and groundwater in specific areas of the province and (b) to assess the probability of contamination of the water resources by human activities and to advise on measures to alleviate such problems.

The project consisted of two separate concurrent programs. One program investigated the Amherst-Oxford-Springhill triangle in Cumberland County and the other concentrated in the Pictou-New Glasgow and Trenton areas in Pictou County. These two areas are designated by the Industrial Development Subsidiary Agreement as regions where industrial growth will be promoted as part of the "industrial corridor". This report deals with the findings of the study in the Cumberland County area.

The Amherst-Oxford-Springhill triangle lies in north-central Cumberland County in the northern part of Nova Scotia adjacent to the Province of New Brunswick (Figure 1.1). Emphasis was placed on the areas surrounding the Towns of Amherst, Oxford,

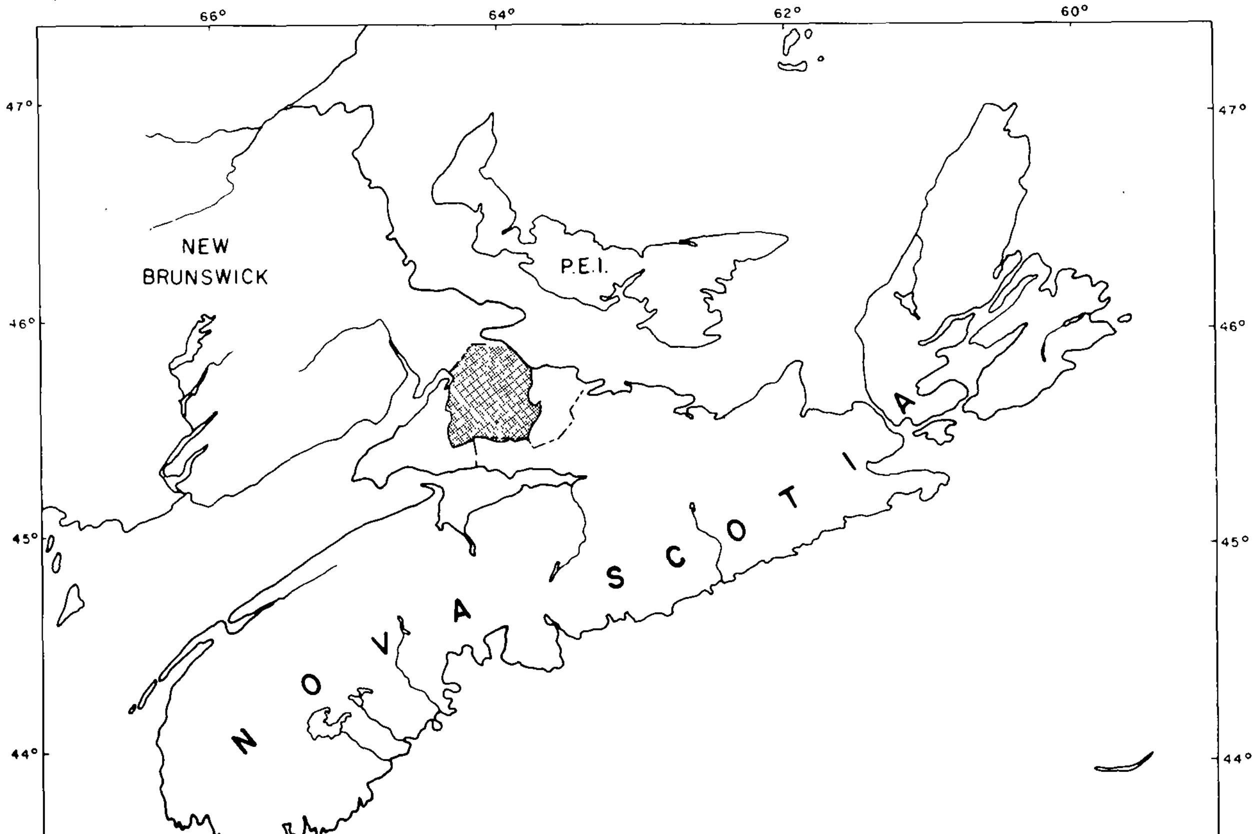


Figure 1.1 Study Area Location

and Springhill. The study boundaries were selected along the natural watershed boundaries of the following river basins: the Maccan, the River Philip, the Shinimikas, the Nappan, the Tidnish and LaPlanche. The study region covers an area of approximately 1,800 km^2 (700 mi^2) (Map in Pocket).

1.2 Previous Work

The first comprehensive geologic report and maps of Nova Scotia were compiled by Sir William Dawson in his four editions of "Acadian Geology" (1855 and later editions). The latest publication dealing with the physiography and geomorphology and effects of glaciation in Nova Scotia is the "Physiography of Nova Scotia" by Goldthwait (1924).

In 1927, Dr. W.A. Bell published the first comprehensive report on the Carboniferous stratigraphy of Nova Scotia. W.A. Roliff (1931) prepared one of the first regional geological map compilations which included most of Cumberland County, portions of New Brunswick and Prince Edward Island. Bell (1938) published the first detailed geological maps of Springhill, Cumberland and Colchester Counties. Shaw (1951) published a bedrock geology map of a northern section of Cumberland County. More recently, Donohoe and Wallace (1978) published preliminary geological maps of the Cobequid Mountains. Nowland and MacDougall (1973) provide an outline of the distribution and description of various soil types of Cumberland County.

Various reports have been written on the occurrence of economic minerals and the results, of core drilling in the map area. These reports and drilling records are available for reference at the Technical Records Library, Nova Scotia Department of Mines and Energy in Halifax.

A review of the literature indicates that some 38 water resource related reports concerning the Cumberland County area were completed over the period 1960 to 1979. One of the first comprehensive efforts providing a compilation of basic water resources data of the province was completed by the Atlantic Development Board (1967) through the Groundwater Section of the Nova Scotia Department of Mines. This report provided a summary of existing meteorological, hydrological and water quality data and specifically provided a description of water supplies for all communities over 500 in population. Regional water quality monitoring of surface and groundwater resources was provided by Environment Canada, Inland Waters NAQUADAT program 1973-1976. A report prepared for the Atlantic Development Board by Montreal Engineering Limited (1969) provided generalized hydrological maps of Nova Scotia including areas of Cumberland County.

A number of specific consultant reports concerning the water supply development alternatives of Amherst, Springhill and Oxford have been completed. Of these, a report by H.J. Porter and Associates (1980) prepared at the request of the Cumberland District Planning Commission addresses the water supply requirements of a number of communities of Cumberland County.

Investigation by several engineering consultants reported a number of water supply alternatives for the Town of Springhill. The extension of well systems, development of Leamington Brook and British Lake have been identified as potential water supply options.

Groundwater investigations in the Springhill-Rodney area (Vaughan, 1978) provide detailed information on surficial sands and gravels, and Cumberland Group bedrock aquifers (see section 5.2.4).

On behalf of the Town of Oxford, studies by MacLaren Atlantic Limited (1972 and 1975) investigated surface water resources of River Philip and groundwater potential north and west of the Town and recommended either groundwater to the north or River Philip as potential development alternatives.

In adjacent areas discharge records are available from the Water Survey of Canada for the Wallace River (10DN004) at Wentworth Centre (since 1964), Wallace River (01DN003) at Howard's Mill (for various periods between 1923 and 1933), and for Kelley River (01DL001) I.H.D. basin at the Chignecto Game Sanctuary (since 1969).

In addition to climatic and hydrometric records, well log and pump test data are on file at the Nova Scotia Department of the Environment, Halifax.

1.3 Physiography

The study area can be divided into two distinct physiographic units, the broad Cumberland Plain and the east-west trending range of the Cobequid Mountains. The Cobequid Mountains form the southern boundary for the study area. Goldthwait (1924) described this range as "a remnant of the ancient Atlantic Peneplain". This narrow plateau varies from 13 to 16 km (8 to 10 mi.) in width with a rolling summit level 260 m to 300 m (850 to 1,000 ft.) above sea level. This lowland plain is characterized by a series of roughly parallel ridges having a trend similar to that of the Cobequid Mountains, but lower in elevation. These ridges become less pronounced further to the north, where in the

Amherst area, the land is essentially flat-lying with an occasional low ridge crossing the plain.

Dendritic drainage patterns were established before Pleistocene glaciation. Antecedent rivers now occupy these ancient river valleys, crossing geological trends at right angles. Beginning as narrow, steeply incised trenches in the Cobequid Mountains, these river valleys broaden over extended flood plain areas as the river course meanders north toward the coast. Drowning of river mouths at the close of the ice age resulted in the development of broad extended estuaries characteristic of major river systems in northern Nova Scotia.

1.4 Climate

Cumberland County is located in a cool, humid, temperate climatic zone with weather displaying great variability throughout all seasons (Nowland and MacDougall, 1973). Meteorological stations with the longest records are at the Nappan Experimental Farm, Parrsboro, and at Oxford. Table 1.1 presents long-term regional climatic data.

The long-term averaged precipitation and temperature values are generally uniform across the County with Oxford being slightly higher in precipitation and the number of frost free days. The average snowfall amounts to between 152 to 203 cm (60 and 80 in.) a year and commonly covers fields to a depth of 30.4 to 45.7 cm (12 to 18 in.) in mid-winter (Nowland and MacDougall, 1973).

1.5 Population and Land Use

The population of Cumberland County in 1976 was 35,915, with 48% of the people living in rural areas and 52% living in urban areas. Service industries are the largest employers, with 58% of the work force engaged in activities such as utilities, transportation, businesses and public administration. Manufacturing and construction account for 22% of the work force, and resource industries such as forestry, mining, fishing, and trapping for 6%. Agriculture accounts for 5% of the work force; the remaining 8% is involved in industry of one form or another.

Approximately 80% of Cumberland County is covered in productive forested lands. Agricultural land and other improved land occupy 11% of the total area of Cumberland County. The remaining 10% being covered by urban development, water and non-productive lands (N.S. Department of Development, 1979).

1.6 Water Resources Data Base Inventory

A comprehensive water resources data base inventory has been prepared as a second component and major objective of this project. This inventory is designed to make accessible the information utilized in the preparation of this report and to compile in one place the pertinent water resources data available for the study area.

The subject index file incorporates the following:

a) Well Log Inventory

This file includes information on location, well specifications, yields and log of approximately 500 domestic, commercial and industrial wells drilled within the study region.

b) Test Drilling

This index lists detailed specifications and logs of 16 test wells drilled during the course of this study as well as information provided by existing wells. Aquifer and well hydraulics, water quality, and detailed lithology are included.

c) Meteorological Data

This file includes temperature, precipitation and evaporation data obtained from 7 stations established during the course of this investigation and 6 existing stations either within the study region or incorporated in a regional analysis.

d) Hydrological Data

This file includes hydrographic records, rating curves and charts of 5 stations established for study pur-

Table 1.1

Average Precipitation and Temperature Cumberland County

	Nappan	Parrsboro	Oxford
Mean Daily Temperature (C°)	5.6	5.9	5.6
Mean Total Annual Precipitation (mm)	1038	1194	1079
Number of Days Without Frost	172	172	182

poses as well as I.W.D. historical and active (2) hydromet stations located within the study region and used for regional analysis.

e) Watershed Analysis

The watersheds of Wallace, Philip and Maccan were analyzed in some detail. Hydrographs, hydraulic characteristics, water balance calculations and basin geomorphic characteristics are included.

f) Surficial Geology

Detailed grain size analysis of 21 selected sediment samples and descriptions of 312 overburden inspection test pits are listed in this index.

g) Water Quality

This file contains a two part quality index providing detailed water chemistry of both surface water and groundwater. This file incorporates all information, including historical information not represented in the report Index D. Original reports and tabulated results are listed.

h) Map Index

The map index comprises 16 national topographic series grid maps (1:1320) which cover the study area (Figure 1.2). These maps are keyed to the inventory subject index and therefore portray information that is site-oriented such as well locations, test drilling sites, water quality sampling stations, hydrological and meteorological stations. Regional topography, bedrock and surficial geology are also provided at this scale.

This data base inventory is now on open file at the N.S. Department of Environment library.

1.7 Acknowledgements

The Nova Scotia Department of the Environment gratefully acknowledges the funding and assistance provided by the Canada Department of Regional Economic Expansion and the Nova Scotia Department of Development during the course of this study. We extend our appreciation to the members of the Project Monitoring Team represented by George Dargie, Department of Regional Economic Expansion, Les Stewart, Nova Scotia Department of Development, Don Ambler, Inland Water Directorate and John Jones, Nova Scotia Department of the Environment.

The project was implemented by James Vaughan from May, 1977 to July, 1978. George Somers continued this study during the remaining project time, ending in October, 1979.

Hydrometeorological information was prepared by Wilfrid Byers. Geological mapping and drilling programs were supervised by George Somers. Field support was provided by Frank Cruickshanks, Leslie Farnell, and Robert Porter. Drafting work was prepared by Elaine Limpert and John Cameron. Don

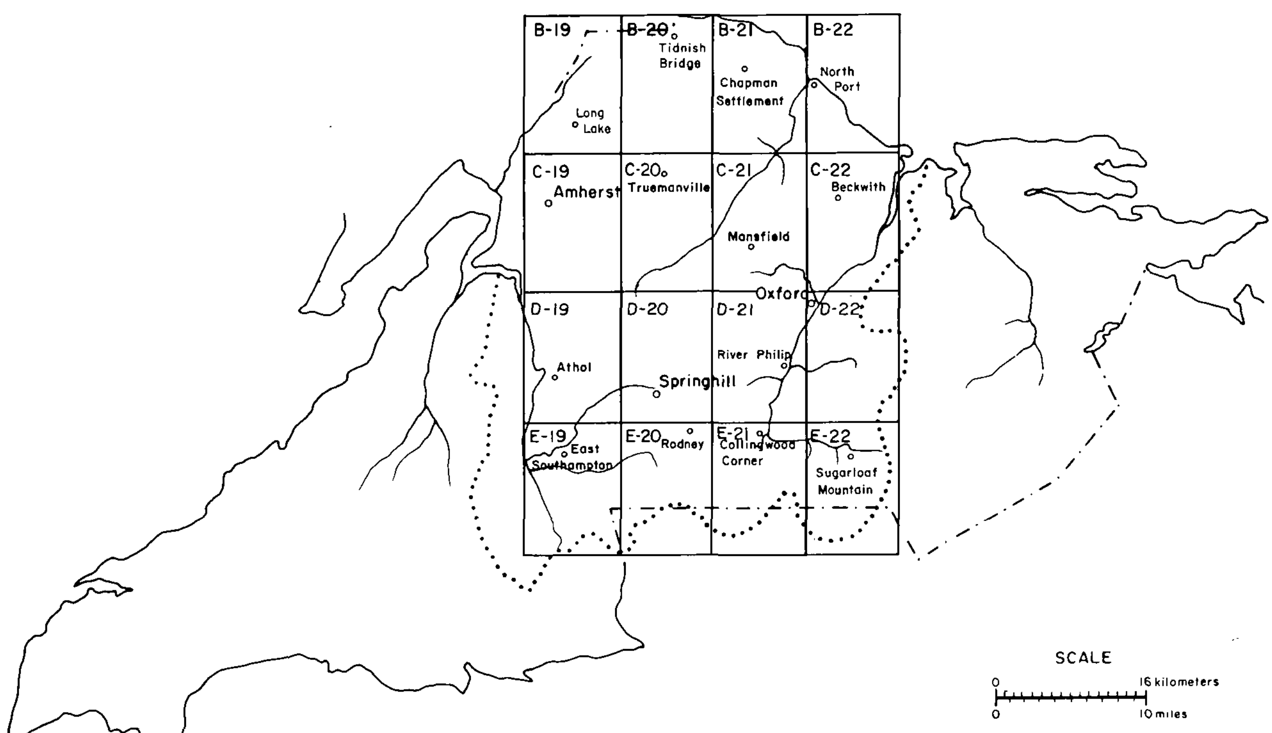


Figure 1.2 Index Map, Cumberland County

Ambler, Inland Waters Directorate and Merlin MacAulay, Atmospheric Environment Service provided advice on technical components of the program.

Assistance in collecting hydrometeorological information was provided by the staff of the Nappan Experimental Farm, the Cobequid Fish Hatchery and instrument readers Norman Weeks, Bud Crouse, Leonard Bower, Reverend Ingersall and Jack Palmer, residents of Cumberland County.

This report was critically reviewed by Dr. C.L. Lin and D.M. McCready, Nova Scotia Department of the Environment. Critical comments on specific sections of this report were provided by Dr. H. Donohoe, Nova Scotia Department of Mines and Energy and Dr. D. O'Neil, Atmospheric Environment Service.

CHAPTER 2
Bedrock Geology

2.1 Methodology

During the course of this project all pertinent available geological information assembled is represented both in this report and on a series of base maps which comprise part of the data base inventory. Although this work is basically a compilation of existing data, some modifications were required in order to match information from adjacent map sheets.

2.2 Regional Geology

The study area falls within the Cumberland Structural Basin, one of several basins which together make up the larger Fundy Geosyncline (Copeland, 1959). The basin is bounded on the north by the Caledonia Uplands of New Brunswick and on the south by the Cobequid Mountains of Nova Scotia. The outlines of the basin were probably formed during the Acadian Orogeny in lower Devonian time (Shaw, 1951).

During the Carboniferous period, the basin went through a period of nearly continuous deposition with periodic episodes of rejuvenation of uplift in the bordering upland areas and subsidence of the basin. Sedimentation in the basin was predominantly continental, but the basin did experience two marine transgressions, reaching their peak in mid-Horton and mid-Windsor times (Shaw, 1951). Since the Carboniferous Period there has been little depositional activity in the basin.

Much of the present morphology of the study area is a result of modification by glacial activity. Most of the overburden materials are glacial till. Deposits of glaciofluvial sediments occur along the courses of the larger rivers. The influence of the sea is also evident, especially in the northern part of the study area where there are large areas of marshlands underlain by marine sediments.

2.3 Stratigraphy

2.3.1 Pre-Carboniferous

The oldest rocks in the study area are in the Cobequid Uplands and consist of metamorphosed sediments and volcanics. The metamorphic rocks are mostly of Silurian and Devonian age and include quartzite, grey to green argillite, and metamorphosed andesitic and rhyolitic volcanic flows. These were intruded by plutonic rocks ranging from a grey diorite to a pink granite during Silurian and Devonian to early Carboniferous Periods (Table 2.1) (Eisbacher, 1967 and Donohoe and Wallace, 1978).

2.3.2 Horton Group

The oldest group in the stratigraphic succession of the Cumberland Basin is the Horton Group of the early Carboniferous age (Table 2.1). Although these rocks are not exposed in the study area, their presence has been deduced from exposure in other parts of the basin as well as from information obtained from the logs of deep boreholes (Shaw, 1951). The group is mainly composed of red and grey sandstones and some conglomerate.

2.3.3 Windsor Group

Overlying the continental sediments of the Horton Group are the marine rocks of the Windsor Group, also of early Carboniferous age (Table 2.1). The group is exposed mainly in the crests of two east-west trending anticlinal structures, the Claremont Anticline and the Minudie Anticline, as well as in the Salt Springs area near Springhill (Shaw, 1951). (See Figure 2.1).

Deposition of the Windsor Group took place mainly in a marine environment, although the latter part of the sequence contains largely continental sediments. The marine part of the Windsor Group consists primarily of limestone interbedded with red to brown shales and light grey sandstones, and variably thick sequences of gypsum, anhydrite, and salt.

2.3.4 Canso Group

Following the Windsor Group are the continental sediments of the Canso Group (Table 2.1). Within the study area, the Canso Group is exposed mainly along the Minudie Anticline. This sedimentary sequence lying between the marine strata of the Windsor Group and the base of the Riversdale Group has been included in the Middleborough Formation (Bell, 1943). Although, strictly speaking, the Middleborough Formation includes both rocks of the Canso Group, as well as non-marine Windsor strata, it is a useful division for the purposes of mapping.

2.3.5 Riversdale Group

The sedimentary sequence overlying the Canso Group in the Cumberland Basin is the Riversdale Group of Pennsylvanian Age (Table 2.1). It is well represented in the study area, in the Minudie and

	PERIOD	GROUP	FORMATION OR FACIES	LITHOLOGY
Carboniferous	Pennsylvanian	Pictou Group 2100m	Undivided	red sandstone, conglomerate and shale some grey sandstone and shale
		Cumberland Group	Upper fine facies, 365m	red sandstone and siltstone
			Upper coarse facies, 150m	red conglomerate, and grey sandstone
			Lower fine facies, 150m	grey sandstone, red and grey shale, coal
			Lower coarse facies, 640m	red shale, sandstone and conglomerate
		Riversdale Group	Boss Point formation 1000m	grey and red sandstones and shale
			Claremont Formation 100m	red conglomerate and grit, some sandstone and shale
	Mississippian	Canso Group 220m	Middleborough Formation	predominately red sandstone and shale, some grey sandstone
		Windsor Group 470m	Marine Windsor facies	red shale, gypsum salt, limestone, anhydrite
		Horton Group	Undivided	red and grey sandstone and shale
pre-Carboniferous	Devonian			igneous rocks ranging in composition from granite to diorite
	Silurian			metasediments and meta volcanics

Table 2.1 Stratigraphic Sequence

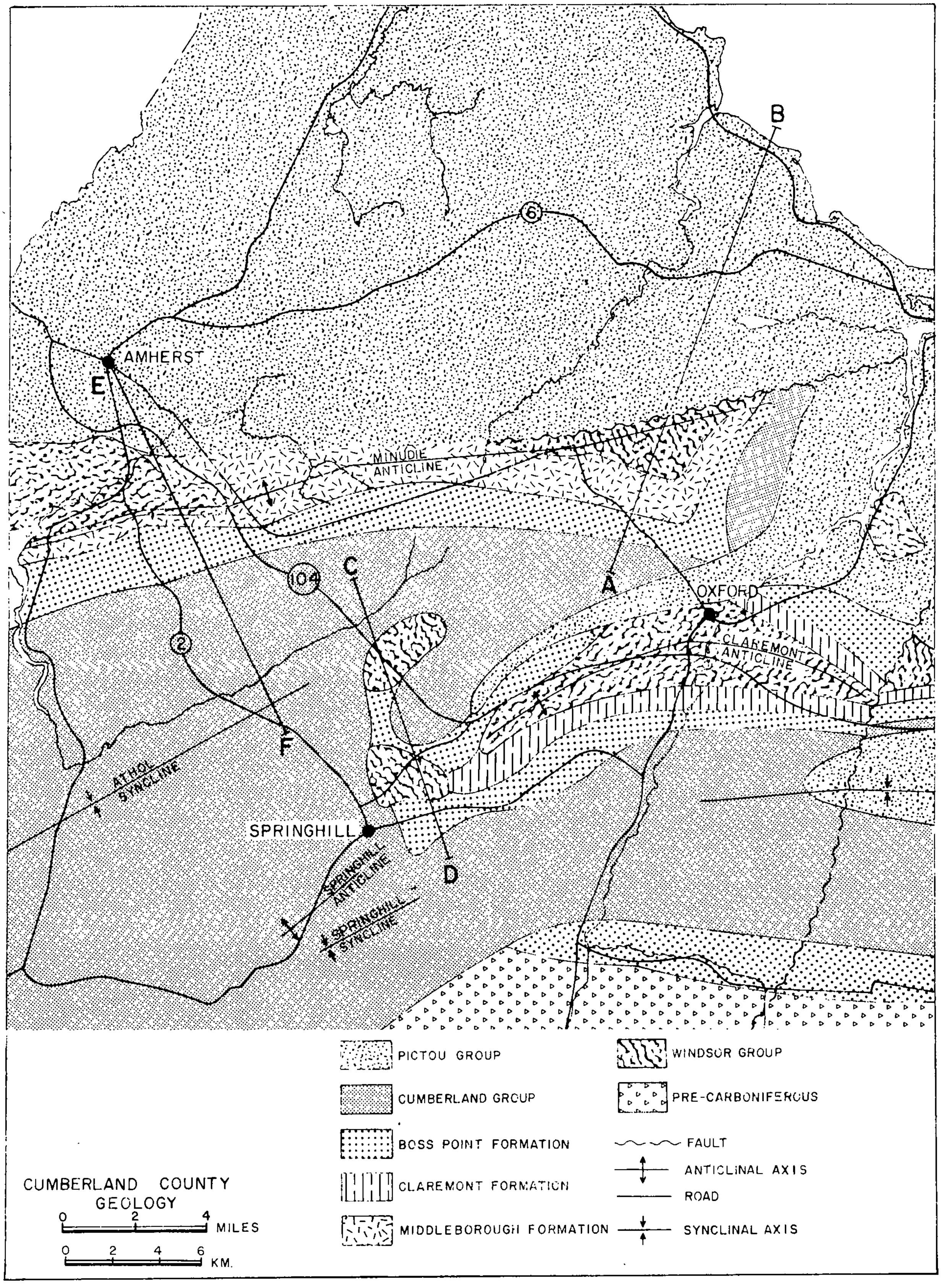


Figure 2.1 Generalized Geology of Study Area

Claremont Anticlines and along the northern margin of the Cobequid Mountains (Shaw, 1951). In the Cumberland Basin, the Riversdale Group has been divided into two formations: the Claremont Formation and the younger Boss Point Formation (Bell, 1944).

The Claremont Formation is exposed mainly along the southern limb of the Claremont Anticline and along part of its northern limb near the eastern extremity of the study area. The Claremont Formation is composed primarily of conglomerate with some sandstone and shale (Shaw, 1951).

The Boss Point Formation is more widely distributed and is exposed along the southern, and part of the northern, limb of the Claremont Anticline and along the northern margin of the Cobequid Uplands. It is composed of grey to grey-green quartz sandstones with varying amounts of red and grey shale (Shaw, 1951). Red conglomerates are found locally along the northern flank of the Cobequid Mountains (Donohoe, personal communication).

2.3.6 Cumberland Group

The Cumberland Group is one of the most widespread and well developed sedimentary units in the Cumberland Basin (Shaw, 1951). It overlies the Riversdale unconformably (Bell, 1944). Within the basin, the lithology changes rapidly in a lateral direction toward the margins of the basin, permitting the subdivision of the group on the basis of lithology into four units (Table 2.1): a) a lower coarse facies, b) a lower fine facies, c) an upper coarse facies, and d) an upper fine facies (Copeland, 1959). On the simplified geology map presented in Figure 2.1, the group is shown as one unit. For further detail see Map 1 in the pocket at the back of the report.

The lower coarse facies is predominantly conglomerate and is exposed primarily around the periphery of the basin close to the contact with the pre-Carboniferous rocks of the Cobequid Uplands. Near this contact, there are up to 2,900 m (9,500 ft.) of coarse, poorly sorted fan conglomerates. Moving northward away from the contact, there is a rapid decrease in the grain size, with sandsone beds starting to appear. Near the axial regions of the basin this basal phase is represented by interbedded red shales and sandstones. The lower fine facies is composed of red and grey shale and sandstones, black calcerobituminous shales and coal. Most of the coal-bearing rock is found near the Town of Springhill and along the northern side of the Athol Syncline between Maccan and Joggins.

Following the coal-bearing lower fine facies is another coarse facies. The upper coarse facies can be distinguished from the lower coarse facies by the presence of lenses of red and grey sandstones and a generally finer texture with more rounded clasts.

The upper fine facies occurs only along the axis of the Athol Syncline. It consists mainly of red shales and sandstones with some grey sandstones (Copeland, 1959).

2.3.7 Pictou Group

The strata of the Pictou Group represent the final stages of deposition in the Cumberland Basin (Shaw, 1951) and unconformably overlie all older rock uinits (Table 2.1). The Pictou Group covers virtually all of the study area north of the Minudie Anticline, and a large portion of the area between the eastern end of the Minudie and Claremont Anticlines. The sediments of this group generally consist of reddish-brown, soft micaceous sandstones, and arkosic grits alternating with zones of red shales and/or mudstones, and occasional red and grey mottled sandstones. There is a thin conglomerate zone at the base of this group in some areas.

2.4 Structural Geology

The study area can be broken into two geologically distinct areas: the sedimentary Cumberland Lowland and the Upland areas of the Cobequid Mountains. The Cobequid Uplands, although complex, can be treated as a single structural element for the purpose of this study.

Three major structural features, the Minudie and Claremont Anticlines and the Athol Syncline dominate the regional character of the sedimentary basin and the distribution of geological units in the region (Figure 2.1). Section A-B (Figure 2.2) illustrates the general relationship of units in a cross-section of the Minudie Anticline near the eastern boundary of the study area. Cross-section C-D (Figure 2.2) illustrates the structure of the area at the western end of the Claremont Anticline near Springhill. Section E-F (Figure 2.3) shows the relationship of sediments in the Minudie Anticline near Amherst and in part of the Athol Syncline to the south.

The Minudie Anticline extends from the western boundary of the study area in an easterly direction, passing just south of Amherst to a point about 24 km (15 mi.) north of Oxford. The Windsor Group is exposed at both the east and west ends of the Anticline, and could be expected to be found at relatively shallow depths along the intervening portion of the anticline, below strata of the Middleborough Formation. On the northern limb of the anticline, the Pictou Group dips gently to the north;

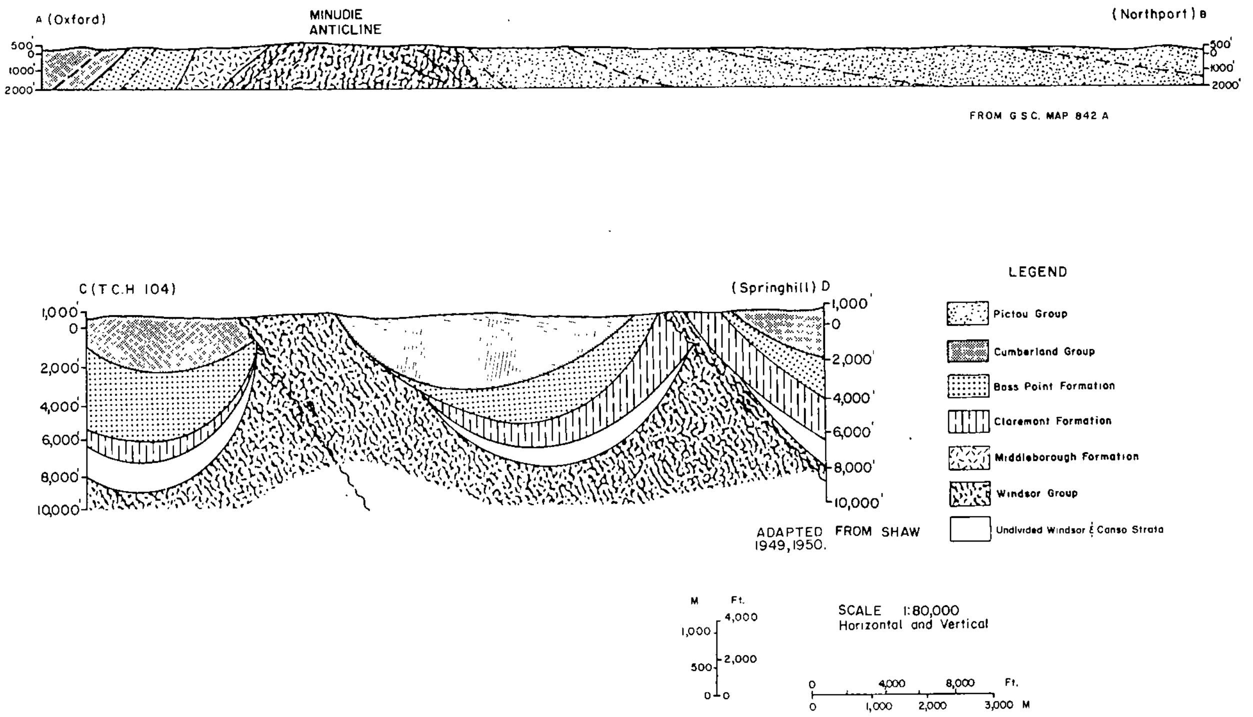


Figure 2.2 Geological Cross Section Cumberland Basin A-B, C-D

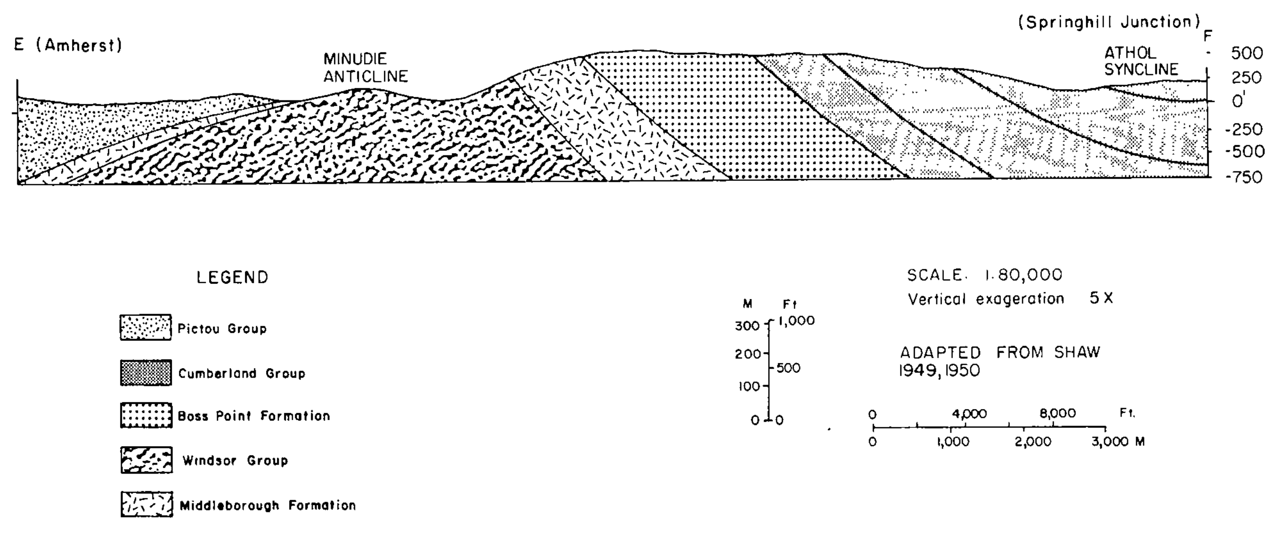


Figure 2.3 Geological Cross Section Cumberland Basin, E-F

on the southern limb, Riversdale and Cumberland strata dip more steeply to the south.

The Claremont Anticline lies in the central and eastern portion of the study area, trending east north-easterly from the area just east of Springhill to the eastern boundary of the study area, passing just south of Oxford. The Windsor Group is exposed throughout much of its length, overlain on the southern limb by Riversdale and Pictou strata.

CHAPTER 3
Surficial Geology

3.1 Methodology

The surficial mapping program entailed mapping on a 0.4 km (0.25 mi.) interval along roads where access by vehicle was possible and on a reconnaissance scale (1—2 km or 0.6—1.2 mi.) in all other areas.

At each inspection site, a hole was dug exposing the soil parent material. The materials were examined, a description recorded, and the site located on a base map. Agriculture Canada's report, Soils of Cumberland County, was used extensively as a field reference (Nowland and MacDougall, 1973).

Soil samples considered to be typical of the overburden materials identified, were analyzed using numbers 4, 5, 10, 35, 60 and 230 mesh sieves (U.S. standard mesh sizes).

Six categories of surficial materials were established. They include: sandy till, rocky sandy till, silty till, clay till, glaciofluvial sediments and peat and muck. Figure 3.1 indicates the general parameters governing the division of till types. It should be noted that

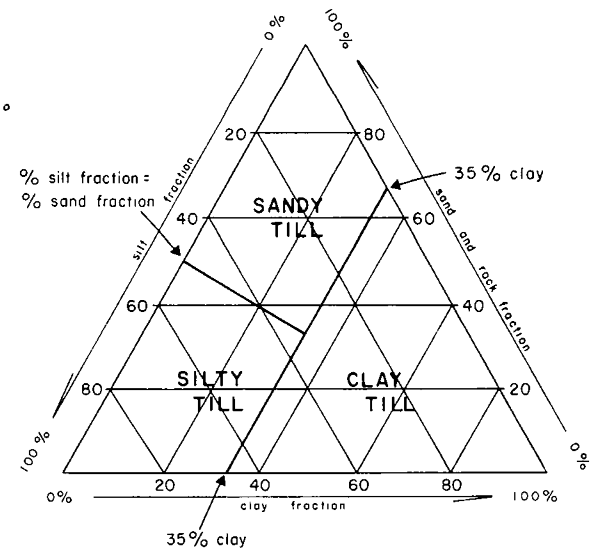


Figure 3.1 Classification of Till Types

rocky sandy tills are defined here as sandy tills in which more than 30% of the clasts are pebble size or larger. Any till having a clay content greater than 35% has been classified as clay till. Although not distinguished on bar diagrams, the silt/clay fines component of sandy till contain clay in less than 35% by weight. Glaciofluvial materials include any coarse grained, water-borne sand and/or gravel *material with low fines* content. In places, these deposits have been reworked by recent stream activity and would more properly be referred to as stream alluvium, but for the purposes of this report they are grouped as glaciofluvial sediments.

The report presents a brief description of the general characteristics and distribution of each category of surficial material. Results of samples analyses are included in the form of a histogram of the grain size distribution for selected samples. Results of the field mapping program are presented in Map 1 (in pocket).

3.2 Glacial Tills

Over 90% of the area is covered with glacial till, with the sandy and rocky sandy tills predominant. In the northern area near Amherst and along the shoreline of the Northumberland Strait, tills average 8 m (27 ft.) in thickness. Further south, in the vicinity of Oxford and Springhill, tills are shallower with a mean depth of 7 m (22 ft.). In topographical depressions till thickness may exceed 9 m (30 ft.). Till thickness could be expected to be more variable in the Cobequid region due to the irregular topography. Along major river valleys where both tills and stratified sand and gravel deposits are found, average overburden thickness is 17.6 m (58 ft.) with a range of depth from 6 to 60 m (20 to 200 ft.).

The northern half of the study area is overlain by a compact sandy till. Moving south, this till grades to rocky or gravelly sandy till, particularly near the Cobequid Mountains. This gradational boundary, represented by a single line drawn across the study area, passes through the Oxford area in the east and Maccan to the west (Map 1). Sample 20 (Figure 3.2) taken north of Sugarloaf Mountain, and sample 2 (Figure 3.3) taken near Hastings, are examples of these two tills.

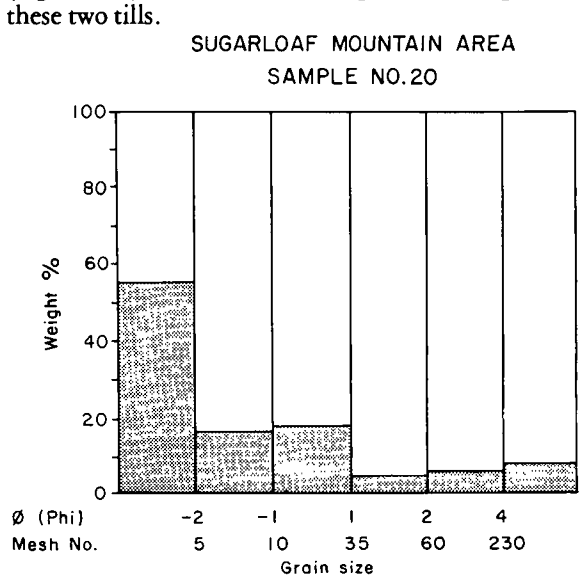


Figure 3.2 Rocky Sandy Tills

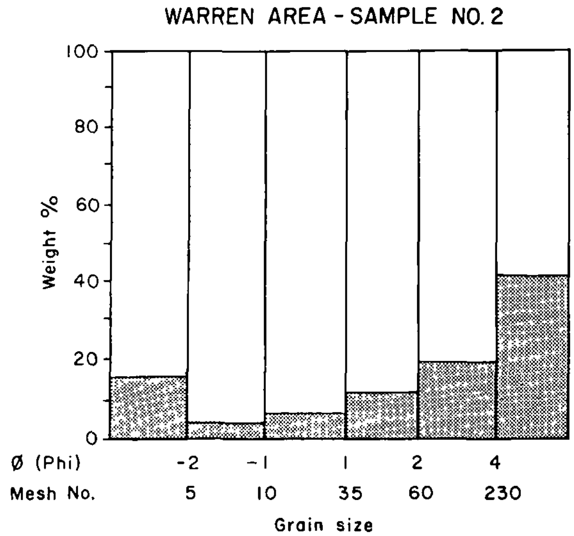


Figure 3.3 Sandy Tills

The rocky sandy till in the Cobequid Mountain area contains boulders, cobbles and gravel sized material in a greater proportion than the rocky sandy till covering the sedimentary lowland.

The largest area of clay till stretches in a discontinuous east-west band from Springhill to Oxford. In much of this area clay till is overlain by a thin sandy zone, usually 0.3^{m} (1.9 ft) or less in depth, although locally it may reach a depth of 1.0^{m} (3 ft).

Another area of clay till is found near Beckwith, in the northeastern part of the study area. A small area is found near the confluence of the Maccan and Nappan Rivers. This till is silty and locally may constitute a silty till. Sample 9 (Figure 3.4), taken east of Oxford, is an example of the clay till.

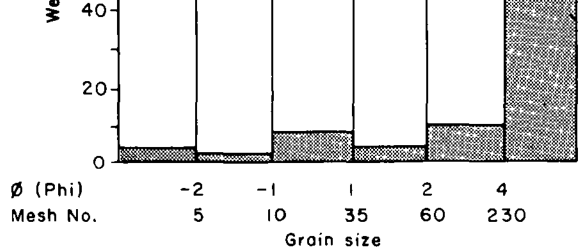


Figure 3.4 Clay Tills

There are relatively few tills in which silt is the dominant component. More often silty tills are found in small, isolated patches.

3.3 Glaciofluvial Sediments

Among the most important elements identified during the surficial mapping program are the glaciofluvial deposits found mainly along the courses of the Maccan River, Black River, River Philip, and between Sugarloaf Mountain and Thomson Station. These deposits owe their origin to the glacial meltwaters which ran north from the Cobequid Highlands during the late stages of glaciation.

Generally, the clastic components of these deposits reflect closely their provenance, with a large proportion consisting of pebbles and cobbles of igneous and metamorphic rocks which can be correlated with similar rocks in the Cobequid Highlands. A bowl shaped bedrock depression situated at Rodney, just south of Springhill is filled by outwash sands and gravels. In places the gravel reaches thicknesses of 18 m (60 ft.). These deposits occupy the headwater areas of both the Black and Maccan Rivers. Further downstream along the Maccan River near Mapleton, glacial outwash again appears. Kame deposits are found on the flanks of many of the surrounding hills. The outwash is found along the entire course of the river from Mapleton down to Athol and merge with more glaciofluvial sediments from West Brook and Lawrence Brook at Southampton. Several small eskers lie on the outwash plain between Southampton and Athol and there is evidence of recent river activity reworking these glaciofluvial deposits. Generally, the deposits are composed of a mixture of sand and gravel, with sand being dominant over gravel.

Most of the sand and gravel along the Black River is found further downstream, close to Oxford. Sand is dominant in this deposit, especially in the lower part of the river basin. The sand is clean and cross-bedding can often be seen.

The entire non-tidal portion of River Philip lies within the confines of an old glaciofluvial outwash plain. This outwash plain originates at the foot of the Cobequid Mountains and runs with a fairly uniform width 0.8 km (0.5 mi.) north toward Oxford. It narrows to about 0.4 km (0.25 mi.) near Oxford Junction and then broadens out into a wide flat plain where it merges with the Black River watershed sand and gravel deposits. Test well No. 16, immediately north of Collingwood Corner, penetrated 12 m (40.0 ft.) of gravel and sand. Significant amounts of mud were also found accompanying the sands and gravels at some levels. From Collingwood Corner, south 5.47 km (3.4 mi.) to the Cobequid Mountains, sand and gravel deposits cover an area of

2.26 km^2 (1.4 mi^2) and are known to exceed 36.8 m (120.0 ft.) in depth. Sample No. 8 (Figure 3.5) from the Oxford area is an example of outwash sand and gravel. The only large area of outwash sands and gravels which does not follow the course of a first order river lies between Thomson Station and

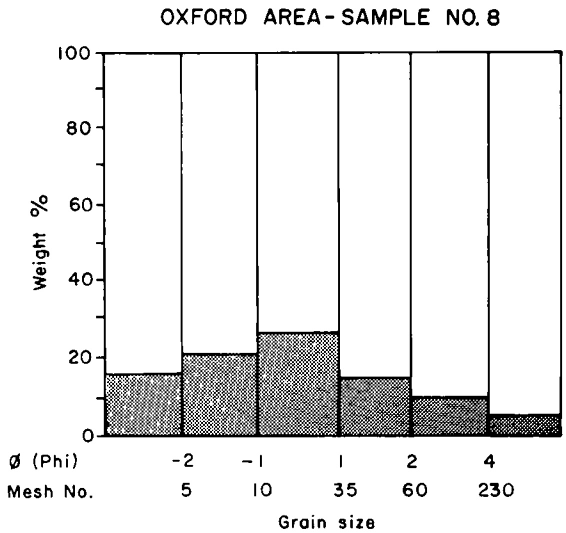


Figure 3.5 Glaciofluvial Sediments

Sugarloaf Mountain. From its overall outline and internal structure, it appears that the origin of this outwash plain may be similar to the deposits found along the Maccan River and River Philip. The lithology of the clastic components (mainly igneous and metamorphic clasts with lesser amounts of sedimentary rock clasts) indicates a source in a predominantly igneous and metamorphic terrain, presumably the Cobequid Highlands. Internal structures, such as well defined stratification and large scale crossbedding, add further evidence of a glaciofluvial origin. The sands and gravels of this deposit seem to be generally coarser than the deposits found along the Maccan and River Philip Valleys. There are some isolated areas which are composed entirely of sand sized material. Their relationship to the rest of the deposit is not clear.

Areas of silty stream alluvium can be found along Tillits Creek near Thomson Station, East Brook near Springhill, and along the lower part of Baird Brook near Maccan. These deposits have been included with the silty tills because their limited distribution does not merit the establishment of a separate category when considering the surficial geology on a regional scale. Also, the compact texture of these deposits results in hydraulic characteristics similar to silty tills.

3.4 Peat and Muck

A unique feature of the landscape in northern Nova Scotia is the large area of marshland found near the provincial boundary. These marshlands contain marine deposits which generally have a silty clay to clayey texture. The marshlands have a very uniform soil profile and are generally stone free. Shown below are the results of the analysis of the substratum ("C Zone"), (Whiteside, Wickland and Smith 1945). The results shown are representative of well drained and poorly drained marshland, respectively.

Well Drained Dykeland	- sand	35%
	- silt	31%
	- total clay	34%
Poorly Drained Dykeland	- sand	11%
	- silt	46%
	- total clay	43%

In scattered areas throughout the county peat bogs have formed in old lake basins or other poorly drained topographic depressions. The largest concentration of these bogs is in the Chignecto Isthmus near the provincial border. These deposits have formed from the accumulation of poorly decomposed plant material and are generally of 1.3 m (4 ft.) in thickness (Agriculture Canada, 1973).

CHAPTER 4
Hydrometeorology

4.1 Methodology

Basic meteorological data were obtained from the Atmospheric Environment Service (Environment Canada, 1967 and later additions), and hydrometric data from Water Survey of Canada (Environment Canada, 1977). The station locations are shown on Figure 4.1 and data are given in Tables B1 and B2 (Appendix B).

Meteorological and hydrometric data on the additional stations were obtained by project staff and attendants, until August 1978. The staff of the Inland Waters Directorate completed the winter metering and collection of hydrometric records. Tabulations of daily flow, hydrographs, and an evaluation of the stations are given in Water Survey of Canada (1979).

Long-term data from Kelley River, I.H.D. station and Water Survey of Canada hydrometric station on the Wallace River at Wentworth Centre were used as controls in analyzing variations of runoff within the study area.

Due to frequent flooding problems on the lowland no hydrometric stations were established on the Nappan, Tidnish, and Shinimikas Rivers. By placing two stations on sub-basins of the Wallace River, above the existing station 01DN004, it was possible to calculate the approximate yields of the watershed sub-basins.

Records of the stream flows of the Five Islands River below British Lake were also obtained. Though the Five Islands River flows southerly into Minas Basin, the gauge was a short distance below British Lake, and thus gave records of runoff from a small basin on the highland plateau.

4.2 Meteorology

4.2.1 Precipitation

The mean annual precipitation data for five meteorological stations, typical of the study area are given in Table 4.1.

The Ten-Year Mean is approximately 7% higher than the 30 Year Mean. The longer term mean provides a more conservative basis for calculations of annual yields from the study area.

The average monthly regional precipitation and temperature for 1978 are shown in Table B3 (Appendix B). Data from Sackville, New Brunswick and Tatamagouche, Colchester County are included.

The regional trends (Figure 4.2) indicate that mean annual precipitation (over record period of 10 years, 1967-77) varies from a high of 1,400 mm (55.1 in.) in the Cobequid Mountains decreasing to 1,000 mm (39.4 in.) along the coast to the North. Similarily, summer mean precipitation recorded over the same period varies from a high of 450 mm (17.7 in.) in the

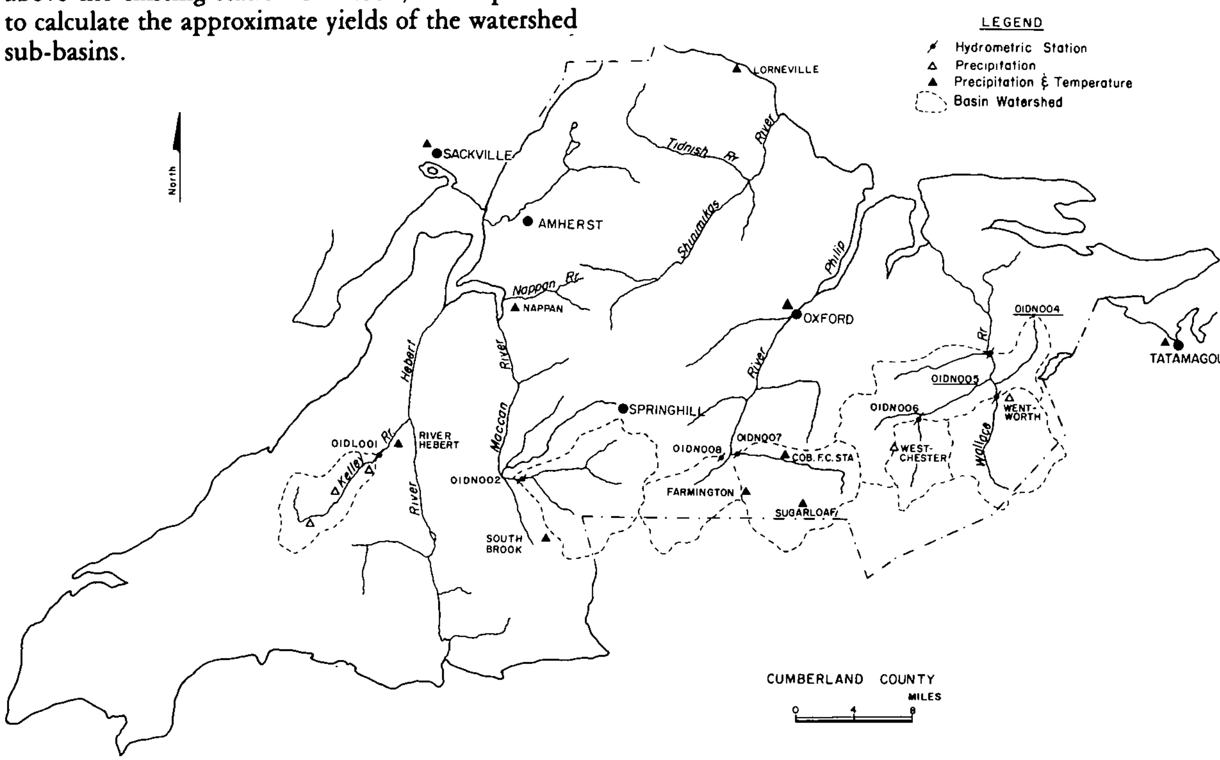


Figure 4.1 Hydrometric and Meteorological Recording Sites

Table 4.1
Mean Annual Precipitation
Cumberland County and Region

Station	A.E.S. Number	Approximate Elevation (m)	(ft)	Mean Annual 1941-70 (mm)	Precipitation 1967-77 (mm)
River Hebert	8204570	15	50	1178.9	1270.0
Sackville, N.B.	8104500	23	77	1043.2	1200.0
Nappan, C.D.A.	8203700	19	63	1038.0	1160.0
Oxford	8204200	13	42	1078.7	1110.0
Tatamagouche	9205775	13	42		1110.0
Ten-Year Mean					1160.0
Thirty-Year Mean				1084.7	

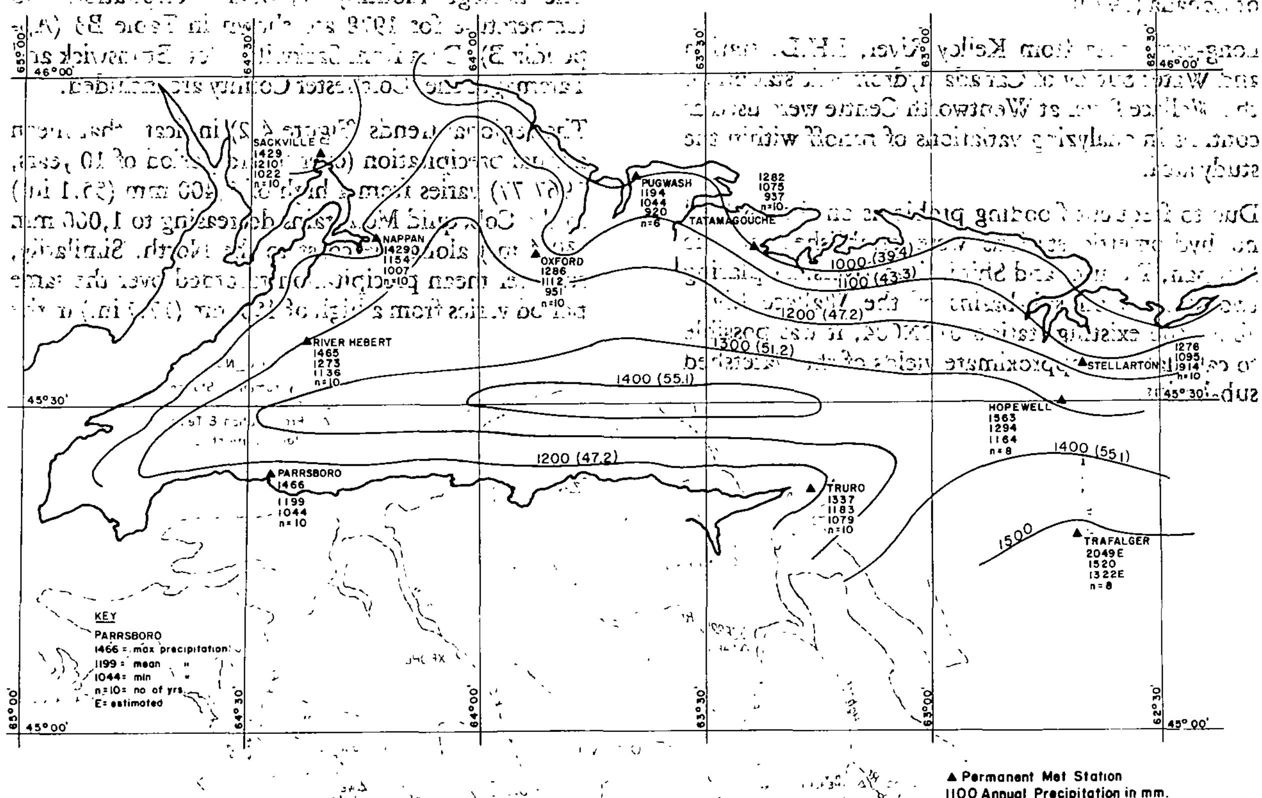


Figure 4.2 Isohyets of Mean Annual Precipitation, 1967-76

southern study area to 400 mm (15.8 in.) along the Northumberland shore (Figure 4.3).

Correspondingly, 1978 annual and summer regional precipitation patterns generally follow the longer-term trends identified above. However, the amount of precipitation occurring during 1978 is less than the 10 year average (Figure B.1, and B.2, Appendix B).

Available records indicate that there are local variations in rainfall patterns that can produce differences in precipitation, and in resulting runoff, in adjoining basins. An example of local variations of precipitation is shown in Table 4.2.

Wentworth Centre and the Fire Control Station east of Collingwood Corner are along the toe of the mountain; the Westchester gauge was on the moun-

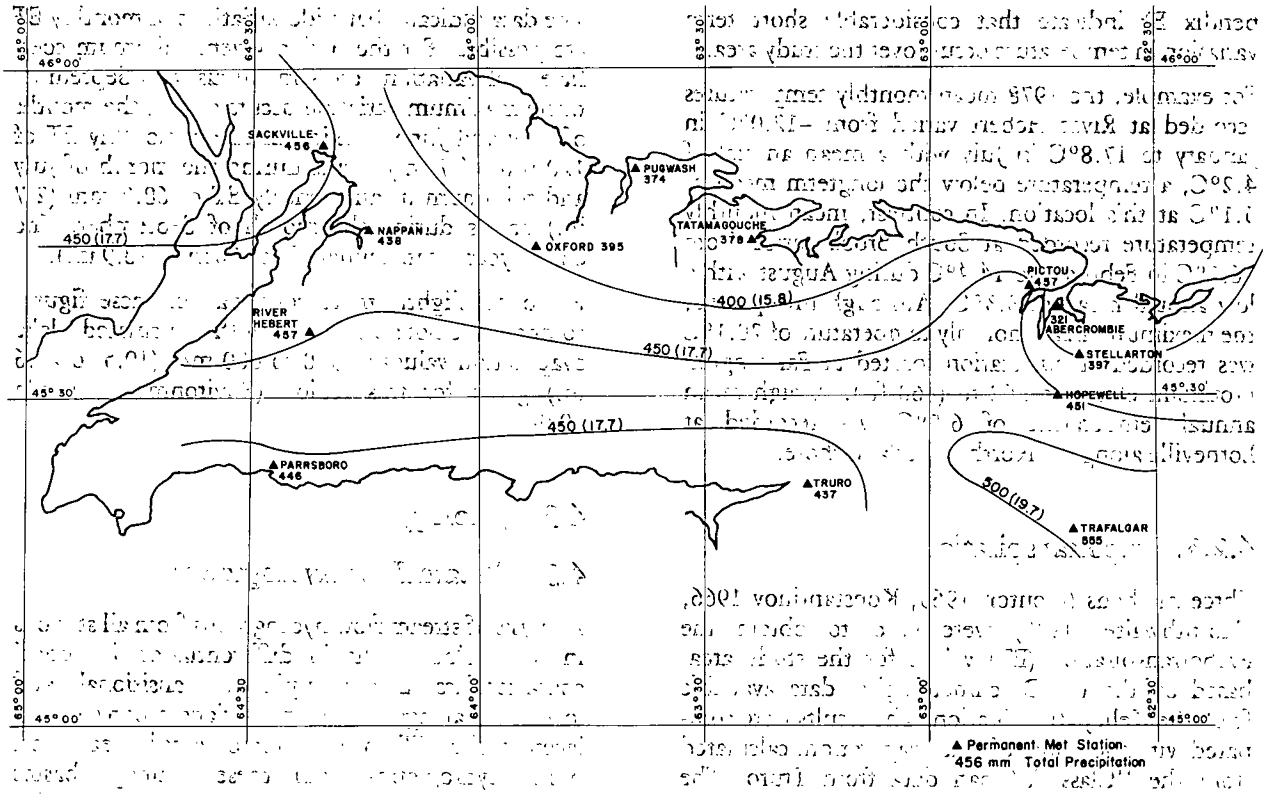


Figure 4.3 Isohyets of Mean Summer Precipitation, 1967-76

Table 4.2

Precipitation Variations

Month	Wentworth Centre	Westchester	Collingwood Corner
June, 1978	114.0 mm	78.7 mm	104.0 mm
July, 1978	92.5 mm	81.3 mm	77.3 mm

tain at an elevation of approximately 280 m (920 ft.).

4.2.2 Temperatures

Mean monthly temperatures of four selected stations for 1978 are shown on Figure 4.4 and mean annual temperatures are given in Table 4.3. In some cases there are gaps in the records; however, the data obtained give an indication of the pattern of the temperatures across the study area.

The longterm average mean annual temperature for the region approximate 5.5°C. The ten year mean for the period 1967-76 approaches 5.7°C. The longterm mean annual temperature range for the study region approximates 7.8°C (Gates, 1973). Temperature data taken during 1978 (Table B3, Ap-

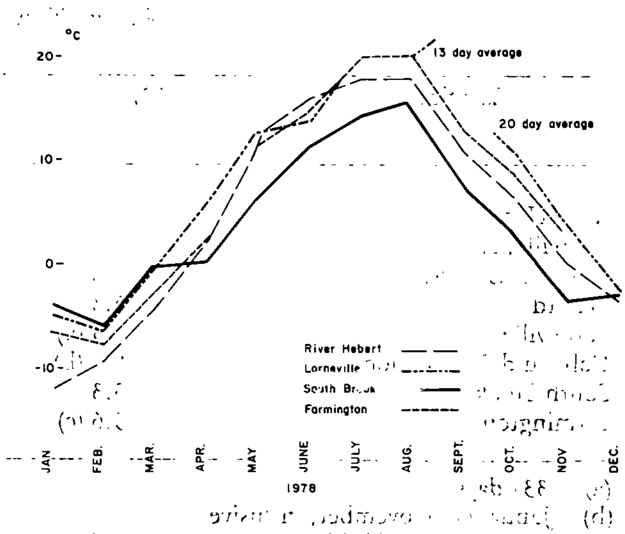


Figure 4.4 Mean Monthly Temperatures, 1978

pendix B) indicate that considerable short term variation in temperature occurs over the study area.

For example, the 1978 mean monthly temperatures recorded at River Hebert varied from -12.0°C in January to 17.8°C in July with a mean annual of 4.2°C, a temperature below the longterm mean of 5.1°C at this location. In contrast, mean monthly temperature recorded at South Brook varied from -6.1°C in February to 14.4°C during August with a low annual mean of 3.3°C. Although unexpected, the maximum mean monthly temperature of 20.1°C was recorded at our station located at Farmington Mountain elevation 262 m (860 ft.). A high mean annual temperature of 6.5°C was recorded at Lorneville along the Northumberland shore.

4.2.3. Evapotranspiration

Three methods (Mouton 1965, Konstantinov 1966, Thornthwaite, 1939) were used to obtain the evapotranspiration (ET) values for the study area, based on the I.H.D. climatological data available from the Kelley River Station. The results were compared with the values of lake evaporation, calculated from the "Class A" pan data from Truro. The calculated lake evaporation from the Truro data was used as a value of evapotranspiration. Table 4.4 gives these data. It was further assumed that the total annual ET occurs during the period May to September exclusive.

The Ten-Year Mean is approximately 7% higher than the 30 Year Mean. The longer term mean provides a more conservative basis for calculations of annual yields from the study area.

The data indicate that wide variations in monthly ET are possible. For the period given, minimum coefficient of variation occurs in August and September while maximum variation occurs during the months of May and June. Maximum mean monthly ET of 120 mm (4.7 in.) occurs during the month of July and minimum mean monthly ET of 68.2 mm (2.7 in.) occurs during the month of September. The eleven year mean annual ET is 480 mm (18.9 in.).

Although slightly more conservative, these figures compare reasonably well with calculated lake evaporation values of 500 to 600 mm (19.5 to 23.6 in.) given for this region (Environment Canada 1978).

4.3 Hydrology

4.3.1 Stream Flow Hydrographs

Analysis of stream flow hydrographs from all stations in the region results in differentiation in runoff characteristics among upland, transitional and lowland drainage basins and variances between adjacent basins. When compared on a unit area runoff basis, hydrographs from these drainage basins display similar shape and characteristic sharp peaks. Hydrographs, of Maccan and East and West Philip however, show distinct differences both in the time of peak occurrence and the magnitude of the peaks (Figures B.3 and B.4 Appendix B).

The upland watershed areas of the Cobequid Mountains produce hydrographs having sharp peaks, short time of concentration and high stream flow velocities. During an individual storm event, flow at

Table 4.3

Annual Mean Temperature, °C

Location	1978	Mean Average 1941-70	Mean Average 1967-76
River Hebert	4.2	5.1	6.2
Sackville, N.B.	5.1	5.6	5.4
Nappan, C.D.A.	5.0	5.6	5.5
Oxford	5.3	5.6	5.8
Lorneville	6.5 (a)		
Cobequid F.C. Station	5.6 (b)		
South Brook	3.3		
Farmington	5.6 (c)		

(a) 331 days
(b) January to November, inclusive
(c) January to November, inclusive

Table 4.4

Lake Evaporation (mm)

Year	May	June	July	August	September	Total
1965	93.2	111.0	122.0	97.0	64.0	487.0
1966	73.7	84.6	122.0	102.0	68.3	451.0
1967	69.1	107.0	103.0	92.5	62.2	434.0
1968	87.9	92.7	141.0	112.0	67.1	501.0
1969	83.8	113.0	122.0	105.0	71.6	495.0
1970	86.4	113.0	136.0	95.3	51.6	482.0
1971	87.6	106.0	118.0	104.0	75.7	491.0
1972	116.0	102.0	109.0	118.0	72.6	518.0
1973	65.5	110.0	95.8	85.3	67.8	424.0
1975	87.9	130.0	128.0	110.0	69.3	525.0
1977	103.0	69.1	121.0	107.0	64.3	464.0
$\overline{x}$ (11-Year Average)	86.6	104.0	120.0	103.0	68.2	480.0
S	14.5	16.3	13.3	9.5	6.4	32.6
C_v	0.17	0.16	0.11	0.09	0.09	0.07

(Calculated From "Class A Pan" Data) Truro, N.S.

the gauge (West River Philip) rises rapidly to a maximum and then quickly dies away (Figure 4.5). Such streams are often described as "flashy".

A striking variation appears in the low flows at the end of the summer (Table 4.5). The West Philip and the Maccan not only give a higher unit flow, but occur much later in the season. Unit flow hydrographs for all metered basins are given in Appendix B.

To further evaluate the regional hydrology, annual and summer streamflows were assembled for the sub-basins of Wallace, Philip, Maccan and Kelley Rivers and results are given in Table 4.6. In the absence of lake storage and potential dam sites in the study area, analysis of minimum summer yields are most important in terms of water supply potential. An example of a detailed summer yield analysis for Wallace River sub-basins are given in Table B.4 (Appendix B).

Evaluation of metered summer stream flow data for all stations for 1978, allows for a grouping of three overlapping stream discharge zones within the region (Table 4.6). They are: (a) Upland with summer yields ranging from 220-370 mm (8.7-14.6 in.) (b) Transitional, draining both Upland and Lowland areas yielding 150-280 mm (5.9-8.7 in.) and (c) Lowland yielding 120-170 mm (4.7-6.7 in.) respectively. These values could be expected to vary during any particular year, however, the relative grouping of the data should remain. The magnitude of runoff

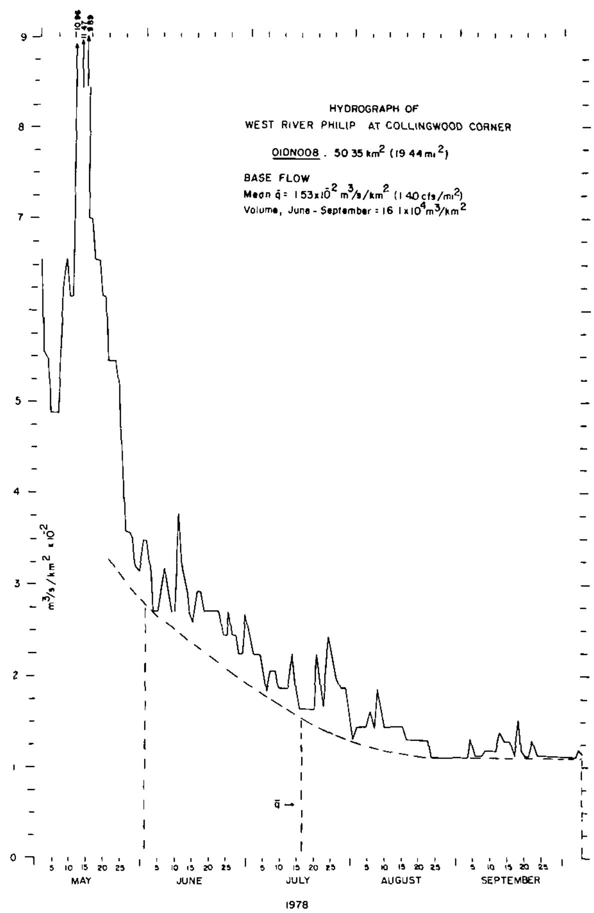


Figure 4.5

Table 4.5

Low Flow Comparison
River Philip and Maccan

River	Date	cfs	cfs/mi²	m³/s/km² x 10⁻²
River Philip (01DN007)	August 30/78	10.1	0.25	0.26
West River Philip (01DN008)	October 11-14/78	19.5	0.81	0.89
Maccan River (01DL002)	October 14/78	21.2	0.56	0.61

Table 4.6

Stream Flow Summary
Cumberland County
1978

Basin	Station Number	Area km² (1)	Annual Runoff (mm) (2)	May-Sept. Runoff (mm) (3)	Col. (3)/Col. (2)
			(A) Upland		
Roaring River	01DN006	41.8	951.0	227.0	0.24
East River Philip	01DN007	102.0	912.0	283.0	0.31
Maccan River	01DL002	98.4	903.0	245.0	0.27
West River Philip	01DN008	53.6	879.0	372.0	0.31
				Average	0.30
			(B) Transitional		
Wallace River	01DN004	298.0	842.0	185	0.22
Wallace River	01DN005	116.0	682.0	189	0.28
				Average	0.25
			(C) Lowland		
Kelley River	01DL001	63.2	862	121.0	0.14
Average all basins			862	Average	0.16

values for transitional watersheds depends to a certain extent upon the relative areas of upland and lowland drained at any particular metering site.

Due to the number of factors involved, it appears that it is not reasonable to transfer unit runoff from, for example, the River Philip to the Nappan River, or from the Wallace River to the Shinimikas River.

To find the annual or monthly yield of the more northerly lowland watersheds, an estimate may be made by using the yield of the Wallace or the Philip Rivers in millimetres (inches) over the drainage area, and a ratio of the estimated rainfall based on the isohyetal curves given in this report or those by Gates (1973). The yield, therefore, would follow a similar trend from the relation, Runoff = Precipitation - Water Loss.

Long term (10 year) summer runoff data compiled for stations in Cumberland and Pictou Counties are

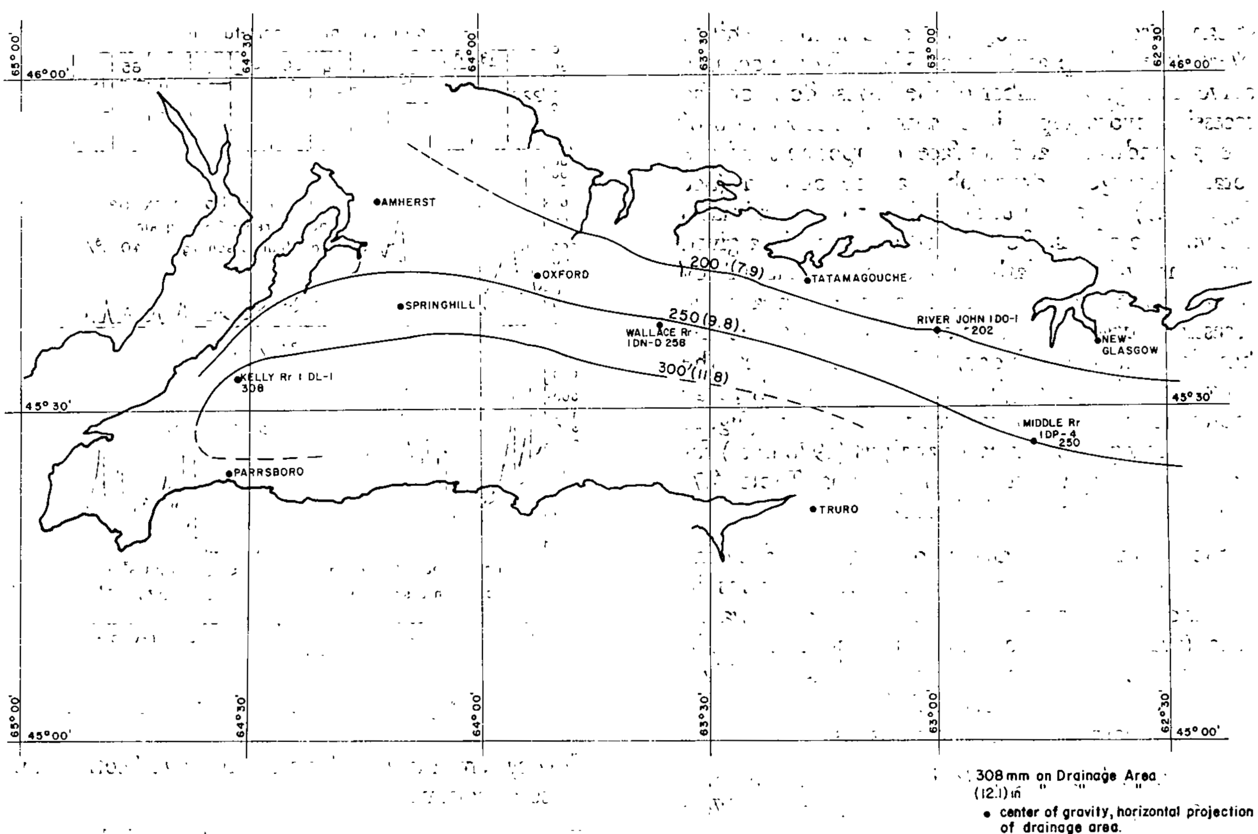


Figure 4.6 Iso-Runoff Curves—Mean Summer Runoff, 1967-76

given in Figure 4.6. Regional runoff patterns vary in a north-south direction. Runoffs occurring in the southern highland region average 300 mm (11.8 in.) on the drainage area to 200 mm (7.9 in.) along the coast.

Summer runoff conditions for 1978 express a similar regional pattern with highest stream flows recorded along the north toe of the Cobequids of 300 mm (11.8 in.), falling away north toward the coast to 100 mm (3.9 in.) (Figure B.10). The 1978 runoff data, again confirms that 1978 represents a dry period.

For 1978, annual runoff is greater along the northern flank of the Cobequid Mountains, 900 mm (35.4 in.), diminishing to 700 mm (27.6 in.) toward the shores of the Bay of Fundy and Northumberland Strait (Figure B.11).

Long term stream flow records are not available for the Cobequid region. On the basis of 1978 data, highest annual and summer runoffs are expected in this region. The values expressed in this report should approximate minimum long term flow conditions.

Stream flow stations located at Kelley River (OIDL001) and Wallace River (OIDN004) although outside the study area, should provide a reliable basis for estimates of yield in the study region.

The differences in runoff characteristics over the region may be attributed to a number of important related factors. As shown in Figures 4.2 and 4.6 regional runoff trends correlate closely with regional precipitation patterns. Equally important are the differences in the physical characteristics of the various basins, such as slope or drainage density described in section 4.3.3. Differences between adjacent basins are less clearly understood; however, variations in rainfall patterns over the east-west axis of the region and differences in physiographic character are some factors likely to account for these differences.

Within the region, significant sustained low flows are limited to the Upland and to a lesser extent Transitional watershed lands. In terms of surface water supply potential, these mountain areas are of greatest importance to the region. In contrast, the northern Lowland watersheds of Tidnish, Nappan and Shinimikas hold very limited surface water potential.

4.3.2 Groundwater Hydrographs

Base Flow: Two hydrograph analytical techniques were employed to assess the baseflow component of stream discharge hydrographs of East River Philip, West River Philip and Kelley River. By sketching a curve through a number of the lowest flows on the recession hydrograph, it is assumed a separation of the groundwater and surface components of the total discharge hydrograph may be defined (See Figure 4.5). The area under this curve approximates the volume of base flow, in m^3 (cfs-days) in a given time interval. Similarly, a method developed by Kunkle (1962) indicates that the area beneath the recession curve (logarithmic) is assumed to be the baseflow in m^3 (cfs-day). The area under the horizontal line through the lowest daily discharge represents the minimum groundwater flow (Figure 4.7). A comparison of basin analysis (1978 data) for both hydrograph methods is given in Table 4.7. Both methods produce similar results.

Although the values calculated are governed by the assumptions drawn, the quantitative variations in four month yields between West River Philip watershed (average 165.0 o: 6.5 in.), East River Philip (average 63.0 mm. or 2.5 in.) and Kelley River (average 17.0 mm or 0.7 in.) further distinguish these regional watershed characteristics.

Groundwater Recharge: Review of streamflow and meteorological data (see Section 4.3.2) of the West River Philip watershed, physiography and geological character of the Cobequid Mountain region suggests groundwater flow networks are probably shallow and localized. This effectively reduces the importance of the Cobequid Mountain region as a major groundwater recharge area for the sedimentary lowlands. Supportive evidence for this conclusion is described by Lin (1975) in studies of slate and quartzites of Smiths Cove, Nova Scotia, and in detailed

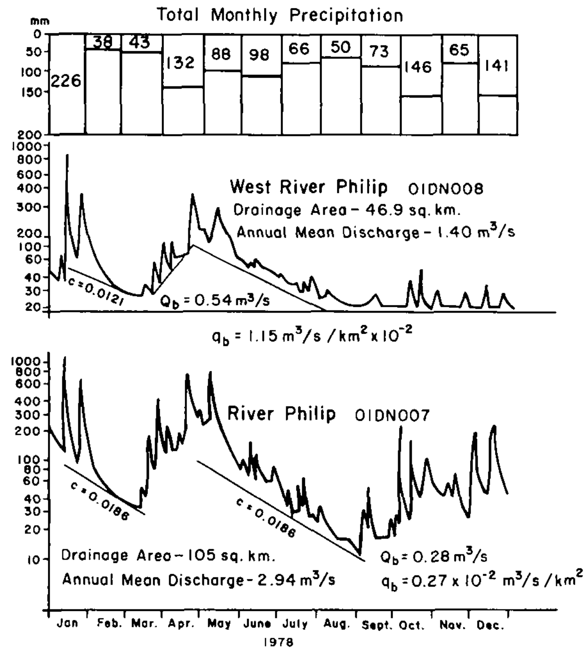


Figure 4.7 Base Flow Analysis

flow system analysis of northern Nova Scotia (Lin, personal communication).

To maximize the usefulness of the available long term data for the region west of the study area, detailed analysis (after Kunkle, 1962) of Kelley River streamflow and groundwater hydrograph data for the years 1971 to 1978 is presented in Table B.5. From this table, the most conservative ratio of total groundwater to total annual precipitation is 0.14 (TGW/TAP = 0.14). Since the greater proportion of the study area is underlain by sedimentary rock

Table 4.7

Comparison of Groundwater Yields
June to September, 1978

Basin	A* 4 month yield (mm)	B* (mm)	Average (mm)
West River Philip (01DN008)	161.0	169.0	165.0
East River Philip (01DN017)	70.0	55.0	63.0
Kelley River (01DL001)	18.0	15.0	17.0

A* Recession curve sketched on arithmetic paper.
B* Recession curve straight line on logarithmetic paper (Kunkle, 1962).

similar to that found in the Kelley River basin, and the precipitation on the mountain slopes is greater than that on the lowland, this ratio is accepted in estimating the minimum potential groundwater recharge for the study area. The estimated yield would then be 890 mm x 0.14 = 130 mm (5 in.) (See Table 4.9). As the yields in 1975 and 1978 were the lowest since 1970 (when the first full year of streamflow data were obtained from the Kelley River Basin) these estimates should be conservative.

During the period of 1971-78, the Kelley River data give ratios of annual streamflow to annual precipitation that approach unity. In 1972, the ratio exceeds unity. This may be an anomaly during dry periods but an obvious explanation is not at hand.

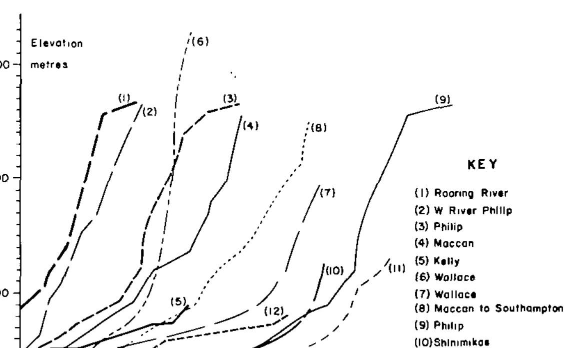
4.3.3 Basin Analysis

Basin analysis provides a description or "Fingerprint" of watershed physiographic characteristics. An indepth analysis of stream frequency, density, length, slope, erosional phase and other parameters provide a quantitative basis for the appreciation of the variations and similarities in watershed physiography. This will enhance the interpretation or prediction of basin response to climatic events.

The basin analysis consisted of three parts:

1. Stream Profiles
2. Hypsometric Curves
3. Geomorphic Parameters

Stream Profiles: Figure 4.8 describes the stream profiles of 12 major rivers in the region. The Cobequid Mountains give rise to steep relatively short, stream profile segments (1 and 2, Figure 4.8) between elevations of approximately 100 m (328 ft.) and 330 m (1,082 ft.). In contrast, Nappan and Shinimikas stream profiles (10 and 11, Figure 4.8) are long and gradual, rising sharply over a short distance in the Fenwick Hills and Hastings area,



4.8 Stream Profiles

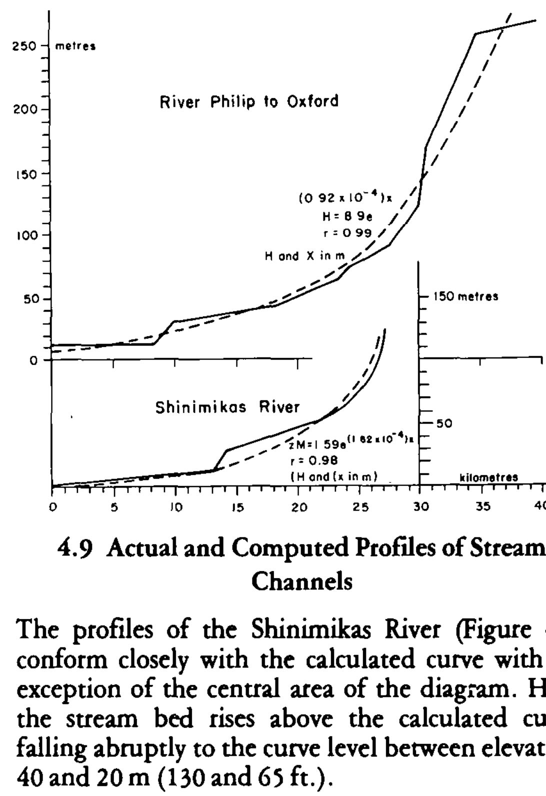
respectively. Any deviation from an ideal stream profile is indicative of the underlying bedrock control.

According to Strahler (1952) a stream profile may be approximated by an exponential curve which may be defined by the relationship:

$$H = ae^{(bx)}$$

Where: H = elevation above datum (sea level)
x = the distance horizontally from the origin
a = constant
b = constant
e = base of natural logarithms 2.7182

Two selected stream profiles and calculated curves are given in Figure 4.9. The profile of River Philip to Oxford falls above the calculated curve in the Cobequid Mountain area and slightly below the curve in the lowland area, reflecting the relative difference in the bedrock erosional resistance between the igneous and metamorphics in the mountains and the sedimentary units in the lowland.



4.9 Actual and Computed Profiles of Stream Channels

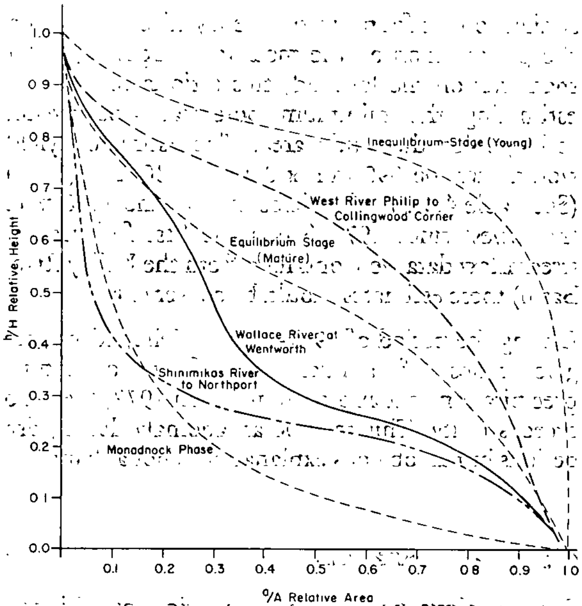
The profiles of the Shinimikas River (Figure 4.9) conform closely with the calculated curve with the exception of the central area of the diagram. Here, the stream bed rises above the calculated curve, falling abruptly to the curve level between elevations 40 and 20 m (130 and 65 ft.).

Similarly, the River Philip profile rises above and falls below the calculated curve between elevations 40 and 15 m (130 and 50 ft.). This particular feature is indicative of areas of resistant sandstone bedrock.

Hypsometric Curves: Several methods have been developed to characterize the relative stage of stream development or maturity. Strahler (1952) identified a number of parameters and a graphic technique designed to describe the erosional stage of a given stream. Calculations of Strahler's parameters "s", "r" and "z" are given for all basins in Table B.6 and selected hypsometric curves are presented in Figure 4.10. Of these parameters, "s" is perhaps the most significant. The value of "s" is an indication of the youth, maturity, or old erosional age of the basin (Strahler, 1952).

West and East River Philip at Collingwood Corner and the Wallace River at Westchester, having their outlet along the toe of the Cobequid Mountains, are midway between "young" and "mature" erosional state or between "Inequilibrium or Equilibrium" phase. The hypsometric curve for Wallace River at Wentworth Centre reflects the predominance of the lowland sedimentary area. The hypsometric curve of the Shinimikas River watershed (Figure 4.10) displays a much more advanced erosional state approaching the "monadnock" or "old age" phase.

Geomorphic Parameters: In analyzing stream patterns, a number of key parameters were evaluated and are given in Table 4.8. A more detailed account is shown on Table B.6, Appendix B. Results of these analyses show the prominent stream drainage pattern is genetically defined as "dendritic". In areas of dendritic stream patterns, the material subject to erosion may be bedrock or unconsolidated deposits; it may be sedimentary, igneous or metamorphic and the structure may be simple or complex. Dendritic or insequent streams are apparently not controlled by such factors as regional slope, structural trends or rock differences (Miller and Miller, 1961).



4.10 Hypsometric Curves

Table 4.8

Basin Analysis, Geomorphic Parameters

Basin	Station Number	Drainage Density km/km²	Channel Maintenance m²/m	Frequency No./km²	Length Overland Flow (km)	Ratios R_B	R_L	R_A	R_B/R_A	R_L/R_A
Maccan	01DL002	0.74	1350	0.30	0.68	4.57	6.45	6.31	0.72	1.02
West River Philip	01DN008	0.74	1420	0.37	0.71	3.89	5.12	5.24	0.74	0.98
Roaring River	01DN006	0.66	1520	0.29	0.76	2.82	4.07	3.80	0.74	1.07
	Average	0.71	1430	0.32	0.72	3.76	5.21	5.12	0.73	1.02
East Philip	01DN007	0.70	1420	0.26	0.71	4.57	6.46	6.46	0.70	1.00
Maccan to Southampton		0.70	1420	0.27	0.71	3.98	5.01	4.90	0.81	1.02
Philip to Oxford		0.73	1380	0.32	0.68	3.16	3.63	3.63	0.87	1.00
Wallace River	01DN005	0.78	1280	0.36	0.64	3.24	3.98	3.84	0.84	1.04
Wallace River	01DN004	0.68	1480	0.34	0.46	3.39	3.89	3.89	0.87	1.00
	Average	0.72	1400	0.31	0.64	3.67	4.59	4.54	0.82	1.01
Shinimikas		0.69	1450	0.30	0.79	3.55	3.80	4.17	0.85	0.91
Nappan		0.66	1520	0.34	0.76	3.09	3.00	3.63	0.85	0.83
	Average	0.67	1485	0.32	0.77	3.32	3.40	3.90	0.85	0.87
Kelley*	01DL001	1.81	800	2.17	0.20	4.57	5.37	5.62	0.81	0.96
Kelley to confluence**		0.50	2000	0.23	1.00	4.17	4.90	5.62	0.74	0.87

* Taken from map with scale 1 inch = 2,000 feet
** Taken from map with scale 1:50,000

Analysis of the data given on Table 4.8 appears to bear this out. Although the values of ratios R_B, R_L and R_A are found to generally decrease in magnitude from highland, transitional, and lowland sub-regions, the ratios of R_L/R_A approach unity. This suggests that stream length to order, and stream drainage area to order, are factors governed by one or more common variable. Since geological structure, soil and bedrock type, topographic relief, and climate vary over the region, the uniformity of erosional resistance may be the most significant factor governing drainage pattern, drainage frequency and other such characteristics. The relative differences in erosional resistance give rise to distinct parameter values. For example, the values of R_L and R_A indicate that the Cobequid Mountain area is characterized by long streams draining large watershed areas. The lowland areas of Nappan and Shinimikas have shorter streams draining smaller watershed areas. Intermediate values result when calculations are determined at points in the river channel which drain combined upland and lowland watershed areas and, generally, vary according to the proportion of upland and lowland watersheds drained.

According to Strahler (1952), Bifurcation Ratio R_b (Stream branching) of stream orders may range between 3.0 and 5.0 for watersheds in which the geologic structures do not distort the drainage pattern. A normal basin has a constant of about 4.0, the theoretical value for a minimum is 2.0. All of the values fall within this range, emphasizing the cross grain character of river valleys in the study area.

In general, low drainage density is favoured in regions of highly resistant or highly permeable sub-soil materials under dense vegetation cover and where relief is low. The basins of Cumberland County have drainage densities varying from 0.66 to 0.78 km/km^2 (1.06 to 1.26 mi/mi^2). These low values might be expected to occur in the mountain basins which are characterized by highly resistant rocks. For the lowland rivers it is apparent the well-drained top-soil and sandy tills on largely forest covered lands of low relief, also give rise to low drainage densities.

Summary: Wide variance in basin physiographic characteristics illustrate why watershed response to climatic events differ significantly within the study region and as such, may be successfully employed for interpretation and forecasting of basin hydrology.

Steep stream profiles, greater stream length and drainage area per stream order, are related to the characteristic "flashy" hydrograph shape and high unit runoffs (Figure B.7), recorded along the base of the Cobequid mountains.

Areas of low stream gradient and low drainage densities are expected to give rise to broad based "lazy" hydrographs with comparatively longer time to peak and gradual recession limb, and lower basin unit runoff (Figure B.9).

4.3.4 Water Balance

The water balance on a basin may be expressed by:

$$R = P - Et \pm \Delta S$$

where: R = runoff
P = the precipitation
Et = the evapotranspiration
ΔS = the change of storage, all in millimetres on the drainage area

In estimating the water balance over the whole of the study region, two divisions were used: a) The Upland-Transitional basins lying on the slopes and along the toe of the Cobequid Mountains and b) The basins lying completely on the lowland. For the study area, water balance calculations indicate an average annual runoff total of 910 mm (35.8 in.) for the Upland-Transitional areas and 520 mm (20.5 in.) for the Lowland areas with water loss of 139 to 370 mm (5.5 and 14.6 in.) respectively (Table 4.9). The weighted average runoff for the entire region is equivalent to 500 mm (19.7 in.) over the drainage area. In most cases, the annual metered yield is greater than anticipated.

For practical purposes, the terms Et and Δs may be regarded as a single term denoted as (Et $\pm$ Δ S) and called "water loss". Water loss for the year varied from a low of 99 mm (3.9 in.) at Wallace No. 01DN006 to a high of 368 mm (14.5 in.) for Wallace No. 01DN005, assuming an annual uniform precipitation of 1,050 mm (41.3 in.) (Table 4.10). These values may be expected since 1978 was a dry year.

If evapotranspiration is assumed to be equivalent to lake evaporation calculated from Truro Class A Pan data, change in groundwater storage varies from -112 mm (4.4 in.) at Wallace No. 01DN005 to -427 mm (16.8 in.) at Kelley River No. 01DL001. This implies that during 1978 groundwater is derived from storage accumulated over some previous period.

Detailed analysis of Kelley River historical data (Table 4.11) for water years 1972 through 1975, indicate similar results. With the exception of 1973-74, when 52 mm (2.05 in.) were added to storage, the removal of groundwater from storage predominates over this longer period. These results may either imply long term cyclic trends related to climatic changes or bring into doubt the assumption regarding Et and ΔS components of the water balance equations.

Although these discrepancies may be due, in part, to errors in measurement and estimation of evapotranspiration parameters, the magnitude and consistency of the change in storage suggests that the equation fails to express completely, the events occurring within this region. Perhaps additional parameters or factors have yet to be evaluated.

Table 4.9

Estimated Annual Yield Over Study Area

	Cobequid Mountain North Slope	Lowland	Total
Approximate Area, km^2	290	1510	1800
Estimated Precipitation, mm	1050	890 (1)	
Estimated Average Water Loss, mm	139	370 (2)	
Average Measured Annual Runoff, mm	910		
Estimated Annual Runoff, mm		520	580 (3)
Estimated Annual Runoff, $m^3 \times 10^6$			1050
Estimated Annual Runoff, Ig $\times 10^8$			2300

(1) Average of Sackville, N.B.; Nappan; Oxford; Lorneville.
(2) Taken from Wallace 01DN005, as highest value.
(3) Weighing Yield and Areas. (0.910 x 290) + (0.520 x 1510) / 1800 = 580 mm

Table 4.10

Water Balance
1978 Calendar Year
For All Metered Basins

Basin		Wallace		Philip	W. Philip	Maccan	Kelley
Station Number	01DN004	01DN005	01DN006	01DN007	01DN008	01DL002	01DL001
Area Sq. km.	301	116	41.8	102	53.6	93.4	63.2
1. Precipitation (P) mm	1050	1050	1050	1050	1050	1050	915
2. Evapotranspiration* (ET) mm	480	480	480	480	480	480	480
3. Annual Runoff (R) mm	842	682	951	912	879	903	862
4. Change of Storage S) S mm	-272	-112	-381	-342	-309	-333	-427
5. Water Loss mm	208	368	99	138	171	147	53

* Calculated lake evaporation from Truro Class A pan data, for dry year 1975.

Runoff = Precipitation -(Evaporotranspiration $\pm$ Change of Storage)
Water Loss = P - R = $E_T \pm \Delta S$
ΔS = P - R - E_T
Line 4 = Line 1 - Line 3 - Line 2
Line 5 = Line 1 - Line 3

Table 4.11

Water Balance
Kelley River
1972-1975

	Water Years 1972-73 (mm)	1973-74 (mm)	1974-75 (mm)	Total (mm)	Average (mm)
1. Precipitation	1320	1220	1020	3560	1190
2. Evapotranspiration	350	450	560	1360	450
3. Annual Runoff	1170	718	862	2750	920
4. Change of Storage	-200	+ 52	-402	-550	-180
5. Water Loss	150	502	158	810	270

* Calculated lake evaporation from Truro Class A pan data, for dry year 1973.

CHAPTER 5
Hydrogeology

5.1 Methodology

Sixteen (16) test wells were drilled throughout the study region, primarily in areas yet unexplored, to assess the potential yield and evaluate hydraulic characteristics of bedrock and surficial aquifers. In view of future water supply requirements, Amherst, Springhill, and Oxford areas were selected for investigation.

Drilling operations were conducted using cable and rotary equipment; pump tests were conducted on 7 of these wells using diesel driven line shaft and electric submersible pumps. Test well data in conjunction with well inventory data, geological mapping and watershed analysis were utilized to identify and evaluate various surficial and bedrock hydrostratigraphic units. Test well and control well detailed statistics are given in Table C.1, Appendix C and graphic testhole logs are given in Figure 5.3. Approximately 500 well logs were located in the field and are plotted on the inventory maps sheets. Table 5.1 and Figures 5.1 and 5.2 present statistical summaries of well log data.

5.2 Hydrostratigraphy

Trescott (1968), Hennigar (1972), and others have equated the various geological groups and/or formations with hydrostratigraphic units. Although, in

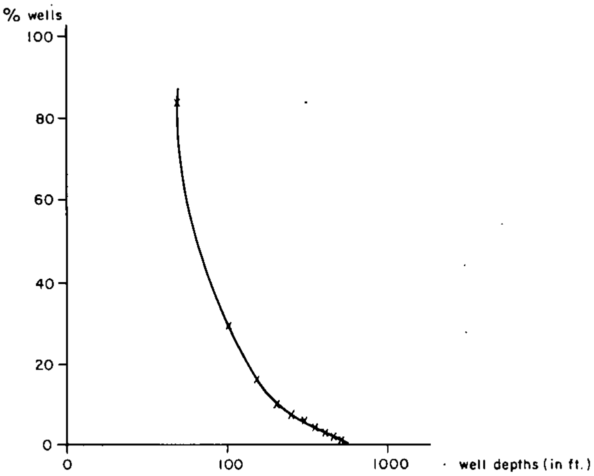


Figure 5.1 % Wells versus Depths

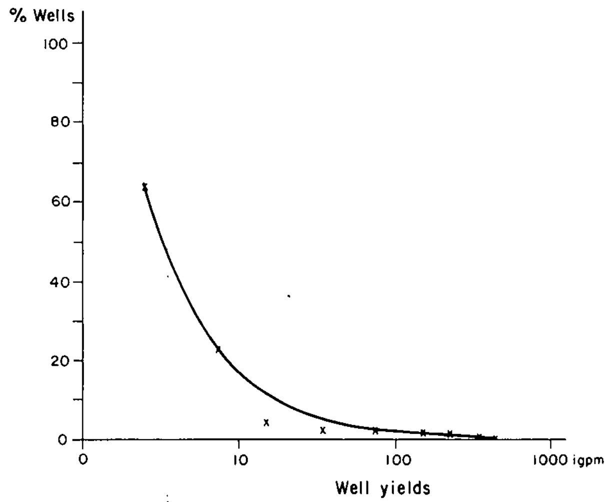


Figure 5.2 % Wells versus Yields

Table 5.1

Cumberland County Drilled Well Data

Number of Wells	Group or Formation		Well Depth* m.	Yield* L/s	Specific Capacity* L/(s.m.)
217	Pictou:	excluding basins	26.30	0.44	0.0326
		including basins	25.65	0.43	0.0318
13	Windsor:	including basins	22.00	0.38	0.0273
		only one well			
5	Middleborough		19.89	0.34	0.0273
40	Boss Point:	including basins	27.82	0.47	0.0273
		only 2 wells in basin			
56	Cumberland:	excluding basins	28.52	0.64	0.0323
		including basins	28.35	0.58	0.0298
3	Precarboniferous:	all in river basin	30.00	0.44	0.0174

*Arithmetic mean

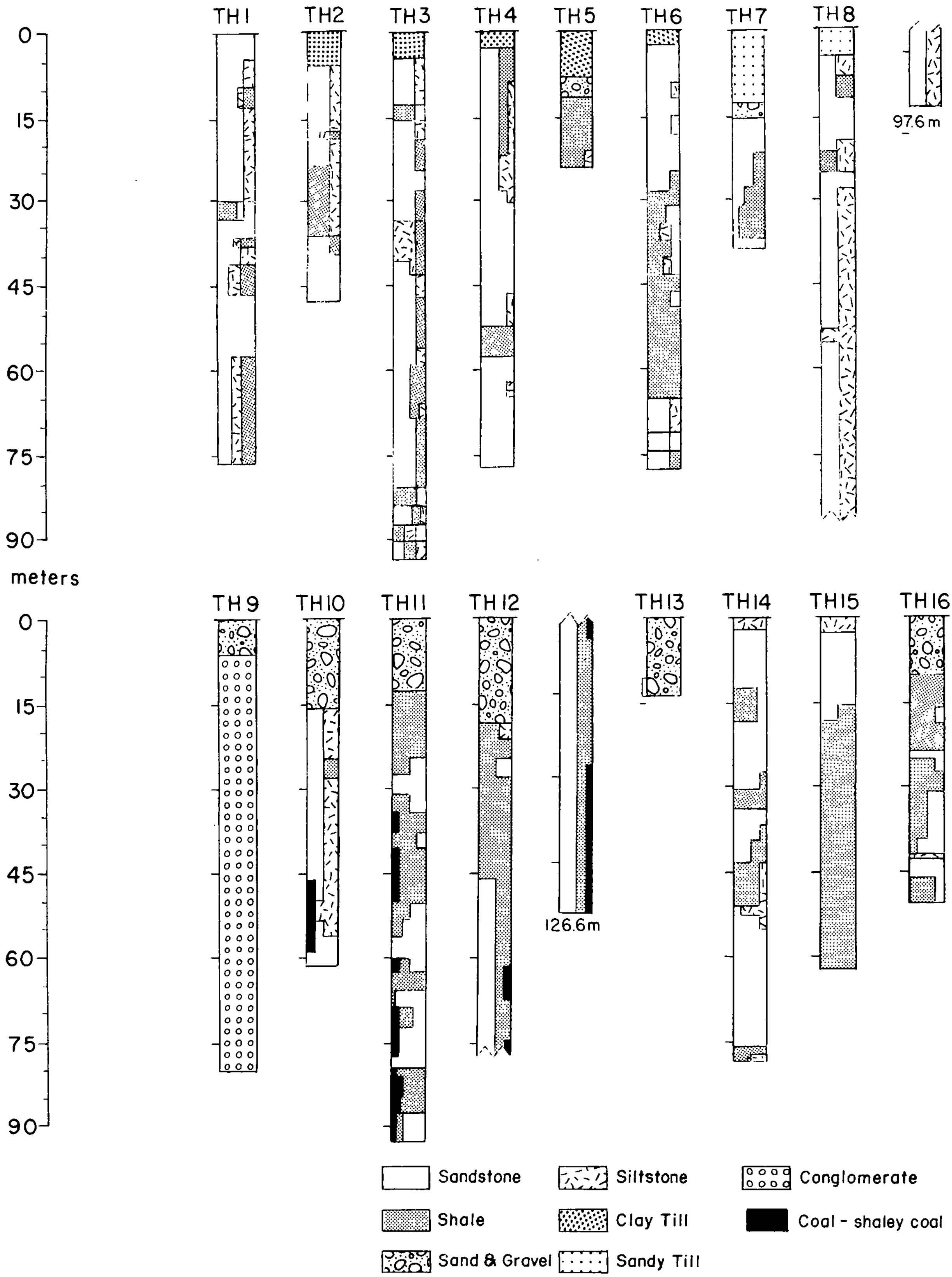


Figure 5.3 Test holes—Summary of Graphic Logs

a broad sense, distinct water quality characteristics may be attributed to various geological groups, groundwater yields are primarily governed by the relation of lithology to primary and secondary permeability, other physical subsurface geological conditions, topography, and hydraulic boundaries. The following description of the various hydrostratigraphic units are based largely on the hydrogeological similarities of various bedrock types.

In the broadest context, there exist 4 separate hydrostratigraphic provinces within the study area. They are:

a) Igneous and metamorphic rocks of the Cobequid Mountains; massive conglomerates of lower Cumberland and Riversdale Groups;

b) Sedimentary sequences of Pictou, Cumberland, and Riversdale Groups within the Cumberland sedimentary basin;

c) Pleistocene and recent stratified deposits and;

d) Till sheets.

Within these groups there no doubt exist many distinct hydrostratigraphic units; however, data remain insufficient to delineate the complexities of these individual systems.

5.2.1 Stratified Surficial Deposits

A number of significant stratified sand and gravel glaciofluvial deposits have been identified within the study area. Generally confined to ancient bedrock river valleys, these deposits are associated with Philip, Black, Maccan, and Little Forks antecedent river valleys.

Evaluation of a sand and gravel aquifer in the Rodney-Springhill area has determined that there exists saturated, well-sorted sand and gravel desposits lining a buried river valley, which spans what is now the Black and Maccan River watershed divide. (Figure 5.4). The southern most extent is characterized by kame deposits with the remaining valley floor consisting of esker and terraced outwash deposits of glacial origin. These deposits extend from Rodney to Saltsprings and cover an area of 324 ha (800 ac.).

Detailed evaluation was concentrated on the southwest half, covering an area of approximately 202 ha (500 ac) because the remaining northeast quadrant of this deposit is eroded to, or very near, the bedrock surface. Test wells No. 9, No. 10, No. 11, No. 12, and No. 13 are drilled through this deposit. Analysis of pump tests conducted on test well No. 13, an 8

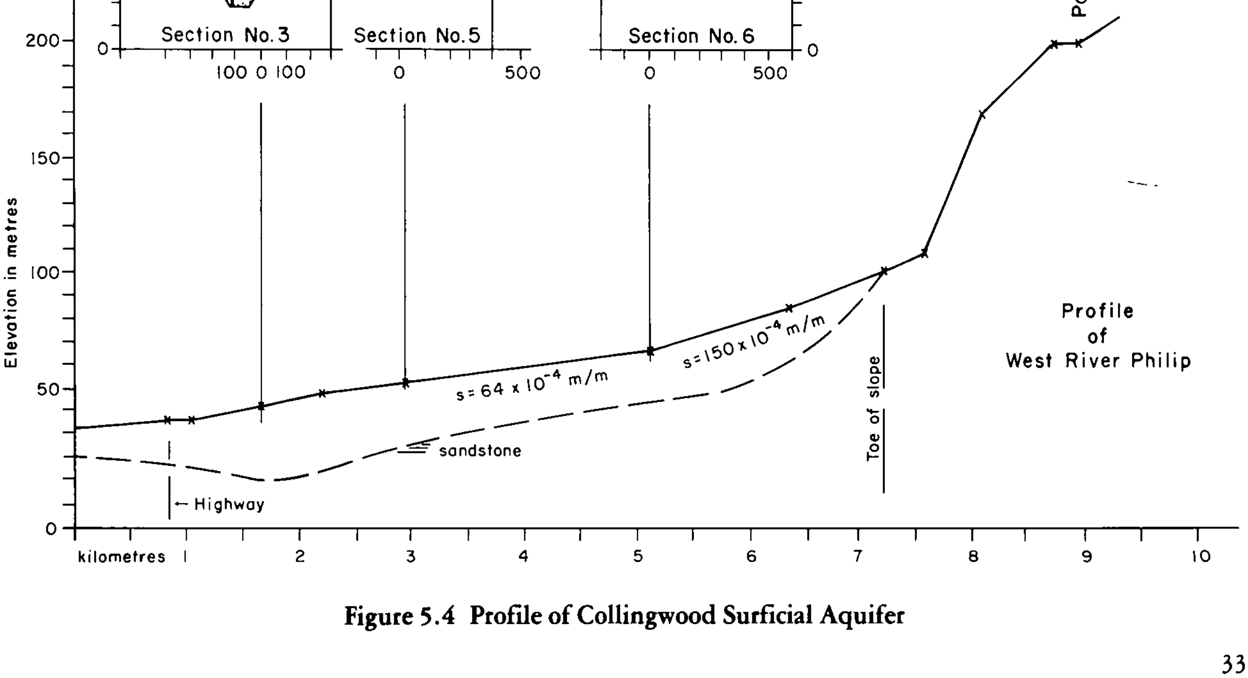


Figure 5.4 Profile of Collingwood Surficial Aquifer

inch diameter screened well set to a depth of 13.7 m (45 ft.), indicates this section of the deposit is saturated to within 2.1 m (7 ft.) of surface; has a transmissibility coefficient varying from 300 to 600 $m^3/(day.m)$ (20,000 to 40,000 igpd/ft.) and has a potential yield of 15.2 L/s (200 igpm) from this particular well. Hydrological analysis suggests these deposits may yield a minimum of 38 L/s (500 igpm) or 3.2×10^3 m^3d (0.7 MIGD), if properly developed.

The Community of Collingwood Corner lies on a sand and gravel aquifer found to extend from Collingwood Corner South 5.5 km (3.4 mi) to its termination in the Cobequid Mountains, and north 15.3 km (9.5 mi) to Oxford paralleling River Philip (Figure 5.5). Test hole No. 16, drilled just north of Collingwood Corner (Map 1), penetrated 12.2 m. (40 ft.) of stratified sand, gravel, silts, and clays of which 9.1 m. (30 ft.) were saturated. North of test hole No. 16, these deposits are found to thin near Oxford Junction and again thicken to 12.2 m. (40 ft.) at Oxford. The importance of these deposits north of Collingwood Corner as a potential water supply resource are diminished somewhat due to extensive mining between Collingwood Corner and Oxford Junction, and saturation by a saline groundwater at Oxford. South of Collingwood Corner, a number of domestic water wells penetrate up to 40 m. (130 ft.) of saturated sands and gravels (Figure 5.5). The estimated minimum safe yields of the surficial aquifers located between Collingwood Corner and the Cobequid Mountains approximates $4.5 \times 10^3 m^3/day$ (1 MIGD). Figure 4.8 indicates the full potential of these aquifers may exceed these estimates by an order of magnitude (See Sections 4.3.1—4.3.2), depending upon the nature of the interconnection between the aquifer system and the superimposed West River Philip and other hydraulic and geological boundary conditions. Minimum baseflow recorded for West River Philip at Collingwood Corner for the low flow period in September, 1978 totals $5.2 \times 10^4 m^3/day$ (21.4 cfs). Although it is yet to be confirmed, the major portion of this minimum flow at Collingwood Corner is likely derived from this surficial aquifer. Con-

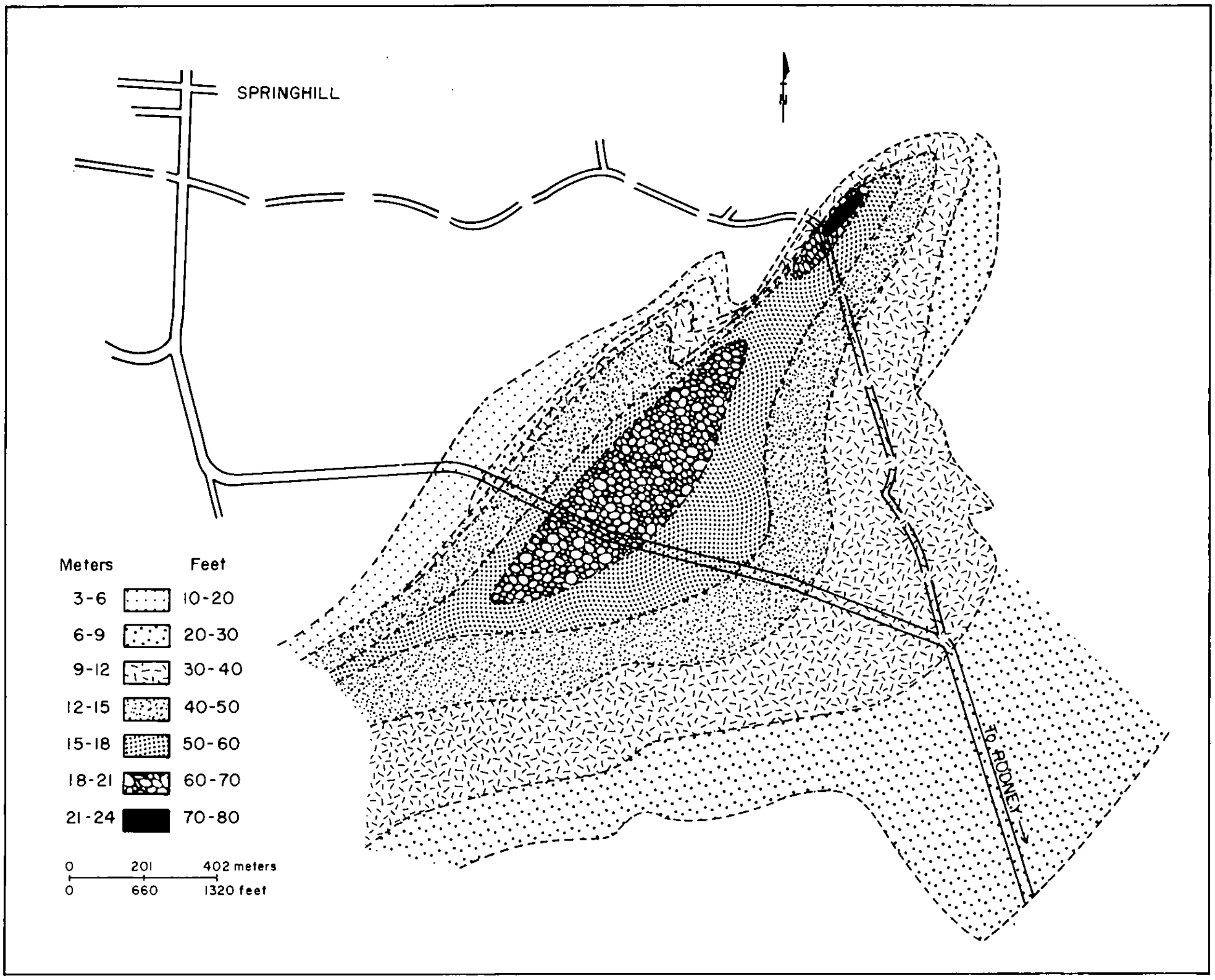


Figure 5.5 Isopach of Surficial Aquifer, Springhill, N.S.

servative estimates of recharge over the deposit surface area approximates 4.5 x $10^3 m^3$/day (1 MIGD). Table 5.2 summarizes the various parameters quantitied or assumed for the purpose of analysis. The accuracy of the interpretation is limited to the availability of control data.

Lesser outwash and stream alluvium deposits are found lining the flanks and river beds of the lower Maccan and Little Forks Rivers. Results of surficial mapping and review of well log data indicate that these deposits are eroded to base level, leaving the remaining terraced deposits largely unsaturated.

It is possible the lower tidal portion of the Maccan River may contain thick sequences of sand and gravel as evidenced by sand and gravel extraction pits at various points along the river and the log of a well located at Maccan. This particular well penetrated 27.4 m. (90 ft.) of stratified sands, gravels, and fine sediments. Information regarding their extent and potential yields are not available; however, they may represent the infilling of an extensive bedrock river valley. The potential value of these aquifers may be limited by groundwater quality and by current and projected aggregate mining activities.

In the Amherst region, dyked marshlands may overlie significant sand and gravel deposits as evidenced by Nova Scotia Department of Transportation drill hole records located between Amherst and Fort Lawrence and test hole No. 7 drilled on the west end of Fort Lawrence ridge. These bore holes penetrate 12.2 m. (40 ft.) of stratified and saturated sands and gravels at La Planche River and 2.4 m. (8 ft.) at test hole No. 7 and may yield substantial quantities of potable groundwater if lateral extent and suitable water quality can be proven.

5.2.2 Non-Stratified Surficial Material

Glacial tills mantle much of the remaining study area. Based on well log data for the entire area, till thickness generally varies from 3 m. to 9 m. (10 to 30 ft.) averaging to 4.6 m. (15 ft.) and appears to thin in areas of topographic highs, with the exception of the Cobequid Mountains portion of the study area, where till distribution and thickness are widely variable. The composition of these tills depend upon the nature of the adjacent bedrock, however, the southern half of the region reflects a mixture of material, some of which may be derived from distant sources, probably the Cobequid Mountains.

Generally, only small quantities of water may be obtained from these deposits. However, sandy till and rocky sandy till may provide an alternative to bedrock aquifers and supply water for domestic purposes given sufficient provision for storage.

Clay till deposits are located within the central region and in a number of isolated pockets throughout the area (Map 1). Grain size and textural characteristics limit the ability of this material to transmit significant quantities of water. However their presence is important in groundwater protection and waste disposal site selection.

5.2.3 Igneous, Metamorphic and Conglomerates

Igneous, metamorphic and conglomerate rocks found within the Cobequid Mountains cover the southern-most section of the study area.

The ability of these bedrocks to store and transmit

Table 5.2

Surficial Aquifer Yields

	Springhill	Collingwood Corner
Sand and Gravel, Surface Area (km^2)	2.0	3.6
Volume Saturated Gravel ($m^3 \times 10^6$)	4.3	45.
Available Storage (Volume) ($m^3 \times 10^3$)	0.15	1.5
Minimum Potential Annual Yield (Volume) ($m^3 \times 10^3$)	3.4	4.5

Assumption: 1) porosity 0.25
2) specific yield 20%
3) available drawdown 70%

groundwater depend essentially on the orientation, aperture width, depth and lateral extent of fault, fracture and jointing systems and local topographical relief. The broad extensively eroded Cobequid plateau and northern slope is characterized by narrow, steep-sided hill and valley topography where dissection by stream networks expose highly fractured crystalline and massive conglomerate bedrock. According to Eisbachler (1967), the various streams and valleys in the Cobequid Mountains follow the trends of fractures, and in places, (eg. Wentworth Valley), structural alignments in bedrock. The granites within the Cobequid sections of River Philip and Maccan River watersheds are characterized by the presence of closely spaced, high angle, north-south and widely spaced east-west fractures. Where lower Cumberland and Riversdale conglomerates are in contact with the Silurian and Devonian igneous rocks along the south slope of the Cobequid Mountains, fractures within the conglomerates are found to diminish in number and spacing with increasing distance from the contact.

Test well No. 9 was drilled 79 m. (260 ft.) into a continuous, massive sequence of coarse cemented conglomerate of lower Cumberland facies at Rodney; very few fractures or shears were encountered at depth, which account for the observed low yields of 0.15 to 0.30 L/s (2 to 4 igpm) from this well.

A single well located at Poison Lake and drilled in granite or metamorphics to 70 m. (230 ft.) reports a blow test yield of 0.11 L/s (1.5 igpm) (Table 5.3). Hennigar (1972) indicates that wells drilled into similar rocks in the Truro area produce yields ranging from 0.19 to 0.53 L/s (2.5 to 7 igpm) (Table 5.4). These results are generally substantiated by well log reports and experience of local well drillers. In rare instances wells drilled into these rocks may yield in the order of 3.8 L/s (50 igpm) (Trescott, 1969).

5.2.4 Pictou/Cumberland Sandstones

The most important sedimentary hydrostratigraphic units within the study area are those permable sandstones found within the Pictou Group and

Table 5.3
Yield Data on Drilled Wells In The Cobequid Mountain and Rodney Areas, Cumberland County

	Poison Lake	Springhill
Well Depth (m)	70.0	79
Depth to Water (m)	17.4	16.5
Reported Yield (L/s)	0.11	0.30
Lithology	granite	conglomerate

Table 5.4

Yield Data on Drilled Wells In the Cobequid Mountain Area Colchester County

Grid Location	11E11A14	11E11A26	11E11A34
Well Depth (m)	19.	27.	16.
Depth to Water (m)	3.4	6.1	4.3
Casing Length (m)	8.2	9.1	4.9
Reported Yield (L/s)	0.53	0.30	0.19
Lithology	slate	slate	granite

Summarized and interpreted from well driller's records.

Cumberland Group (non-coal bearing). These sandstone sediments may comprise a major portion of the Pictou Group extending from Amherst towards the eastern study boundary; north northeast to the coast of Northumberland Strait; and of Cumberland and Pictou sediments in areas north of Oxford and south of Springhill, and from Springhill east to Westchester and west to Maccan River at Southampton. Thick sandstone sequences have been identified in the Town of Amherst wells, in test wells No. 1 (Tyndel Road), No. 4 (Mansfield), Town of Oxford test well No. 0X-8B-76 (immediately north of Oxford), testhole No. 14 (Mount Pleasant), test wells No. 10, No. 11, No. 12, (Springhill), Town of Springhill well No. 2 and the Springhill Penitentiary wells. Perhaps the most distinguishing characteristic of the sandstone units is the occurrance of both primary permability associated with interstitial flow and secondary permability within fracture zones and bedding plane partings.

Results of pump test analysis of wells drilled into Pictou sandstones indicate transmissibility values varying from 27 to 180 $m^3/(day.m)$ or (1800 to 12000 igpd/ft.) and individual well yields varying from 7.6 to 38 L/s (100 to 500 igpm). Saturated sandstone sequences of Cumberland Group exhibit transmissibility values ranging from 12 to $52m^3/(day.m)$ or (800 to 3,500 igpd/ft.) and well yields varying from 7.6 to 23 L/s (100 to 300 igpm). Data from a few selected wells drilled into these units are given in Table 5.5.

5.2.5 Interbedded Sediments

Continuous interbedded sequences including sandstone, siltstone, conglomerate and shale were encountered in the Pictou, Riversdale and Cumberland Groups. These sediments are found over much of the study region. For example, interbedded sediments were encountered in test wells No. 6 at Fort Lawrence, No. 2 at Beecham Road, No. 3 at Hastings, and are identified in well logs at Oxford, Springhill and many domestic wells located over much of the above geological groups.

The available data indicates that the interbedded units have transmissibility values varying from 5.2 to 15 $m^3/(d.m)$ or (350 to 1000 igpd/ft) (Table 5.6). Analysis of historical pump test data available for the Town of Oxford well field consisting of 5 wells drilled into Riversdale interbedded sediments indicate an average formation transmissibility of 15 m^3 (day.m) a (1000 igpd/ft.) Average well yield approximates 5.9 L/S (70 igpm) with a maximum well yield potential of 1.6 x $10^3 m^3/day$ or (0.36 MIGD) (Table 5.6) The upper limit of these units are similar to the lower limits of the sandstone units. The range of overlap may vary according to the interpretation of lithology and hydrological characteristics.

The upper facies of the Cumberland Group located in the western central portion of the study region contain thick (914 m, 3000 ft.) sequences of red beds. Test well data are not yet available for this sequence however, the groundwater potential of this unit may be significant. In general, where these sedimentary sequences occur, yields in the order of 1.9 to 7.6 L/s (25 to 100 igpm) may be possible and would likely vary according to the depth of saturated thickness penetrated.

Table 5.5

Data Obtained From Drilled Wells In Pictou-Cumberland Sandstone

Geological Group / Area	**Pictou** Tindle Rd.	**Pictou** Amherst	**Pictou** Oxford	**Cumberland** Springhill	**Cumberland** Springhill	**Cumberland** Mt. Pleasant
Owner—TH. No.	TH No. 1	Town	OX-8B-76	Penitentiary	TH No. 11	TH No. 14
Coefficient of Transmissibility $m^3/(day.m)$	180.	42.	27.	49.	28.	15.
Coefficient of Storage	-	-	1.0x10^{-3}	1.56x10^{-4}	1.49x10^{-3}	-
Yield (L/s)	38	23	7.6	23	14	7.6
Depth (m)	76	130	111	152	91	78

Table 5.6

Data Obtained From Wells Drilled In Pictou-Cumberland-Riversdale Interbedded Sediment

Location	Owner or Test Well Number	Depth (m.)	Coefficient of Storage "S"	Coefficient of Transmissibility "T" $m^3/(d.m)$	Long Term Yield (L/s)
Springhill	Town	67.7	-	5.2	2.0
Nappan	CDA	46	4.9×10^{-3}	14.9	5.3
Oxford	Town Well No. 5	110	1.2×10^{-2}	15.0	7.6
Oxford	*Town Wells No. 1 to No. 5	-	-	15.0	5.9
Oxford	OX-1-75	80	-	11.2	2.7
Fort Lawrence	TH No. 6	76	-	-	1.9
Beecham Road	TH No. 2	49	-	-	1.9
Hastings	TH No. 3	49		6.7	2.3

*Average Yield

5.2.6 Shales and Evaporites

Thick sequences of red shales interbedded with thin siltstone and sandstone laminae have been identified in Pictou, Cumberland, Riversdale and Windsor Groups. Evaporites (salt, gypsum, anhydrite) are restricted to areas of Windsor Group. In the study region shales and evaporites are found along the axis and limbs of the Claremont Anticline between Springhill and Oxford. Also these units occur over a wide area south of Amherst from Nappan west to the Maccan River and from Nappan east to Mansfield over a narrow belt following the axis of the Minudie Anticline. Well logs indicate that shales may often be encountered in areas of Boss Point formation along the north flank of the Cobequid Mountains from Collingwood Corner to Westchester and over much of Cumberland Group from River Philip east to Thomson Station.

Because of the fine particle size of shales, flow through these sediments largely depends upon the degree and extent of fracturing and related secondary permeability. Characteristically, these sediments have low transmissibility and rarely produce significant yields, often barely meeting domestic requirements. For example, test wells No. 16 at Collingwood Corner, No. 15 at Thomson Station and No. 8 at Rodney indicate yields from shales vary from 0.11 to 0.30 L/s (1.5 to 4 igpm) (Table 5.7). Yields from wells drilled into shale and penetrating 33 m. (100 ft.) of saturated thickness may be expected to yield from less than 0.08 to 0.38 L/s (1 to 5 igpm).

Table 5.7

Data Obtained From Wells In Pictou-Cumberland-Riversdale Shales

Location	Owner or TH No.	Well Depth	Coefficient of Transmissibility	Potential Yield
		m.	"T" $m^3/(day.m)$	L/s
Collingwood	No. 16	49.4	-	0.11
Thomson Station	No. 15	62.5	-	0.11
Rodney	No. 8	97.6	-	0.30
Fenwick	L & F	15.2	1.2	0.15

5.3 Special Studies

The Town of Springhill, with a projected demand of $4.5 \times 10^3 m^3/day$ (1 MIGD) relies on a combined surface water and groundwater supply source. The surface water supply is dervied from Leamington Brook, a tributary to Maccan River, at a location approximately 13 km (8.0 mi.) due south of the town. The Town constructed a deep well 150 m. (500 ft.) in the early 1950's to augment the Leamington reservoir.

Over the past 10 year period, the Town has experienced water supply shortages because of deterioration of the transmission lines and a lack of sufficient storage. Because the life of the surface water system is not expected to exceed an additional 5 year period, the Town of Springhill decided to review the various water supply alternatives. The options as identified by Alderney Consultants Ltd. (1974) include: a) British Lake, b) Lower Leamington Brook, c) Reconstruction of the existing town system.

Due to the lack of basic hydrological data in the Springhill area, groundwater was not considered as a feasible option. A special study was initiated under the terms of the project agreement to quantify the available water resources in this area. This study consisted of test drilling, pumping, stream gauging, water quality sampling and hydrological analysis of various alternatives.

Test drilling operations began in February, 1978 and were completed by June 15 of that year. Stream gauging programs commenced on September 16, 1977 and ended December 31, 1978. Further efforts by the N.S. Department of the Environment were undertaken to establish streamflows from the British Lake system.

5.3.1 Test Drilling Results

A total of 6 test wells were drilled in the Rodney area (Figure 5.6).

Pump tests on well No. 11, No. 12 and No. 13 indicate a combined total long term capacity of approximately $2.6 \times 10^3 m^3/day$ (0.58 MIGD). Blow tests on wells No. 10 and No. 12 and the occurrence of known overflows in the area suggest that bedrock aquifers in this area have potential for additional yields in the order of $1.31 \times 10^3 m^3/day$ (0.29 MIGD). A pump test analysis on the Springhill Penitentiary well located in the southwestern section of the bedrock channel indicates a safe long term yield of $1.96 \times 10^3 m^3/day$ (0.43 MIGD). The reported yield from the Town of Springhill production wells approximates $1.78 \times 10^3 m^3/day$ (0.39 MIGD). In summary, test results and related information disclose known groundwater supplies within sand and gravel deposits and Cumberland Group sediments at the Springhill-Rodney area with a water supply development potential of $6.8 \times 10^3 m^3/day$ (1.5 MIGD).

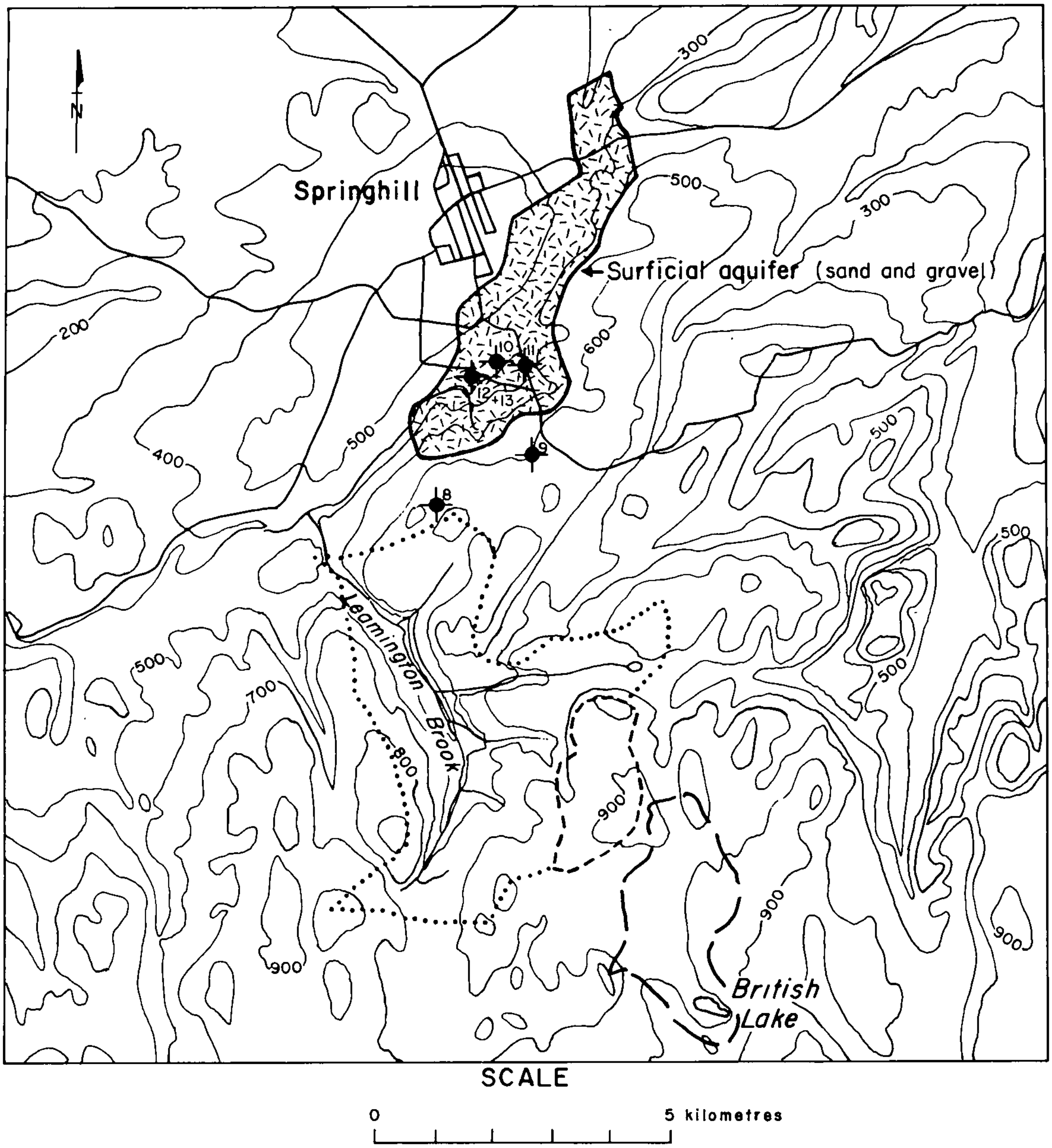
5.3.2 British Lake

The initial proposed source of water supply was British Lake located 14.5 km. (9.0 mi.) south of Springhill; having a surface area of 11.0 hectares (28.0 acres) and a drainage area of 8.8 km^2 (3.4 $mi.^2$) at the proposed dam site on Five Island River below British Lake (see Figure 5.6). This basin is on the southerly side of the divide of the Cobequid Mountains. Based on data from rain gauges at South Brook, Sugarloaf and Westchester, and a hydrometric station located at British Lake, the summer runoff (May to September) was estimated to be 380 mm (15.0 in.). The minimum mean daily flow was $1.2 \times 10^3 m^3/day$ (0.26 MIGD) or $1.4 \times 10^2 m^3/day/km^2$ (80,000 ig /day.$mi.^2$). From these data, it was concluded that British Lake Basin could supply a demand of $5.3 \times 10^{-2} m^3/s$ or $4.5 \times 10^3 m^3/day$ (1 MIGD).

5.3.3 Lower Leamington Proposal

The site of the proposed Lower Leamington intake structure is above the confluence of Leamington Brook and Maccan River at an elevation of 100 metres (330 ft.), 6 km (3.7 mi.) south of the Springhill standpipe. A proposed backup storage dam is to be located approximately 8.5 km (5.3 mi.) due south of Springhill, spanning Cleveland Brook at the point 0.8 km (0.5 mi.) east of the confluence of that watercourse and Leamington Brook at an elevation of 187 m (613 ft.).

Preliminary hydrological evaluation of the Leamington Brook Watershed was based on a point in the riverbed at elevation of 145 m (475 ft.), below the confluence of Cleveland and Leamington Brook, thereby defining a contributing drainage area of 19.5 km^2 (7.53 $mi.^2$). Using hydrometric measurements on the Maccan River, the minimum summer yield would be $6.4 \times 10^{-3} m^3/(s.km^2)$ or (0.59 cfs/mi^2). This unit yield suggests that the watershed at this point was capable of a minimum supply of $11 \times 10^3 m^3/day$ (2.4 MIGD), approximately 2.5 times the projected water supply demand of the town. Calculations indicate that a minimum safe yield of $14 \times 10^3 m^3/day$ (3.4 MIGD) may be obtained by placing an intake at elevation 100 m. (330 ft.) at a point above the confluence of Leamington and Maccan establishing a total contributing area of 27 km^2 (10.5 m^2).



LEGEND

....	Leamington Brook watershed (proposed)
- - - - - - - - -	Leamington Brook watershed (existing)
—— —— ——	British Lake watershed (proposed)
(well symbol) 10	Test Well # 10

Figure 5.6 Water Supply Alternatives For Springhill

5.3.4 Selection Process

Beyond water quantity data, primary factors investigated included: water quality, engineering feasibility (i.e. hydrogeology of dam sites), economics (methodology and assumptions drawn), and annual operational costs. Other significant parameters include watershed management strategies such as designation, purchase or other control-protection mechanisms, population trends, demand projections, and historical preferences of the community. The British Lake proposal was initially considered as the preferred option.

Results of these investigations and others, provided the additional information required for a thorough hydrological analysis of the various water supply options. This led to the establishment of groundwater as an additional alternative. After reconsideration of these options, the town selected the Leamington Brook alternative as a source for future water supply (Figure 5.6). The groundwater may yet play a role in meeting the town's growing demands.

CHAPTER 6
Water Quality

6.1 Methodology

Maccan, Philip, Shinimikas, Tidnish and Nappan Rivers were monitored for baseline chemical water quality. River Philip and Maccan were sampled in January, June and October, 1978, Shinimikas and Tidnish in August, 1978 and Nappan in July, 1979.

Similar sampling programs were conducted for groundwater quality evaluation. Samples were taken from test wells, and from a number of strategically located wells throughout the study region. Complete chemical data for surface water and groundwater are listed in Tables D1 and D2, appendix D, respectively. Surface and groundwater sample stations are given on Figure 6.1.

This chapter discusses water type, major constituents, variation, and suitability in terms of Guidelines for Canadian Drinking Water Quality 1978.

6.2 Surface Water Quality

Water Quality Trends: Results indicate that water qualities of Maccan and Philip Rivers are generally of good quality and are similar and consistent throughout each river system (with a number of minor exceptions discussed later in this section). Significantly, a shift in water quality character occurs through seasonal and varying flow conditions. Tables 6.1 and 6.2 summarize averaged concentrations of River Philip and Maccan for each sampling period.

Analysis of January 1978 samples depicts the water of River Philip and Maccan as having a predominantly saline component, low in Total Dissolved Solids (TDS), soft, slightly acidic and mildly corrosive (Figures 6.2 and 6.5). June results indicate a shift in chemistry toward a more balanced water type: an increasing alkaline component with higher TDS and hardness, neutral pH and remaining slightly corrosive (Figures 6.3 and 6.6). By October 1978, the water quality shifts further toward an alkaline component, characterized by higher concentrations of bicarbonate ions (Figures 6.4 and 6.7). Again increase in TDS, hardness and pH are recorded; however, the water remains generally soft, neutral in pH and mildly corrosive. Overall, water of both river systems is low in colour, turbidity and suspended solids, with Maccan demonstrating the higher colour and turbidity values of the two.

The alkaline character of groundwaters within Cumberland sedimentary unit and the increase in base flow (as per cent of total runoff) may account for the shift in chemical composition. Figure 6.8 illustrates the relationship between the concentration of mean

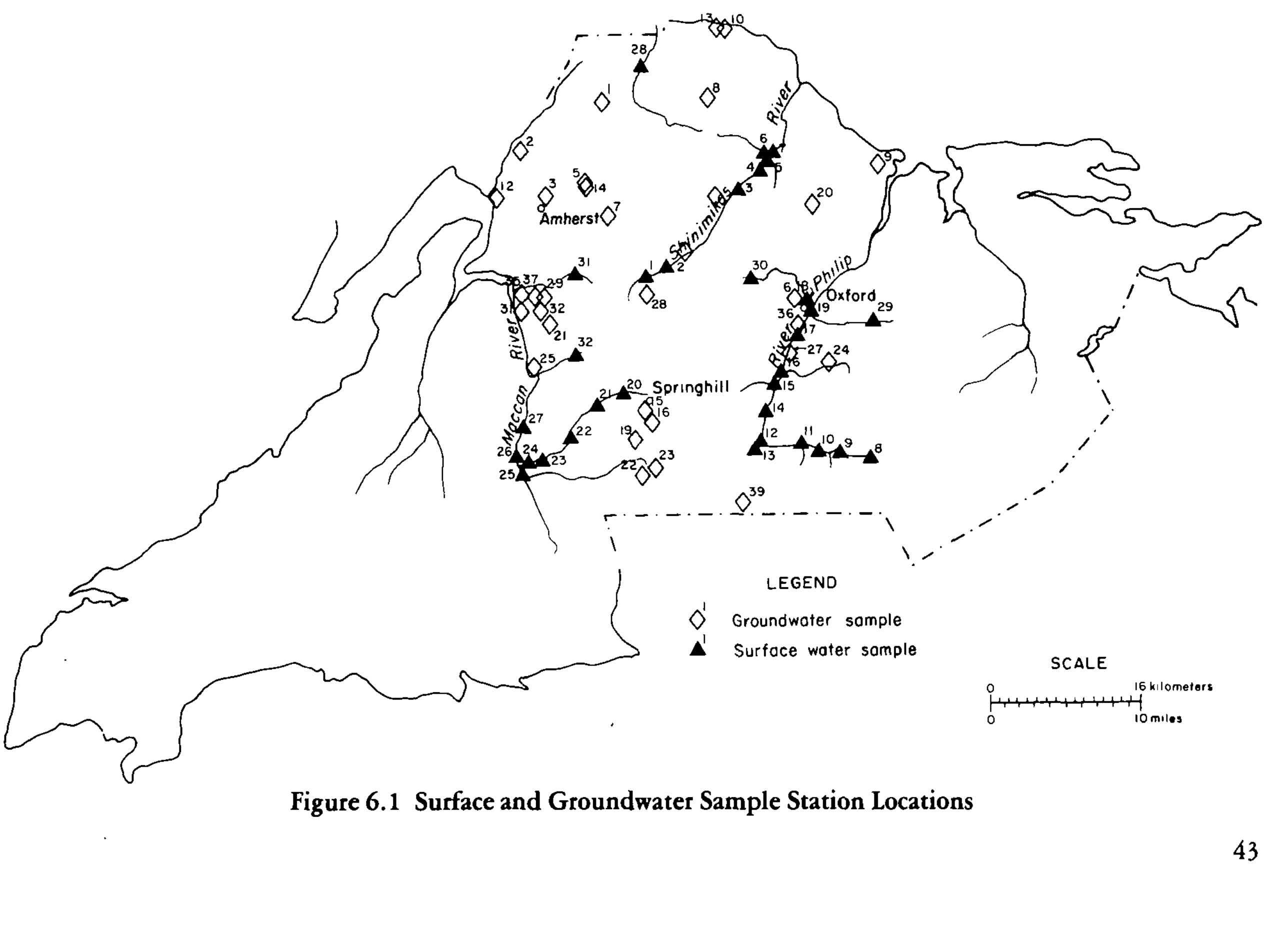


Figure 6.1 Surface and Groundwater Sample Station Locations

Table 6.1

Water Quality River Philip 1978

Element	Mean mg^x/l	Standard Dev. s	No. of Samples n	Variance C_V*
January 30, 1978 (omitting stations 18 and 19)				
Na	2.22	0.29	10	13%
Ca	2.00	0.37	10	19
Mg	0.56	0.08	10	15
$CaCO_3$(AlK)	3.72	0.94	10	25
$CaCO_3$(Hard)	8.05	0.64	10	8
Cl	3.00	0.42	10	14
SO_4	3.60	0.41	10	11
PO_4	.010	.002	10	19
June 1, 1978 (omitting stations 18 and 19)				
Na	2.62	0.53	10	20%
Ca	2.38	0.24	10	10
Mg	0.73	0.12	10	16
$CaCO_3$(AlK)	7.21	0.90	10	13
$CaCO_3$(Hard)	9.02	0.79	10	9
Cl	3.92	0.94	10	24
SO_4	2.21	0.19	10	8.4
PO_4	—	—	—	—
October 3, 1978 (omitting stations 18 and 19)				
Na	3.70	0.86	10	23%
Ca	5.20	0.70	10	13
Mg	1.26	0.22	10	17
$CaCO_3$(AlK)	13.6	2.07	10	15
$CaCO_3$(Hard)	18.4	2.27	10	12
Cl	5.63	1.51	10	27
SO_4	3.40	0.74	10	22
PO_4	0.02	—	—	—

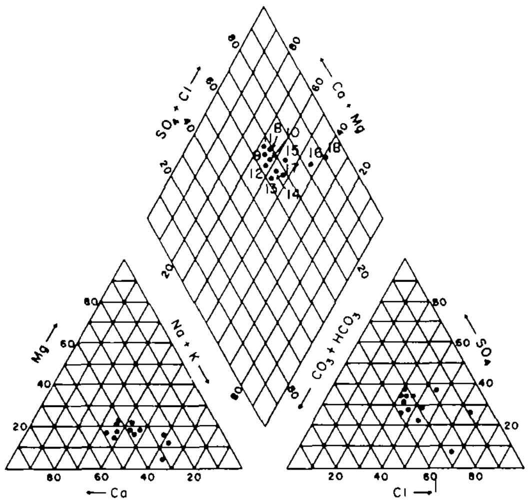
NOTE: The ratio of (std. Dev. / Mean) is reduced by omitting two stations at Oxford.
*C_V = S / X x 100

Table 6.2

Water Quality Maccan River 1978

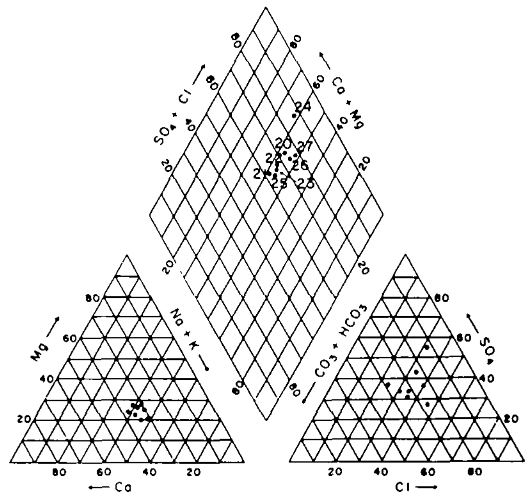
Element	Mean mg/1	Standard Dev. s	No. of Samples n	Variance C_V*
		January 31, 1978		
Na	3.11	0.91	8	29%
Ca	2.63	1.32	8	50
Mg	1.17	0.54	8	46
$CaCO_3$(AlK)	4.53	0.72	8	16
$CaCO_3$(Hard)	11.9	5.47	8	46
Cl	4.22	1.80	8	43
SO_4	6.60	4.13	8	63
PO_4 (ortho)	0.020	.003	8	17
		June 6, 1978		
Na	4.70	2.87	8	61%
Ca	3.70	2.32	8	63
Mg	1.58	0.83	8	53
$CaCO_3$(AlK)	10.3	3.60	8	35
$CaCO_3$(Hard)	16.0	9.33	8	58
Cl	6.68	3.84	8	57
SO_4	6.34	6.94	8	109
PO_4	.043	.013	8	30
		October 3-4, 1978		
Na	6.48	2.15	8	33%
Ca	7.85	5.87	8	75
Mg	2.45	1.30	8	53
$CaCO_3$(AlK)	20.0	11.9	8	60
$CaCO_3$(Hard)	29.8	19.7	8	66
Cl	12.3	11.7	8	95
SO_4	12.8	17.3	8	135
PO_4	0.02	—	8	—

*C_V = S / X x 100



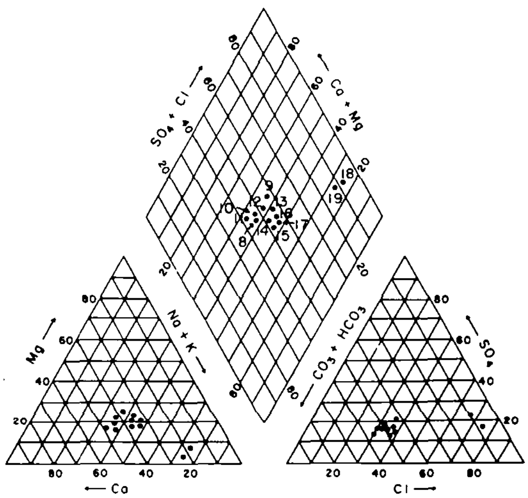
Per cent of total equivalents per million

Figure 6.2 River Philip, January 30, 1978



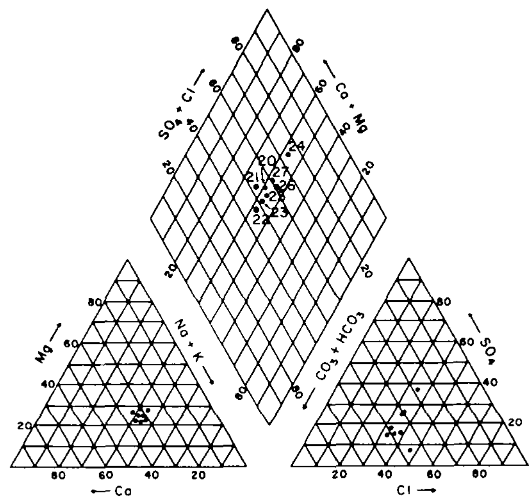
Per cent of total equivalents per million

Figure 6.5 Maccan River, January 30, 1978



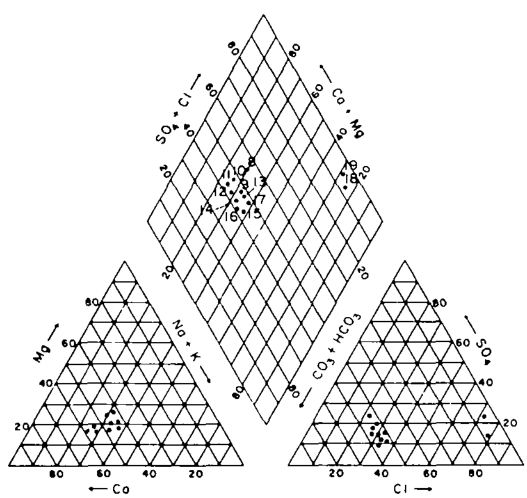
Per cent of total equivalents per million

Figure 6.3 River Philip, June 1, 1978



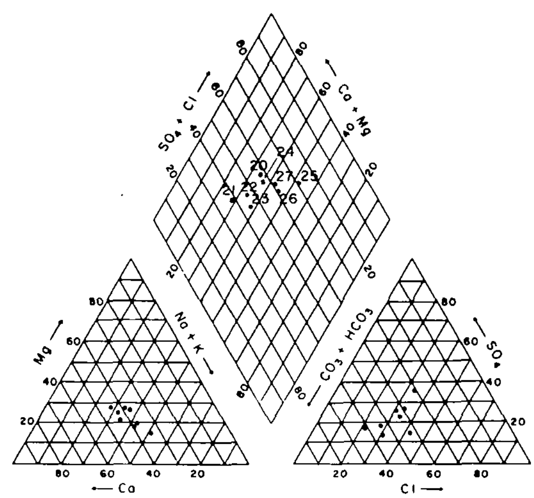
Per cent of total equivalents per million

Figure 6.6 Water Quality Maccan River, June 6, 1978



Per cent of total equivalents per million

Figure 6.4 River Philip, October 3, 1978



Per cent of total equivalents per million

Figure 6.7 Water Quality Maccan River, October 3-4, 1978

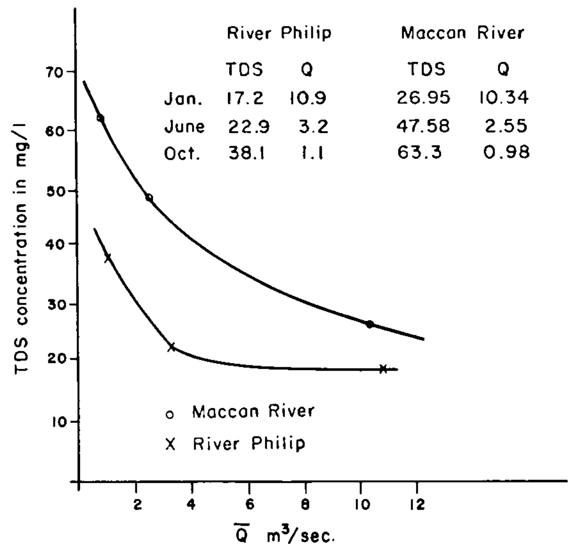


Figure 6.8 Average TDS Concentration vs. Mean Discharge For All Stations Maccan River and River Philip

TDS and mean discharge for all sample stations on River Philip and Maccan. The high TDS concentrations during low flow conditions reflect the influence of base flow or groundwater with an alkaline character and higher TDS concentrations. As the overland component of runoff increases in proportion to total flow, concentrations are increasingly dilute and reflect the acidic character of rainwater.

Treatment for Iron and Manganese: Iron and manganese concentrations for Maccan and Philip Rivers are for the most part within the recommended acceptable limits of 0.3 mg/1 for iron and 0.05 mg/1 for manganese. Maccan demonstrates slightly higher concentrations: a mean value (for all stations) of 0.22 mg/1 for iron and 0.03 mg/1 for manganese. Means for River Philip are 0.16 and 0.01 mg/1, respectively. The maximum recorded iron concentrations 0.9 mg/1 for Maccan (Sample No. 23(a)) and 0.55 mg/1 for River Philip (Sample No. 11(b)) suggest that levels that are undesirable in domestic or municipal water supplies can occur. It is likely that treatment facilities for iron and manganese removal would be necessary.

Influence of Windsor Group: At stations No. 19, River Philip and No. 18, Black River (tributary to River Philip), a water character which differs significantly from the remaining watershed areas is identified (Figure 6.4). Throughout the year, water quality is increasingly dominated by strong saline influences. At sample station No. 19, chlorides vary from a low in January 1978 of 2.13 to a high of 145.0 mg/1 in October (Sample No. 19a and No. 19c). TDS values exceed 400 mg/1 at station No. 19 (Sample No. 19c) in October 1978. Tide influence is not responsible for the strong saline character at these localities. Re-sampling of Black River in 1979, above the 50 foot contour, sample No. 30 (Table D.1) again describes a saline water character with a chloride concentration of 91 mg/1. Review of the bedrock geology suggests the Windsor Formation, a known salt bearing unit, is the responsible agent. Black River watershed is largely underlain by Windsor Group (Map 1). Dissolved salts, derived from groundwater dissolution of bedrock and surface erosion, provide a mechanism for salt transport to Black River and the main River Philip above station No. 19. Saline groundwaters have been identified near the Trans Canada Highway bridge, west of Oxford.

When plotted against cumulative area drained (Figure 6.9), water quality data for River Philip demonstrates fairly consistent TDS concentrations above station No. 17. Stations No. 18 and No. 19 show a significantly higher TDS concentration com-

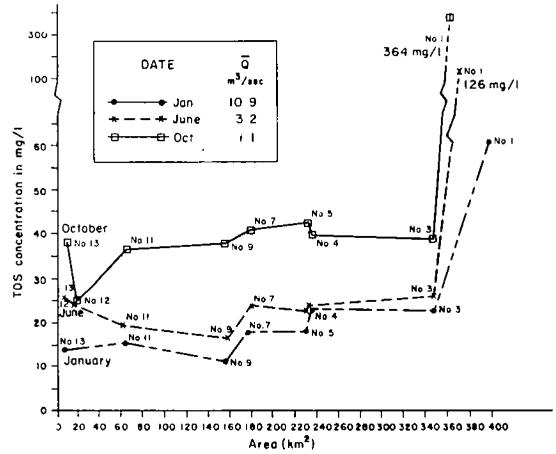


Figure 6.9 Mean TDS Concentration Versus Area Drained—River Philip

pared to the remaining watershed. The relatively high concentrations of dissolved salts, although below the acceptable recommended limits, reduces the suitability of the Black River watershed as a potential water supply. The Environmental Survey Section of this report describes other poential problems within this watershed.

Although minor variations are identified between the Cobequid Mountain and lowland watershed areas, no other clearly discernible geochemical influences were recognized within the watershed boundaries of Rivers Philip and Maccan. Curiously, there is an apparently consistent shift towards saline character, for any given flow condition as the water mass moves from the Cobequid region across the Cumberland lowlands (Figure 6.9). The significance of this event is not clearly understood.

Water Quality in Cobequid Mountains: Data have shown that a number of tributaries discharging from

Table 6.3

Surface Water Quality Cobequid Mountains in mg/l

	Station No. 10 Sample No. 10a	Station No. 13 Sample No. 13a	Station No. 21 Sample No. 21a
Sodium	2.0	2.5	2.3
Potassium	0.19	0.3	9.3
Magnesium	0.5	0.7	0.9
Calcium	2.2	2.2	1.8
Hardness	7.8	8.7	8.6
Alkalinity	3.6	5.0	4.8
Sulphate	2.6	4.1	4.5
Chloride	3.4	3.1	2.1
Iron	0.036	0.172	0.18
Manganese	0.006	0.006	0.03
Total Dissolved Solids	15.5	21.3	20.2
pH	6.2	6.4	6.5

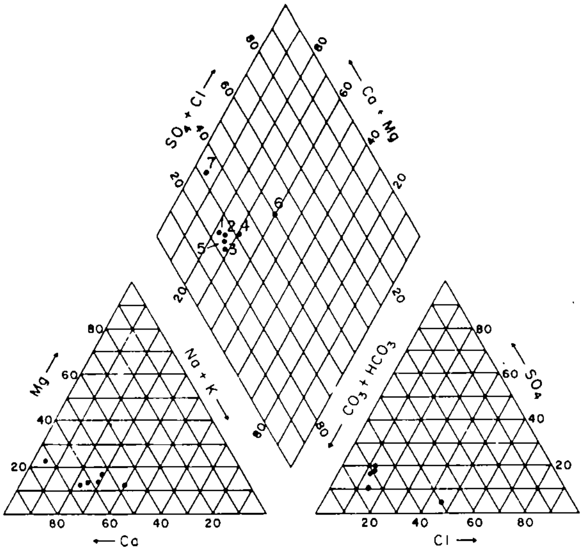
Sample Date: January, 1978

Table 6.4

Surface Water Quality
Shinimikas, Tidnish and Nappan in mg/l

	Station No. 2* Sample No. 2 Shinimikas	Station No. 6* Sample No. 6 Shinimikas	Station No. 28* Sample No. 28 Tidnish	Station No. 31** Sample No. 31 Nappan
Sodium	4.0	13.4	3.8	4.7
Potassium	0.81	1.3	0.41	0.4
Calcium	10.3	14.6	6.2	8.4
Hardness	32.7	48.3	22.1	25.0
Alkalinity	31.0	35.1	19.2	21.0
Sulphate	1.9	2.1	2.1	5.0
Chloride	4.4	23.0	5.6	5.0
Iron	0.76	0.83	0.4	0.28
Manganese	36.0	0.27	0.05	0.05
Colour	50.0	65.0	90.0	150.0
Turbidity	2.7	9.0	4.5	1.8
pH	7.4	7.5	7.3	7.2

*** Sample Date: August, 1978**
****Sample Date: July, 1979**



Per cent of total equivalents per million

Figure 6.10 Water Quality Shinimikas River, August 17, 1978

the Cobequid Mountains have excellent chemical water quality. Generally, water derived from the igneous and metamorphic rock of the Cobequid Mountains is very low in TDS and hardness, slightly acidic, and low in iron and manganese.

Jackson Brook Station No. 10, West River Philip Station No. 13, and Leamington Brook Station No. 21, are several such examples (Table 6.3).

Water Quality, Lowlands: In terms of flow conditions, the relative suitability of the Shinimikas, Tidnish, and Nappan River systems as a water supply resource is limited. Therefore, a single set of samples (stations No. 1 to No. 7) was taken from Shinimikas and a single sample, (stations No. 28 and No. 31) from the Tidnish and Nappan respectively, during low flow conditions. Selected samples are given in Table 6.4.

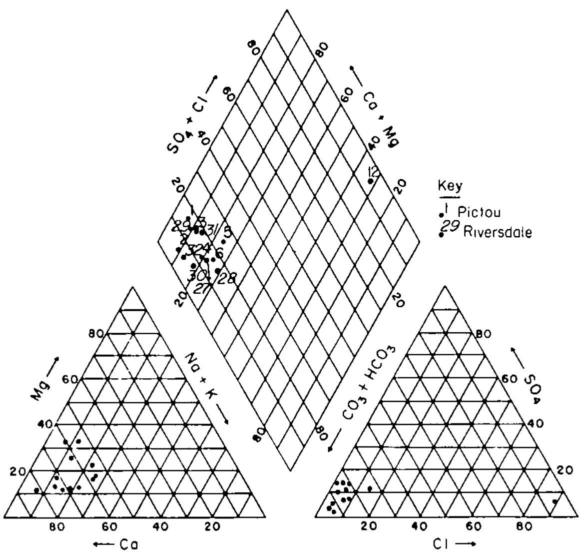
Water qualities of these watersheds are similar (Figure 6.10). Dominantly alkaline in type, they are characterized by bicarbonate ions or "carbonate hardness". Although TDS concentrations are significantly greater than Philip or Maccan, the waters remain soft, high in colour, low in turbidity, high in pH and slightly incrusting. Iron and manganese concentrations may vary widely, exceeding recommended limits in some localities, i.e., stations No. 1, No. 6, and No. 7. High temperature, 20°C, and low dissolved oxygen reflect the low stream gradient and the near zero flow conditions at the time of sampling, both characteristics of these rivers.

Colour may be associated with iron, manganese, and dissolved organics, particularly, humic acids (see Sample No. 6, Table D1). The alkaline character of these waters reflects the dissolution of carbonate from the sedimentary bedrock, of the Pictou Group over which these rivers flow.

6.3 Groundwater Quality

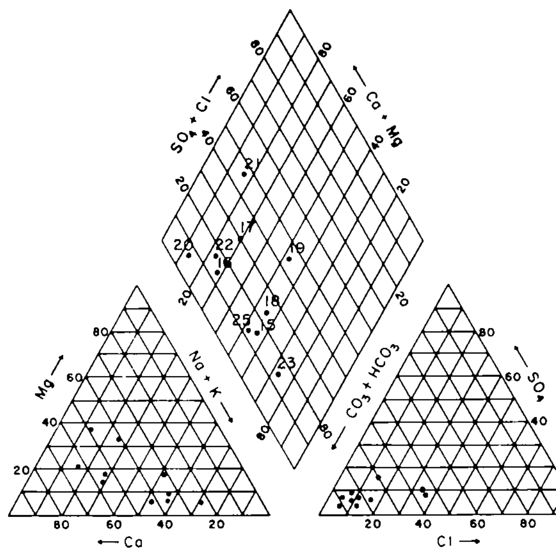
Water Quality from Sandstone and Interbedded Sediments: The lowland sedimentary sandstone and interbedded aquifers of Pictou, Cumberland and Riversdale Groups, demonstrate similar water quality characteristics.

The most important dissolved ions in these units are calcium, magnesium, bicarbonate and carbonate



Per cent of total equivalents per million

Figure 6.11 Groundwater Quality Pictou and Riversdale Sandstone and Interbedded



Per cent of total equivalents per million

Figure 6.12 Groundwater Quality Cumberland Sandstones and Interbedded

Table 6.5

Groundwater Quality Data (mg/l)

Pictou—Cumberland—Riversdale
Sandstone and Interbedded Sediments

	Geological Group/Location		
	Pictou Tindle Road, Test Hole No. 1 **Sample Number 15**	**Cumberland** Springhill Test Hole No. 11 **Sample Number 16**	**Riversdale** Oxford Junction **Sample Number 27**
Sodium	15.0	14.0	13.0
Potassium	0.8	1.9	2.8
Calcium	34.0	27.0	38.0
Magnesium	11.0	4.2	5.2
Hardness	130.0	86.0	117.0
Alkalinity	114.0	104.0	135.0
Sulphate	3.2	7.5	8.5
Chloride	12.0	6.5	8.5
TDS	135.0	145.0	168.0
pH	7.8	8.0	8.1

ions. The carbonates are major contributors to the total dissolved solids and constitute most of the hardness and alkalinity.

Plots of selected water samples (Piper, 1944), taken from the above Pictou, Riversdale and Cumberland hydrostratigraphic units are shown on Figures 6.11 and 6.12, respectively. These groundwater samples have similar chemical composition and may be described as a calcium magnesium carbonate and bicarbonate water. Chemical data of a number of selected analyses are given in Table 6.5.

Of these samples, hardness varies from 86 to 130 mg/l. with pH ranging from 7.8 to 8.1. Total dissolved solids range from 135 to 168 mg/l.

Minor Iron and Manganese: Iron and manganese are generally not a problem in Pictou sediments, with concentrations remaining within the limit of 0.3 mg/l for iron and 0.05 mg/l for manganese (Guidelines for Canadian Drinking Water, 1978).

Within the Cumberland and Riversdale sandstones and interbedded units, iron and manganese problems may occur, particularly where Cumberland Group coal measures are encountered. Although not a health hazard, minor aesthetic problems associated with the staining of plumbing fixtures and clothing do occur. Usually iron and manganese concentrations are within effective treatment limits.

Hydrogen sulfide gas, also associated with the coal measures of Cumberland Group, presents a minor water quality problem. Chlorine treatment and physical aeration processes can produce stable oxides of sulfide (Fair, Geyer and Okun, 1968). For domestic purposes, charcoal filters are usually effective.

Water Quality from Shales: Shale sequences of Pictou, Riversdale and Cumberland Groups, produce groundwaters which are generally highly alkaline, very soft, contain a wide range of chloride salts; are high in TDS concentrations and pH. Sodium bicarbonates are responsible for the soft condition of the water; monovalent cations (Na^+) do not contribute to hardness. The occurrence of high sodium concentrations may be related to the shale sediment's releasing of sodium to solution aided by a strong cation exchange process.

Samples No. 7 taken from test well No. 3 at Hastings and No. 24 taken from test well No. 15 at Thomson Station are examples of this water type (Table 6.6, Figure 6.13). Although test well No. 3 is drilled into Pictou Group interbedded sediments, the high proportion of shales penetrated by this well illustrate the influence of shales on the insitu groundwater quality and is therefore included apart from water qualities considered typical of the interbedded units.

When examined on a regional scale, these groundwaters are found to be widespread. Major areas of occurrence are found along the Claremont and Minudie Anticlines and over much of the Riversdale and Cumberland Groups (Map 1).

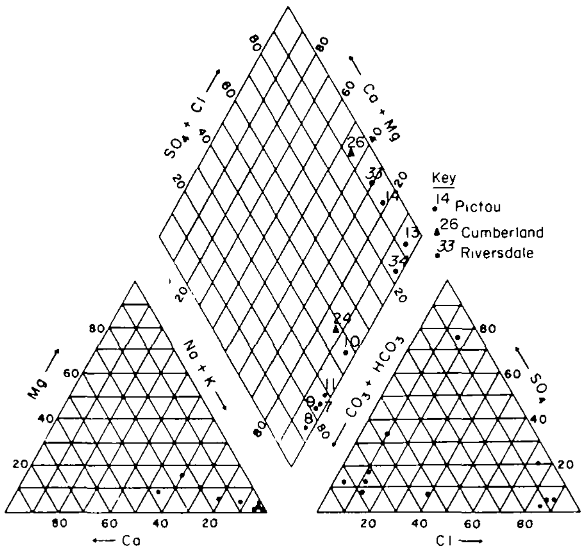


Figure 6.13 Groundwater Quality Pictou Riversdale and Cumberland Shales

Shales and associated salts: Of particular interest is sample No. 14, (Figure 6.13) taken from a well drilled into Pictou Group shales at Hastings. The highly saline waters (chloride 1575 mg/l) in this well suggests that areas north of the Minudie Anticline may be influenced directly by underlying salts intruded or in contact with Pictou sediments.

Well No. OX-1-75 drilled in Riversdale interbedded sediment (also penetrating a high proportion of soft shales) southwest of Oxford, demonstrates a saline influence on water quality (Sample No. 33, Table 6.6, Figure 6.13). In this case, the Claremont Anticline with similar evaporite occurrences as the Minudie structure, may account for salt diffusion in groundwater. Salt water surfaces at Salt Springs and has been reported in a number of domestic drilled wells located along the axial region of this structure. Also brackish surface and groundwater are reported over Windsor Group west of Oxford (Maclarren Atlantic Ltd. 1975).

Sample No. 34 taken from test well No. 16 at Collingwood Corner defines a saline water that contrasts with the alkaline water expected from Riversdale shales at this location. In this instance, the strong sodium chloride balance (chloride concentration of 570 mg/l) is not readily explained (see Figure 6.13). The absence of salts within the Cobequid Mountain bedrock suggests that salts are associated with the Boss Point Formation rather than adjacent formations. The location of this well within an ancient buried river valley of River Philip suggests that tectonic events, associated sea level rise and drowning of the river valley, may have provided a mechanism for salt invasion of fresh water aquifers.

Sample No. 26 (Figure 6.13) was taken from a domestic well reportedly drilled into Cumberland hard shale in Southampton. Although an unusual occurrence, these results are consistent with reports by a local well driller, Mr. R. White, that a number of wells in the Southampton area encountered salt or brackish water at depth and were subsequently abandoned. Brine solutions in Riversdale shale bedrock

Table 6.6
Groundwater Quality Data (mg/l)
Pictou—Cumberland and Riversdale Shales

	Geological Group/Location		
	Pictou Hastings No. 3 Sample No. 7	Cumberland Thomson No. 15 Sample No. 24	Riversdale Oxford - 1-75 Sample No. 32
Sodium	150.0	125.0	74.0
Potassium	3.7	6.9	3.6
Calcium	1.0	14.0	20.0
Magnesium	1.0	2.6	5.2
Hardness	41.0	46.0	72.0
Alkalinity	326.0	155.0	56.0
Sulphate	51.0	25.0	16.0
Chloride	34.0	85.0	133.0
TDS	449.0	784.0	307.0
pH	9.3	8.8	7.7

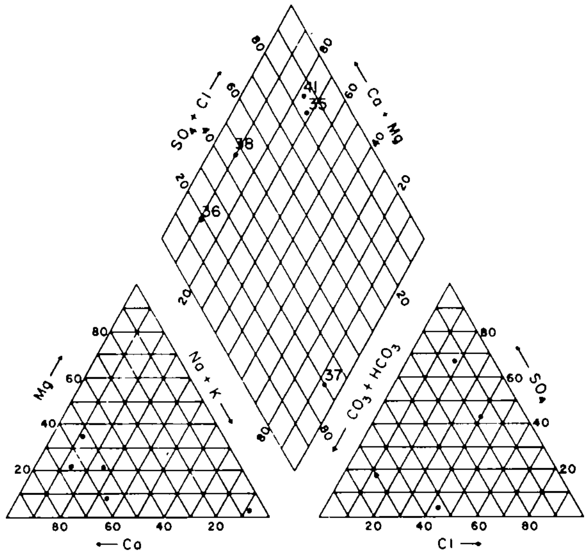
aquifers at Three Brooks, Pictou County, have been described by Vaughan (1976).

Water Quality from Windsor Shales and Evaporites: Groundwaters from the shale and evaporites from the Windsor Group are generally of very poor quality. The occurrence of evaporite deposits in this group contributes excessive amounts of sulphate, hardness, and total dissolved solids. The absence of drilled wells in this unit is itself testimony to the poor quality of the water. Only 4 wells, drilled in Windsor bedrock, were sampled and the results plotted in Figure 6.14.

For example, sample No. 35 taken at Nappan, had a concentration of total dissolved solids of 690 mg/l consisting predominantly of calcium sulfate contributing to a substantial level of permanent hardness (Figure 6.14, Table 6.7).

Residents of Maccan, Nappan and Oxford are familiar with the problems Windsor groundwater present. It was necessary in Maccan, for example, to supply a residential area, located in Windsor Group sediments with water from the Agricultural Experimental Farm well field, which extracts groundwater from nearby Riversdale Group Sediments (see sample No. 31, Figure 6.11).

Windsor Group evaporites may influence water quality of overlying surficial aquifers. Water sample No. 41 (Figure 6.14) taken from surficial sand and gravel deposits at Nappan, penetrated by Test Hole No. 5, exhibits a water quality character similar to Windsor bedrock. Although lower in TDS (225 mg/l) and hardness (106 mg/l), the influence of



Per cent of total equivalents per million

Figure 6.14 Groundwater Quality Windsor Shales and Evaporites

Windsor sediment from underlying bedrock is apparent.

As previously mentioned, surficial sand and gravel aquifers located west of the town of Oxford are saturated with chloride salts. Although aquifer evaluation indicated an excellent supply potential, chloride concentrations in excess of 1000 mg/l make the aquifer unsuitable for municipal use (Maclarren Atlantic 1975).

In some areas underlain by Windsor Group

Table 6.7

Groundwater Quality Data (mg/l)
Windsor Shales and Evaporites

	Nappan Sample Number 35 (mg/l)	Oxford Sample Number 36 (mg/l)
Sodium	63.0	36
Potassium	12.0	3.8
Calcium	108.0	22.0
Magnesium	27.0	8.6
Hardness	382.0	91.0
Alkalinity	80.0	82.0
Sulphate	320.0	10
Chloride	69.0	7.0
pH	7.8	8.1
TDS	690.0	128

sediments, wells are known to yield groundwaters of acceptable quality. Sample No. 36 (Figure 6.14) at Oxford Junction describes such a groundwater (Table 6.7). Relatively low in TDS (128 mg/l) and hardness (91 mg/l), this water supply is suitable for most purposes and is generally good quality water. The strong calcium bicarbonate alkalinity may reflect the influence of limestone on groundwaters. For the most part, the Windsor Group within the study area is predominated by gypsum anhydrite and related salts.

Saltwater Intrusion: Sample No. 13 taken from a domestic well at Lorenville, drilled into Pictou Group shales (Figure 6.13) and located near the shoreline of Northumberland Strait, has a sodium chloride balance indicating that this well may penetrate the freshwater/saltwater zone of diffusion, induced salt water to intrude the aquifer as a result of pumping or to be associated with formation salts as in sample No. 14.

Of special interest is sample No. 12 (Figure 6.11) taken from test well No. 7 at Fort Lawrence (west) which indicates chloride concentrations of 7500 mg/l. It is believed that the interbedded sediments of Pictou Group are intruded by salt water at this locality or influenced by connate saline waters associated with the deposition of marine marshland sediments.

Water of saline quality is severely limited in its use and its appearance along the anticlinal axis of the Minudie and Claremont anticlines and other areas of known Windsor sediments, brings into question the potential of these areas to supply potable water.

There is also the possibility that salts may influence the water quality of aquifers now in use in the Towns of Amherst and Oxford if the resource is not properly managed. The occurrence of salts within Pictou Formation east, west and south of Amherst, further illustrates the need for judicious well field management, if damage to these aquifers is to be prevented.

Turbidity: Sediment and associated high turbidity are commonly reported by local residents as their most pressing water quality problem. Discussion with local drillers indicate that most sediment problems occur in areas predominated by shale bedrock. For example, the Hasting Test Well No. 3 (Sample 7 Table D.2) when pump tested for a 72 hour period, failed to clear. The resulting turbidity ranged from a high of 530 JTU (Jackson Turbidity Unit) early in the test, to a low of 68 JTU at the end of the 72 hour period. Correspondingly, suspended solids ranged from 205 to 87 mg/l, respectively. Disintegration of the soft shales and mudstones are believed to be the cause of this problem. Solutions to the turbidity problems lie in improved well design and water treatment technology or a combination of both.

CHAPTER 7
Environmental Survey

7.1 Introduction

An environmental survey was undertaken to locate activites which could potentially have an adverse effect on water quality. The study began in January 1978 and continued over the summer and fall months of that year. The study area was divided by its natural watershed boundaries into six river basins. The survey results are given in Table 7.1 and locations are shown on Figure 7.1.

The survey included such activities and operations as: forestry, including major timber holdings and sawmills; agricultural feedlots; domestic and industrial sewage outfall; solid waste disposal sites; mining operations, including quarry and gravel pit operations; salt depots for highway de-icing; and industrial activities.

In general, the survey indicates that at present, none of the river basins has activities which present a serious threat to the water quality of the study area. It may also be inferred from Table 7.1 and from Chapter I that Cumberland County is not highly industrialized, and therefore has relatively few activities which adversely affect water quality.

River Philip and the Maccan River Basins support the largest number of sawmills, mining activities, and other domestic and industrial operations while the Shinimikas River, Nappan River and Tidnish River Basins support a low population and are generally agricultural and forest lands. Although the Town of Amherst straddles the boundary of the LaPlanche River and Nappan River Basin, elsewhere in the basins, population is sparse with few industrial activities.

Available chemical analyses of both surface and groundwaters indicate that generally water within the study area is of good quality and is not influenced to any large degree by man-made activities. However, activities identified in Table 7.1 all have the potential to cause serious water pollution problems if left unmanaged. Although site specific investigations were not undertaken, a number of practices in the region should be addressed at this point.

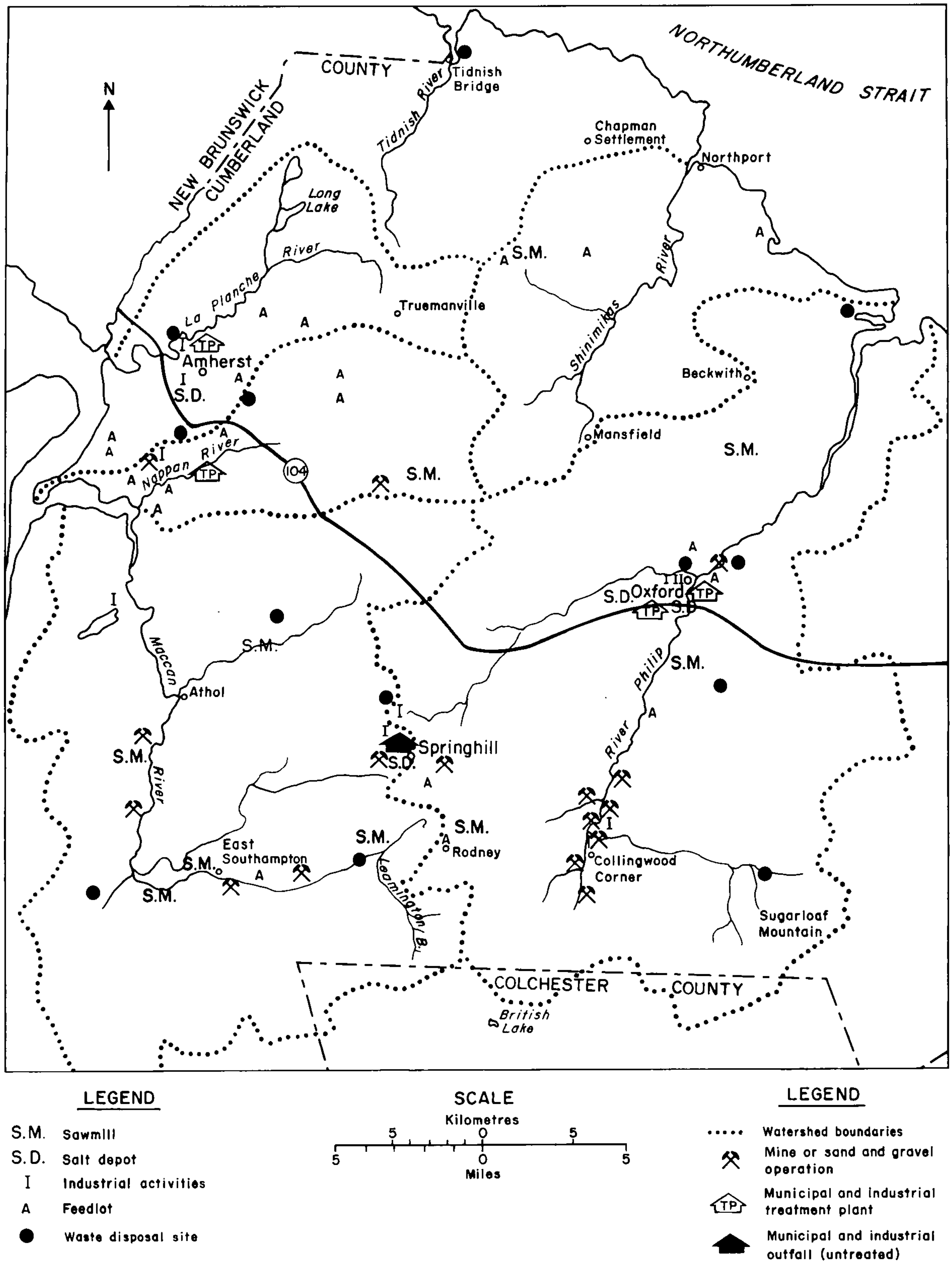
7.2 Forestry

Logging and pulp operations are important industries in the region, particularly in the Cobequid Mountain area. Clear cutting large tracts of land often results in massive soil erosion and silting of lakes, rivers, and streams.

Table 7.1

Environmental Survey

Activity	Maccan	River Philip	Shinimikas	Tidnish	Nappan	LaPlanche
Mining Operation	5	9	0	0	1	0
Sawmill	5	3	1	0	1	0
Treated municipal and industrial stormwater sewage outfall	0	2	0	0	1	1
Untreated municipal and industrial stormwater sewage outfall	1	0	0	0	0	0
Waste disposal site	5	5	0	1	1	1
Industrial activities	1	5	0	0	1	2
Agricultural feedlots	1	5	4	0	6	5
Highway de-icing salt depots	1	2	0	0	0	1



7.1 Environmental Survey

Maintenance of good water quality may be, in practical terms, impossible where uncontrolled cutting occurs. The introduction of reasonable forest management practices remains the only effective solution to these potential problems.

Woodfiber (sawdust) disposal at several sites in the region involves the tipping of wastes over a water course embankment where solids, humic acids and related organic leachates eventually discharge to the water course. Land base disposal, incineration, or shipment to pulpmills are other possible alternatives.

7.3 Agriculture

Cumberland County has an active agricultural community. Land based crop production does not appear to present a serious problem to the water resources of the region. The development of the Blueberry industry has led to the introduction of large planted acreages, much of it in the Cobequid Mountains. Although current operations are carefully managed, it is important that the producers of these and other cash crops in the region maintain effective control over the use and application of herbicides and pesticides to prevent possible water contamination.

Animal waste disposal presents potential point source pollution of both surface and groundwater. Investigations elsewhere in the province have shown that animal waste disposal has led to localized groundwater contamination, usually identified by the loss of the farm well water supply due to nitrate or bacterial contamination. Within the study region, similar problems can be anticipated. The introduction of animal waste management practices, such as properly constructed and maintained liquid waste lagoons, and covered manure tank storage, in conjunction with regular land based disposal (spreading), will serve to minimize the total impact on our water resources and prevent the loss of individual water supplies.

7.4 Mining

Within the area investigated, the extraction of aggregate represents a very real resource conflict. The few significant sand and gravel deposits in this region hold excellent potential for future water supply development. At the same time the aggregate is required for highway construction and other industrial based activities. Removal of the aggregate is generally not compatible with water supply development. Development of longterm water supply strategies serve to focus attention on the need for effective resource management.

7.5 Municipal and Industrial Stormwater-Sewage Outfall

In a number of instances, disposal of untreated sewage and stormwater wastes have been identified as potential problems. In a regional sense, these point source effluents are not yet major environmental problems. However, the increasing load and variety of discharged effluents, resulting from secondary industrial activity and more stringent environmental standards, may necessitate the introduction of treatment facilities.

7.6 Waste Disposal

Disposal of wastes on land is regarded as a principal environmental concern. Both ground and surface water could be contaminated irreversibly as a result of unsatisfactory landfill disposal. In general, the possible contamination of groundwater is regarded as the more critical problem. Under Nova Scotia climatic conditions the rapid formation of a leachate can be anticipated. Its quantity and movement, however, can be markedly reduced by adopting proper site selection criteria and operating methods.

The generation and movement of leachates are controlled by numerous factors which will vary in significance depending on the particular conditions of each case. Some of the major factors to be considered are as follows:

a) Site physical characteristics;
   geological
   hydrogeological
   climatic
   engineering aspects

b) Waste characteristics;
   type
   quantity
   properties
   method of disposition

c) Local conditions;
   water supply—importance and use of aquifers
   environmental impact
   site redevelopment schemes

Most recently Cumberland municipal governments, in cooperation with the Nova Scotia Department of the Environment, have initiated this region's first sanitary landfill operations at Little Forks and Wallace. This is a very important and positive step toward the protection of the areas' major water resources. Continuing efforts to close remaining open disposal sites will further enhance the level of environmental resource protection.

CONCLUSIONS

This water resource evaluation and inventory project has identified and quantified significant surface and groundwater resources within Cumberland County.

Surface Water Resources

1. The Cobequid Mountains represent the most significant surface water resource in the study region: High precipitation, steep slopes, and shallow groundwater flow systems result in sustained high unit area runoffs at metering stations located along the base of the mountain slopes. During 1978, a dry year, this region discharged 910 mm (35.8 in.) while recording a minimum daily discharge of 1.1 x 10^2 m^3(s. km^2) or 1 cfs/mi^2 at West River Philip.

The watershed lands of Leamington Brook draining a total area of 27 km^2 (10.5 mi^2), maintained a minimum daily discharge of 14 x 10^3m^3/day or 3.4 MIGD.

The combined minimum yield of the Cobequid Upland watersheds within the study area covering an area of 249 km^2 (96 mi^2) estimated on the basis of 1978 data approximates 127 x 10^3m^3/day or 28 MIGD.

2. Estimated yields on lowland watersheds determined from stream hydrographs on Wallace River and field observation, indicate that extreme low flow conditions prevail over the lowland watersheds: Although estimated annual runoffs approximate 520 mm (20.5 in), low flow or zero flow conditions during the summer period of 1978 reduce the significance of the lowland watersheds as potential surface water supply resources.

3. Water qualities of Maccan and River Philip: Results indicate that water qualities of Maccan River to Southhampton and River Philip to Oxford are of good chemical quality, and are similar and consistent throughout each river system with a number of minor exceptions. Overall, both rivers are slightly alkaline, low in colour, turbidity, and suspended solids.

Although generally low, concentrations of iron and manganese at times exceed the limit of 0.3 mg/l for iron and 0.05 mg/l for manganese recommended in the Guidelines for Canadian Drinking Water Quality 1978.

Groundwater Resources

4. In terms of groundwater resource potential, the permeable sandstone units within the Pictou and Cumberland Group sandstones and Pleistocene sand and gravel deposits are among some of the most productive aquifers in Nova Scotia. Significant groundwater resources within Pictou sandstone aquifers have been identified at Amherst, north toward Tidnish at TH No. 1, at TH No. 4 north of Mansfield; and in areas immediately north of the Town of Oxford. Cumberland Group sandstone aquifers were identified at Springhill, extending south to Rodney, and in a narrow band from Rodney, west toward Leamington and Southhampton, and east toward River Philip; and may extend further east beyond the western study boundary toward Wentworth.

Pleistocene sand and gravel aquifers have been identified and mapped in areas south of Springhill at Rodney, at Collingwood Corner south to the Cobequid Mountains; and from Collingwood west along East River Philip to Sugarloaf Mountain. Test results at Springhill indicate that yields from these deposits of 3.2 x 10^3m^3/day or 0.7 MIGD are possible. The potential of the surficial aquifer at Collingwood Corner may exceed 22.5 x 10^3m^3/day or 5.0 MIGD.

5. Water qualities of Pictou and Cumberland Group: The important sedimentary hydrostratigraphic sandstone units of Pictou and Cumberland Group and the interbedded sequences of Pictou, Riversdale and Cumberland Groups demonstrate a chemical water quality characterized by calcium, magnesium and bicarbonate alkalinity. Generally low in hardness and total dissolved solids and high in pH, these groundwaters are considered to be of good quality.

Water Supply Alternatives

Investigations have identified a number of water supply alternatives for the region defined by the Amherst-Oxford-Springhill triangle. They are:

Town of Amherst

6. The future water supply requirement of the Town of Amherst can be obtained by the proper development and protection of the substantial groundwater resource identified in Pictou sandstone aquifers north and east of the town.

Town of Oxford

7. A number of water supply options are open to the Town of Oxford. Groundwater to the south of the town in Riversdale interbedded aquifers and north of the town in Pictou and Cumberland sandstone aquifers, hold potential by far exceeding current requirements. Finally the River Philip can provide a

"run of river" minimum water supply approaching 4.5 x 10^3/day (1.0 MIGD).

Town of Springhill

8. This community is rich in water resources. Groundwater in and south of the town hold a water supply development potential of 6.8 x $10^3 m^3$/day (1.5 MIGD). Also Leamington Brook watershed has a supply potential substantially exceeding the current water requirements of the town.

Rural Communities

9. Small communities may rely on the abundant widespread groundwater resource of Pictou, Cumberland and Riversdale bedrock aquifers and surficial sand and gravel aquifers located in an east-west band along the flank and toe of the Cobequid Mountains and at Rodney.

Environmental Survey

10. Each of the six river basins were surveyed to locate activities that might have an adverse effect on water quality and the site of each recorded. In general, the survey indicates that at the present time, none of the river basins have activities which present a serious threat to the water quality of the study area.

Water Resources Data Base Inventory

11. In conjunction with the preparation and publication of the Water Resources Evaluation Project, a Data Base Inventory System has been developed. This subject file and map index incorporates all reference material in this report, along with the information considered useful for any subsequent investigations.

This information resource is unique. For the first time, a comprehensive water resource data file for regions of Cumberland County are organized and easily accessible in one place. This information will serve to encourage the rational development of an industrial base. It will assist in reaching decisions regarding municipal and domestic water supply and waste disposal services; and to define measures which will ensure protection of this region's water resources.

REFERENCES

Atlantic Development Board.

1967: Nova Scotia Water Resources Study; Groundwater Section, Nova Scotia Department of Mines.

——— 1969: Maritime Provinces Water Resources Study prepared by Montreal Eng. Co. Ltd. 5 vol., 13 appendices.

Bell, W.A.

1927: Outline of Carboniferous Stratigraphy and Geologic History of the Maritime Provinces of Canada; Translated by Royal Society of Canada, 3rd edition, V. 21, Section 4, p. 75 - 108.

——— 1938: Springhill, Cumberland and Colchester County, Nova Scotia; Canadian Geological Survey, Geological Map 357A (1:63,630)

——— 1944: Carboniferous Rocks and Fossil Floras of Northern Nova Scotia, Canadian Geological Survey, Memoir 238.

Brown, I.C.

1967: Economic Geology Report No. 24; Geological Survey of Canada, Department of Energy, Mines and Resources.

Copeland, M.J.

1959: Coalfields, West Half Cumberland County, Nova Scotia; Canadian Geological Survey, Memoir 298.

Dawson, J.W.

1855: Acadian Geology; Quarterly Journal of Geological Society, 1st edition.

Donohoe, H.V. and Wallace, P.I.

1978: Geology Map of the Cobequids Highlands, Nova Scotia Department of Mines, Preliminary Map, 78-1.

Eisbacher, G.H.

1967: Tectonic Analysis in the Cobequid Mountains, Nova Scotia Dissertation A65, Science and Engineering, V. 28, No. 5, pp. 1898B-1990B.

Environment Canada

1977: Historical Streamflow Summary Atlantic Provinces, Inland Waters Directorate, Water Survey of Canada, Ottawa, Canada (formerly Fisheries and Environment Canada).

——— 1973-76: The National Water Quality Data Bank (NAQUADAT) Inland Waters Directorate, Water Quality Branch, Ottawa, Canada.

——— 1978: Hydrological Atlas of Canada

——— 1967-78: Monthly Record Meteorological Observations in Canada, Atmospheric Environment Ontario Canada. (Formerly Department of Transport, Canadian Meteorological Service, Ontario, Canada).

——— 1979: Data Report - Water Resources Evaluation Project, Cumberland County, Nova Scotia, October 1977 to March 1979, Inland Water Directorate, Water Survey of Canada, Halifax, Nova Scotia.

Fair, G.M., Geyer, J.C., and Okun, D.A.

1968: Water and Wastewater Engineering, Vol. 2, John Wiley and Sons - Inc., New York.

Gates, A.D.

1973: The Tourism and Outdoor Recreation of the Maritime Provinces, Publications in applied Meteorology REC-3-73, Meteorological Applications Branch, Environment Canada.

Goldthwait, J.W.

1924: Physiography of Nova Scotia; Geological Survey of Canada, Memoir 140. 178 p.

Health and Welfare Canada

1978: Guidelines for Canadian Drinking Water Quality, 1978. Canadian Government Publication Centre Supply and Services Canada, Catalogue No. 448-10/1978.

Hennigar, T.W.

1972: Hydrology of the Truro Area Nova Scotia, Nova Scotia Department of Mines, Report No. 72-1.

Hewlett, J.D. and Nutter, W.L.

1969: An Outline of Forest Hydrology; University of Georgia Press, Athens.

Hibbert, A.R.

1967: Factors Affecting the Response of Small Watersheds to Precipitation in Humic Area, Forest Hydrology: Oxford Press, Pergamm, pp. 275-290.

Konstantinov, A.R.

1966: Determination of Evapotranspiration on the Basis of Air Temperature and Vapour Content. Manual No. 8, lecture notes subject No. 7, Research Institute for Water Resources Development, Budapest, 1968. Israel Program for Scientific Translation Ltd., U.S. Department of Commerce, TT66-51915, 523 pp.

Kunkle, G.R.
1962: The Baseflow Duration Curve, a Technique for the Study of Groundwater Discharge from a Drainage Basin; Journal of Geophysics Research, V. 67 No. 4, (Contribution 163, Research Council of Alberta).

Lin, C.L.
1975: Hydrogeology and Groundwater Flow Systems of the Smiths Cove Area, Nova Scotia; Nova Scotia Department of the Environment.

Morton, F.J.
1965: Potential Evaporation and River Basin Evaporation; Journal of Hydraulics Division, A.S.C.E., HY6.

Nova Scotia Department of Development
1979: Cumberland County Statistical Profile.

Nowland, J.L. and MacDougall
1973: Soils of Cumberland County Nova Scotia. Nova Scotia Soil Survey, Canada Department of Agriculture, Report No. 17.

Piper, A.M.
1944: A Graphic Procedure in the Geochemical Interpretation of Water Analysis; American Geophysical Union, V. 25, p. 914-923.

Roliff, W.A.
1931: Portions of Cumberland, Colchester, Hants and Kings Counties, Nova Scotia; Kent, Westmorland and Albert Counties, New Brunswick; Prince and Queens Counties, P.E.I., Imperial Oil Limited.

Shaw, W.S.
1951: Preliminary Map, Springhill Cumberland and Colchester Counties, Nova Scotia Canadian Geological Survey, paper 51-11.

Strahler, A.N.
1952: Hypsometric Analysis of Erosional Topography; in Bulletin of the Geological Society of America, Vol. 63, pp. 1117-1142.

Thornthwaite, C.W. and B. Holzman
1939: The Determination of Evaporation from Land and Water Surfaces, Monthly Weather Rev., Vol. 67, No. 1, pp. 4-11. ed. Ven Te Chow Handbook of Applied Hydrology 1964.

Trescott, P.C.
1969: Groundwater Resources and Hydrogeology of the Windsor - Hantsport - Walton Areas, Nova Scotia, Nova Scotia Department of Mines, Report No. 69-2.

Whiteside, G.B., Wicklund, R.E., and Smith, G.R.
1945: Soil survey of Cumberland County Dominion Department of Agriculture, Report No. 2, Nova Scotia Soil Survey, Truro, N.S.

UNPUBLISHED REFERENCES

Alderney Consultants Ltd.
1974: Recommendations for the Development of a New Source of Water for the Town of Springhill, Job No. 2818.

H.J. Porter and Associates
1979: Cumberland Regional Sewerage and Water Plan Study, Cumberland District Planning Commission, 10 vols.

MacLaren Atlantic Limited
1975: Report on Groundwater Investigations for the Town of Oxford, Nova Scotia.

1972: Report on Groundwater Investigations for the Town of Oxford, Nova Scotia.

Vaughan, J.G.
1978: Groundwater Evaluation Program, Springhill Area, Nova Scotia; Nova Scotia Department of the Environment, Preliminary Report.

1976: Groundwater Survey for Three Brooks, Pictou County, Nova Scotia, Water Planning and Management Division, Nova Scotia Department of the Environment.

APPENDIX A

PLANNING AGREEMENT

PROGRAM—Physical and Resource Planning

PROJECT—Water Resources Evaluation

1. BACKGROUND

In 1964, the Province of Nova Scotia recognized the need for the evaluation of its groundwater resources to allow for long term planning to optimize their utilization. The Groundwater Section within the Nova Scotia Department of Mines worked towards that goal by investigating selected areas of the Province where high population densities and intensive land use were altering and increasing the demands placed upon the resource.

The following A.R.D.A. funded programs evaluated the natural potential within the respective areas:

Annapolis-Cornwallis Valley	1968
Western Annapolis Valley	1969
Windsor-Hantsport-Walton	1969
Musquodoboit River Valley	1970
Truro	1972
Strait of Canso	1975
Sable Island (funded by the Province)	1976

This represents coverage of approximately 17% of the area of the province. In 1975, the incorporation of the section within the Nova Scotia Department of the Environment, and its subsequent alteration to the Water Planning and Management Division, increased its mandate to encompass not only groundwater, but surface water as well.

Two projects presently underway in the Sydney-Glace Bay and Halifax-Shubenacadie areas are designed to be total water resources evaluations. The completion of the latter two programs by April, 1977 will increase the coverage of the Province to approximately 22%.

With the recent termination of A.R.D.A., the ongoing programs in water resource evaluation have been carried on by the province. These programs have had to be curtailed, however, due to limited financial resources.

In conjunction with DREE and the Community Planning Division of the Nova Scotia Department of Municipal Affairs, two major areas of the province have been designated for future industrial growth and development. The water resources of these two areas have yet to be evaluated as a prerequisite for planned development.

While the priority areas have been identified and agreed to, it is recognized that there will be demands placed upon the Nova Scotia Department of the Environment for the preparation of detailed assessments of specific sites proposed or suggested for industrialization. These assessments are identified herein as "Special Projects".

2. THE PROJECT

A. Objectives

1. To undertake the evaluation of the occurrence, quality and quantity of surface and groundwater in specific areas of the Province.

2. To be able to assess the probability of contamination of the water resources by man-made activities and to be capable of advising on measures to be taken to aleviate these problems.

B. Rational

Water is one of the major requirements of industry, usually in large quantities and of good quality. It may be for boilers, processing lines, sanitation or many other uses. Industry may also disgorge large quantities of water in a contaminated state.

At the present time, there are areas of Nova Scotia where there is insufficient knowledge of the water resources to advise potential industrial users of the quantity, quality and/or the cost of developing adequate supplies.

It is not only necessary to know the water resources before industry moves in, but also the possible consequences on that resource after industry begins using it.

Because the geology of Nova Scotia, both morphologically and mineralogically, is very complex, considerable study has to be made of the water resource before sound recommendations can be made to potential users.

In the first element of strategy of the Industrial Development Subsidiary Agreement it is stated that "In order to make development efforts more effective, it is necessary to take a more analytical approach, identifying opportunities and undertaking research on various factors relevant to a new industry, particularly analysis of financial and market feasibility, and determination of infrastructure requirements". Research into the water resources of an area and the resulting data bank will be a major tool for the encouragement and placement of industries.

Opportunity

This proposal designates two priority areas in the Province where a complete evaluation of the water resources both from the point of view of the potential for its use and the problems arising from its use, is necessary.

1. The Amherst, Springhill, Oxford Triangle
2. The Pictou, New Glasgow, Trenton area

The two areas are designated in the Industrial Development Subsidiary Agreement as areas where Industrial growth will be promoted as part of the "industrial corridor".

The Amherst, Springhill, Oxford triangle is now a growth region with the Amherst Industrial Park developing, a growing food processing industry in Oxford and some industry being promoted in Springhill.

Problems of water resource supply and management have already arisen there. The resulting data from the survey will provide a basis for the solution of these problems.

In Pictou, New Glasgow and Trenton there now exists a shortage of water supply. At the same time, the development of an Industrial Park is one of the priorities of the planners for the area. It is extremely important that the water supply for these three centres is resolved.

In the two foregoing areas there is envisaged considerable industrial growth with increased employment opportunities. This will create a growth in the urban population of the centers. The net result of this will not only be added pressure by industry on the water supply, but also added pressure for domestic water.

It is understood that if funds for the Coastal Zone Inventory Mapping Program are not to be made available, the province will make a further submission to DREE for funding a water resources evaluation of the South Shore, from Weymouth to Lockport. This region will be known as the Yarmouth-Shelburne area.

There is a third element in the proposal, designated as "Special Projects". From time to time there are going to be specific requests for water resource evaluations to be done in a rush for special industrial uses. This will require studies to be made in order to provide direction as rapidly as possible. Such studies could arise, for instance, as a result of a request for infrastructure support under the Industrial Development Subsidiary Agreement.

C. Description of Regional Programs

Data collection will be sufficient to permit an accurate assessment to be made at a regional scale of at least 1" = 1 mile. This will provide the initial, primary input into the regional development plans being created by the Provincial Department of Municipal Affairs.

All basic field data will be presented cartographically at a scale of 1" = 1320 feet; with associated files, that will form a departmental data base. The maps will be prepared in monotones on dylar film which will allow for rapid, inexpensive reproduction. This will facilitate the dissemination of data to governmental and private users. The province will absorb the costs of updating and maintaining the data base.

The co-sponsorship of DREE with the Province will be suitably acknowledged in any publications and/or maps resulting from these studies. The formation of this base provides a format whereby:

1. the data presented on the maps is time independent, in that new information can be easily added and the interpretation thereof updated.

2. the much needed flexibility in the use of information is gained, i.e. from detailed site assessments to regional overviews. In terms of manpower, thus operational costs, the base will allow all users of the information the opportunity to arrive at accurate resource and environmental impact evaluations more efficiently. Because all information will be collected and disseminated from one departmental section, the time involved in research will be substantially reduced.

Investigations in each study area will encompass the following subprograms:

1. All subsurface data for the study area will be collected from 80-100 known sources and located in the field to provide data on: depth to bedrock, depth to water table or piezometric surface, minimum yields of various geological units, subsurface geology, possible sources for sampling groundwater quality, possible sources of contamination of groundwater and temporal as well as spatial distribution creation of water budgets.

2. If data is lacking precipitation, temperature and perhaps evaporation gauges will be installed. Gauge location and data assessment will be determined in conjunction with the Atmospheric Environment Service, Environment Canada.

3. If data is lacking stream sediment and water discharge gauging stations will be installed. Gauge location, installation and data assessment will be in conjunction with the Water-Survey of Canada, Environment Canada.

4. If data are lacking a stream sampling program will be carried out on dissolved sediment loadings.

5. HYDAC surveys will be carried out on major fresh water lakes/reservoirs which could be, or are being used, as a water supply to determine: bathymetry,

storage capacity, surface area for evaporation, depth of unconsolidated bottom deposits and base line data for determining rate of sediment infilling, thus reservoir life.

6. Limnological studies will be carried out on certain fresh water lakes which either could be/are being used as a water supply or to quantify certain environments i.e. bedrock type underlying basin.

7. Bedrock geology maps will be updated by mapping new exposures, and interpretation of results from a groundwater quality sampling and test drilling sub-programs.

8. A groundwater sampling program will be carried out to delineate natural groundwater quality at least at the scale of bedrock "Groups".

9. A test drilling and pump testing program will be carried out to determine both the extent and thickness of gravel deposits and associated groundwater quantity and quality as well as the hydrogeological characteristics of major bedrock aquifers. Of these, certain wells will be selected for longterm monitoring of water level fluctuations through their assimilation into the Divisional Observation well network.

10. All known zones of mineralization and mining activity will be located as an aid to delineating zones of natural degraded water quality.

11. As the surficial geology has not been mapped in any of the three areas, a mapping program will be necessary, utilizing air photo interpretation and groundtruthing.

12. Sediment samples of major pleistocene deposits will be taken to quantify parameters such as: grain size, percent organic matter, ion exchange capacity, pH, conductivity, major cations and anions, and nutrients. This will enable:

(a) "K" factors to be determined for the Universal Soil Loss equation so as to determine spatial trends in erodibility.

(b) assessment of the effects of construction activities on increasing mineral concentrations in surface and groundwaters.

13. Environmentally sensitive areas such as outlined below will be delineated on national topographic sheets at 1:50,000 to add to the data base:

(a) all watersheds prescribed or unprescribed, upstream of sites where withdrawals are made for industrial, municipal or domestic purposes, (b) international biological program sites, (c) protected beaches.

D. Description of Special Projects

Due to the uncertainty of the projects which may be undertaken (i.e. extent of data available, type of data required, aerial extent and accuracy required), it is difficult to breakdown costs. Therefore a lump sum of money has been budgeted on a yearly basis. Any new data collected for these projects will be added to the Departmental data base previously described.

E. Phasing

Each of the two regional studies will require 2 years and 9 months to complete. Based on DREE and provincial priorities the following schedule is proposed.

Amherst-Springhill-Oxford
January 1977 to October 1, 1979
New Glasgow-Pictou-Trenton
January 1977 to October 1, 1979
"Special Projects" will be undertaken as the need arises.

3. COST ESTIMATES/FUNDING

A. Project Costs

The cost of the project would be shared 50% by Canada and 50% by the Province under the terms of the Canada Nova Scotia Planning Subsidiary Agreement.

C. Commitment & Disbursement

Funds for the project are to be approved by the Management Committee. Disbursements will be made by the Department of Development for 100% of the incurred costs. The Department will, in turn, submit claims for 50% of the incurred costs to DREE Nova Scotia according to the terms of the Planning Subsidiary Agreement.

D. Tenders/Awards of Contracts

Subject to the approval of the Management Committee, the following procedures will be exercised in awarding contracts:

(A) Staff to be appointed on contract will be chosen by a selection board in accordance with standard Nova Scotia Civil Commission staffing practices. These contracts shall be terminal.

(B) Contracts for work under sections 2C and 2D of this Project Brief will be awarded following public tender in accordance with procedures established by the Nova Scotia Department of the Environment and the Planning Subsidiary Agreement. It is understood that General Development Agreement Procedures will take precedence.

E. Project Cash Flow

The project costs are estimated as shown in Table 1.

A detailed breakdown of estimated annual cost per project and the underlying assumptions are found in Appendix 2.

4. ORGANIZATION & MANAGEMENT

A. Project Implementation

The project will be implemented by the Water Planning and Management Division of the Nova Scotia Department of the Environment.

B. Project Monitoring & Control

The project team will ensure that an annual progress report for the project is submitted to the Management Committee. The project team will consist of one representative of the N.S. Department of the Environment, one representative of the Department of Development, one representative of the Department of Regional Economic Expansion and one member from the Water Survey of Canada.

5. TIE-IN WITH EXISTING & PROPOSED PROGRAMS

This program, as outlined, has been designed to:

A. provide necessary water resource data for the Regional Development Planning presently being carried out by the Provincial Department of Municipal Affairs.

B. augment the Coastal Zone Inventory Mapping program (to be carried out by the Provincial Department of the Environment) by providing data on freshwater resources to support the Socio-economic structure and to tie-in with the physical-biological coastal processes present in their study areas.

6. CONCLUSIONS & RECOMMENDATIONS

It is recommended that the Management Committee approve funds under the terms of the Planning Subsidiary Agreement for the implementation of this project.

TABLE 1

Estimate of Water Resources Evaluation Budget

Regional Evaluations				
Phasing	3 months Amherst 3 months New Glasgow	full year Amherst full year New Glasgow	full year Amherst full year New Glasgow	1/2 year Amherst 1/2 year New Glasgow
Salaries	7,750 - 2 people	103,600 - 8 people	113,860 - 8 people	29,954 - 4 people
Full Time		2,000 - 10 people	2,200 - 10 people	———
Casuals				
(max. possible)	———			
Travel Expenses				
Room	480	3,840	6,108	2,000
Board	420	14,940	15,360	———
Travel	450	13,550	15,017	———
Special Services				
Drilling	———	22,000	24,000	———
Chemical Analyses	———	5,400	24,000	———
Physical Analyses	———	2,000	2,200	———
Gauges	———	24,400	13,200	———
Hydac Surveys	———	———	8,000	———
Reports	———	———	———	6,000
Equipment & Supplies				
Air photographs	1,100	300	———	———
Drafting				
Equipment & Supplies	13,280	———	220	440
Other	400	1,400	1,260	400
Total/Year	23,880	193,430	225,825	38,794
			Total for Water Resources Evaluation Programs $481,929	
Special Projects		50,000	———	———
Overall Yearly Totals	23,880	243,430	225,825	38,794

Grand Total $531,930

APPENDIX B

Hydrometeorological Data

Table B.1

Instrumentation Meteorological Stations
1978

Location	Type of Equipment	N. Lat.	W. Long	Elevation Ft.	Elevation m
South Brook	Thermograph	45° 32.4'	64° 09.8'	600	183
Farmington	Fisher-Porter Thermograph	45° 34.4'	64° 54.3'	860	262
Cobequid Fish Hatchery	Thermograph Tipping Bucket	45° 35.5'	63° 50.0'	300	92
Sugarloaf Mountain	Sacramento	45° 34.8'	63° 46.8'	1040	317
Westchester	Sacramento	45° 34.9'	63° 41.1'	920	281
Wentworth	Tipping Bucket	45° 39.9'	63° 33.0'	120	37
Lorneville	Thermograph	45° 59.1'	63° 56.5'	30	9

Table B.2

Instrumentation Hydrometric Stations
1978

Basin Station Number	Drainage Area sq. km.	Drainage Area sq. mi.	Gauge Location Lat.	Gauge Location Long
Maccan River at E. Southampton (01DL002)	93.4	36.1	45° 35'25"	64° 12'08"
River Philip W. at Collingwood Corner (01DN008)	50.4	19.4	45° 36'22"	63° 56'00"
River Philip E. at Collingwood Corner (01DN007)	102	39.5	45° 36'29"	63° 55'39"
Roaring River at Westchester (01DN006)	41.8	16.1	45° 37'02"	63° 39'55"
Wallace River at Wentworth (01DN005)	116	44.7	45° 39'38"	63° 38'20"

Table B.3

Monthly Precipitation and Temperature
1978

		Months												
		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total mm
River Hebert	mm	190	56.4	72.4	76.7	43.2	88.4	73.3	15.2	78.7	140.5	48.1	41.8	915
	°C	-12.0	- 9.4	-4.2	2.1	11.2	14.8	17.6	17.8	10.6	6.1	-0.1	-4.0	4.2 Av.
Sackville	mm	238	22.6	72.1	92.5	15.8	90.6	66.1	28.2	78.8	111.7	41.1	87.8	945
	°C	- 6.6	- 7.5	-3.0	2.7	10.4	14.6	17.6	18.1	11.3	7.5	0.4	-4.7	5.1 Av.
Nappan	mm	268	61.2	62.5	86.6	19.3	85.2	53.6	18.5	58.9	138.8	35.5	84.3	972
	°C	- 6.9	-13.6	-3.1	2.1	11.1	14.4	17.4	18.1	11.7	7.7	4.9	-4.4	5.0 Av.
Oxford	mm	259	54.9	48.0	88.9	19.7	75.5	75.5	24.5	66.2	140.1	32.5	83.3	968
	°C	- 6.8	-10.4	-3.5	2.3	11.2	15.4	18.6	18.3	10.6	13.4	-0.3	-4.9	5.3 Av.
Tatamagouche	mm			42.9	70.9	17.3	105							
	°C			-3.8	2.1	9.6	15.8							
Lorneville	mm	119	66.0	22.9	71.1	50.8	45.7	55.9	53.3	48.3	71.1	58.4	22.9	685
	°C	- 4.9	- 6.7	-0.7	5.8	12.9	13.9	19.9			10.5	3.3	-2.9*	5.1 Av.
Sugarloaf Mtn	mm	277	68.6	83.8	135	91.4	81	46	69	73.7	175	66.0	150	1320
	°C							No records (Sacramento gauge)						
Westchester	mm	267	53.3	71.1	127	114	79	81	25.4	81.3	170	63.5	99.1	1230
	°C							No records (Sacramento gauge)						
South Brook	mm	226	38.1	43.2	132	78.7	109	76	61	66	104	63.5	132	1130
	°C	- 3.8	- 6.1	-0.1	-0.3	6.6	11.2	14.2	14.4	7.3	2.9	-3.8	-3.2	3.3 Av.
Farmington	mm													
	°C	- 6.6	- 7.9	-3.0	2.2	12.3	14.6	20.0	20.1	12.6	8.6	2.4		6.9
Cobequid F.H.	mm					95E	104	77.3	20.1	79.9	160			5.6 (1)
	°C	- 5.6	- 9.3	-4.1	2.5	10.5	14.9	18.2	17.8	10.1	6.9	-0.5		5.6 Av.
Wentworth	mm					121E	114	92.5	22.1	55.1				

E = estimate
*25 Day Average
(1) Dec. 77 to Nov. 78 inclusive

Table B.4

Unit Yield - Wallace River Sub-basins - Summer 1978

	Sub-basin	Area	May	June	July	Aug.	Sept.	Total	Av.
		(km^2	....	....	....	Runoff (mm)	....	....	....
1.	E01DN006	41.8	163	29.6	15.6	9.0	9.7	227	45.4
2.	W01DN005	116	106	38.4	23.9	11.9	8.9	189	37.8
3.	01DN004	298	127	26.5	15.7	7.42	7.91	185	36.9

Table B.5

Kelley River Baseflow Analyses after Kunkle 1962

	1971	1972	1973	1974	1975	1976	1977	1978
Total Bank Storage mm	124	275	426	264	143	279	199	96.0
Total Basin Storage mm	15	30	30	17	7	28	26	7.0
Total Groundwater mm	140	305	456	281	149	307	225	129
Annual Streamflow mm	960	1510	882	826	954	1176	1414	858
Annual Precipitation mm		1464	1200	1232	1090	1410	1521	902
Ratio: Bank Storage / Annual Streamflow	0.13	0.18	0.48	0.32	0.15	0.24	0.14	0.14
Ratio: Basin Storage / Annual Streamflow	0.01	0.02	0.03	0.02	0.01	0.02	0.02	0.01
Ratio: Total Groundwater / Annual Streamflow		0.21	0.38	0.23	0.14	0.21	0.15	0.14
Ratio: Annual Streamflow / Annual Precipitation		1.03	0.74	0.67	0.88	0.83	0.98	0.95
Ratio: Total Groundwater / Annual Precipitation		0.21	0.38	0.23	0.14	0.22	0.15	0.14

*Kelley River 01DL001
Drainage Area 73.4 sq. km. (24.4 sq. mi.)

Table B.6

BASIN ANALYSIS GEOMORPHIC PARAMETERS		Kelley River at Eight Mile Ford	Maccan River at East Southampton	West River Phillip at Collingwood Corner	River Phillip at Collingwood Corner	River Phillip at Oxford	Wallace River at Westchester Station	Wallace River near Wentworth	Wallace River at Wentworth Centre (IDN-4)	Kelley River at confluence River Hebert	Maccan River at Southampton	Nappan River to Dam (Aboiteau)	Shinimikas River to Northport	Mean $\bar{X}$	Standard Deviation S	Coefficient of Variation $\frac{S \times 100}{\bar{X}}$
Outlet Latitude	° ' N	45°35.2'	45°35 4'	45° 96.4'	45°36 5'	45°44.1'	45°37.0'	45°39 8'	45°40.7'	45°38.3'	45°35 6'	45°46 3'	45°56.2'			
Outlet Longitude	° ' W	63°27 1'	64°12.1'	63° 56'	63°55.8'	63° 51 9'	63°33.9'	63°33.3'	63°33 6'	64°22.8'	64°15.0'	64°14 6'	64°52.2'			
Area	sq.km	63.2	93 4	53 6	102	394	41.8	116	301	91.5	297	130	179	155	114	74
Maximum Elevation Approximate	m	145	297	313	323	329	343	374	374	145	297	159	183	273	89	33
Outlet Elevation Approximate	m	36.6	40.0	46	46	11	88	27	24	7.6	25	0	0	293	24 8	85
Drainage Density, D.	km/km^2	1 81	0.74	0.70	0 70	0.73	0.66	0 78	0.68	0.50	0.70	0.66	0.69	0.78	0.33	43
Constant of Channel Maintenance, C.	m^2/m	800	1350	1420	1420	1380	1520	1276	1480	2000	1420	1520	1450	1419	265	19
Stream Frequency, F	$streams/km^2$	2.17	0 30	0 37	0.26	0.32	0.29	0.36	0.34	0 23	0.27	0 34	0 30	* 0 31	0 04	14
Ratio F/D^2		0.66	0.55	0.76	0.53	0 60	0 67	0 59	0 74	0.92	0.55	0.78	0.63	0.67	0 12	17
Average length overland flow Lg	km	0.28	0.68	0 71	0.71	0 68	0.76	0 64	0.46	1.00	0.71	0.76	0.79	0 68	0.18	26
Bifurcation ratio of stream orders	R_B	4 57	4 57	3 89	4 57	3 16	2 82	3.24	3 39	4.17	3.98	3.09	3.55	3.75	0 63	17
Bifurcation ratio of stream lengths	R_L	5 37	6 45	5.12	6 46	3 63	4 07	3 98	3.89	4.90	5 01	3 80	3 80	4 71	1 01	21
Bifurcation ratio of stream areas	R_A	5.62	6 31	5 24	6.46	3.63	3 80	3 84	3 89	5 62	4 90	3 63	4.17	4.76	1.06	22
Length main drainage channel	km	15.0	19.5	10.9	18 9	38.0	10.3	15 9	27.3	24.0	25.0	32.5	27.2			
Computed Profile $H = ae^{bx}$, H f x in m.	a	40	37	53	43	8.9	87	20	25	13	23	1.8	1 6			
$\times 10^{-4}$	b	0 52	0.94	1.65	1 10	0.92	1 36	1.75	0.71	0.86	0.93	1 37	1.62			
Strahler's Parameters for Hypsometric Curves		0 66	0 56	0 59	0.58	0.39	0 56	0 47	0 36	0 66	0 37	0 42	0 26			
	r	0 05	0 50	0.50	0.50	0.25	0 60	0 70	0 25	0.05	0.05	0.01	0.01			
	z	0 125	0.50	0.40	0.50	0.60	0 50	0 80	0 60	0 125	0 40	0 20	0 33			

* omitting 2.17 in column one

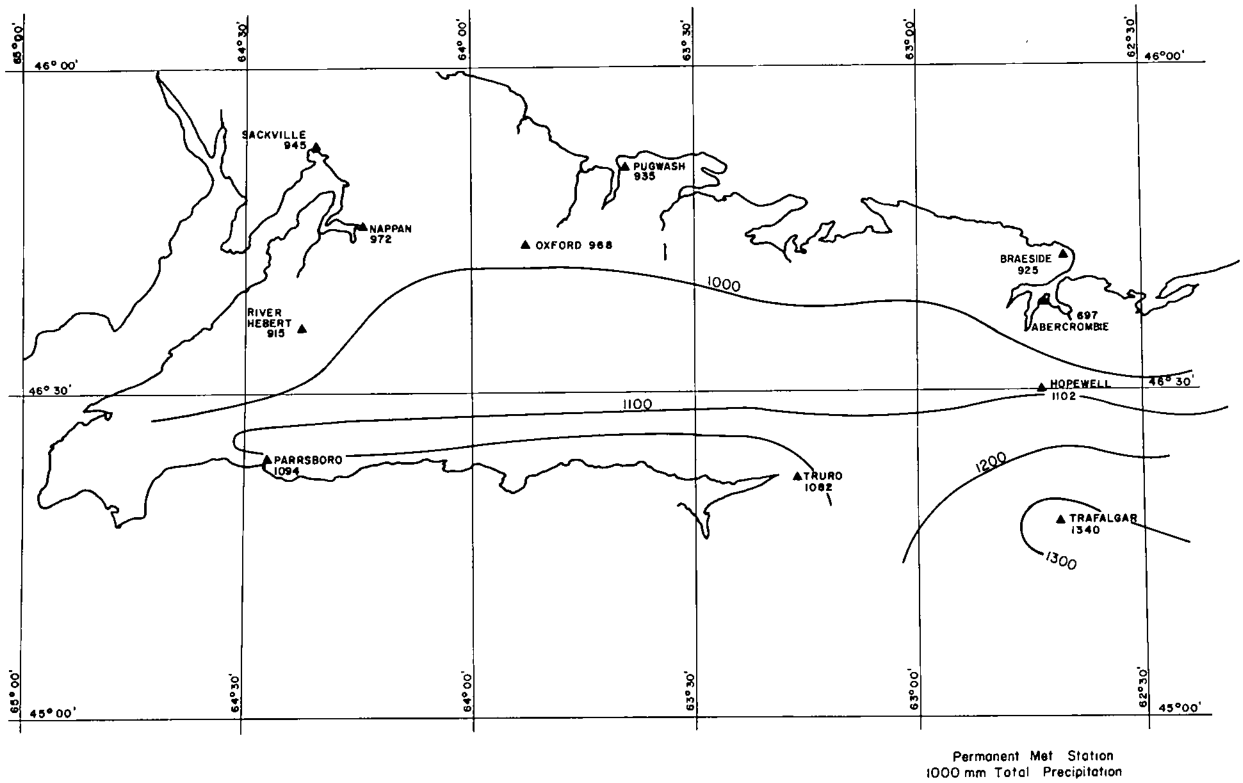


Figure B.1 Isohyetal Map of Total Annual Precipitation, 1978

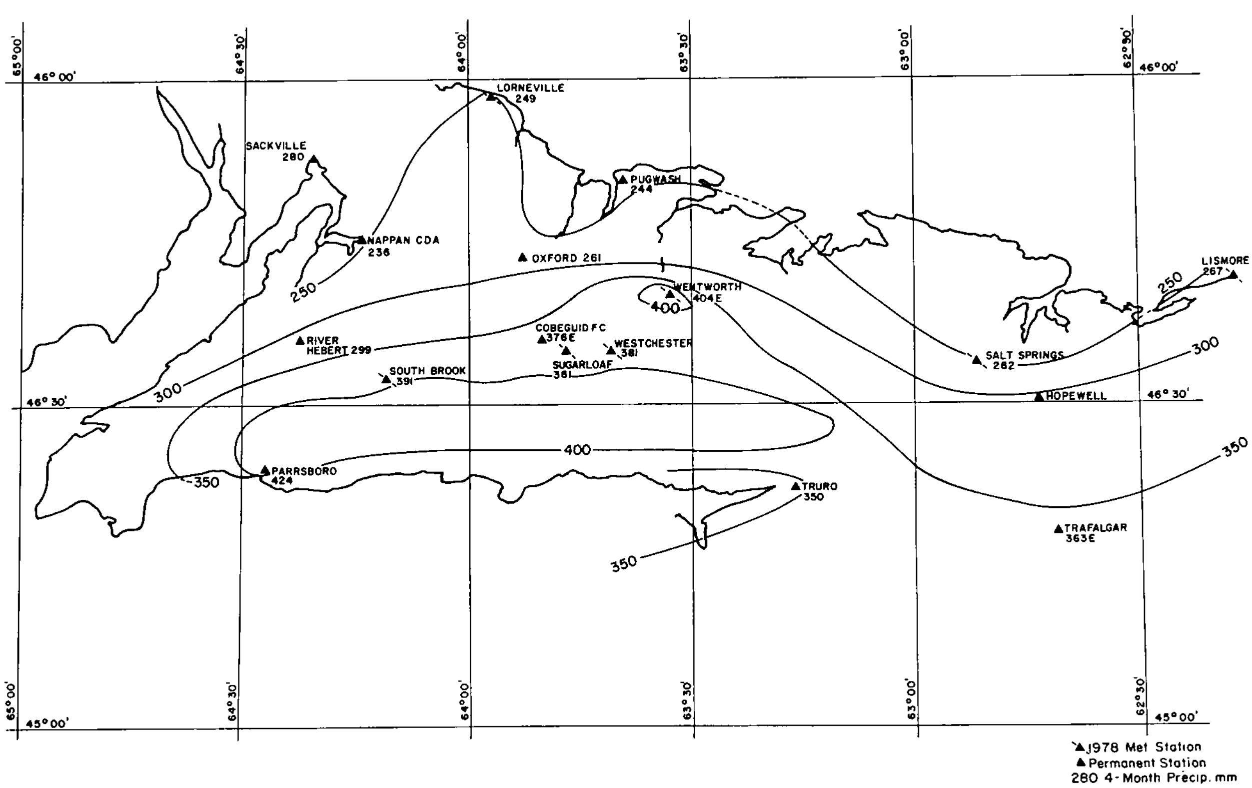


Figure B.2 Isohyetals of Summer Precipitation, 1978

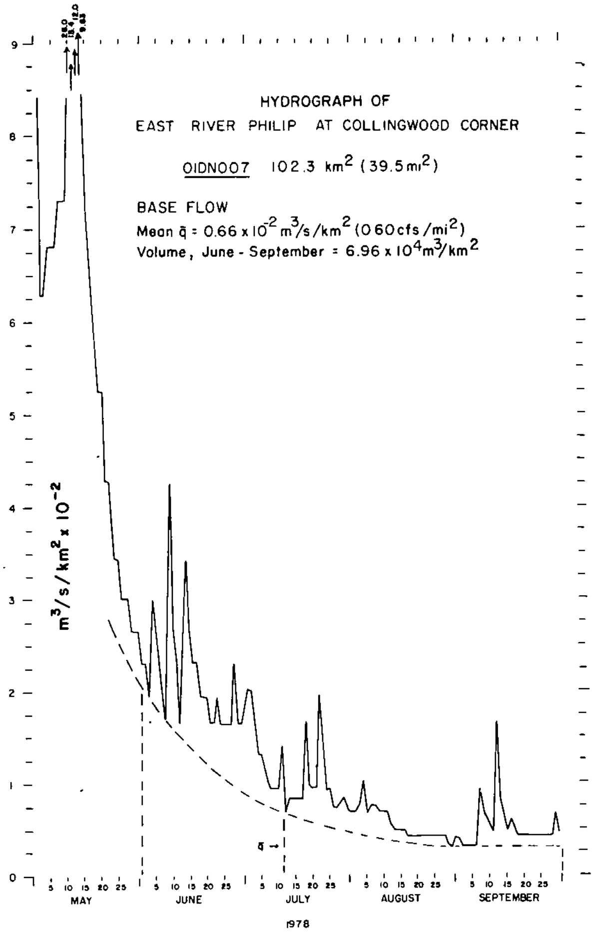


Figure B.3

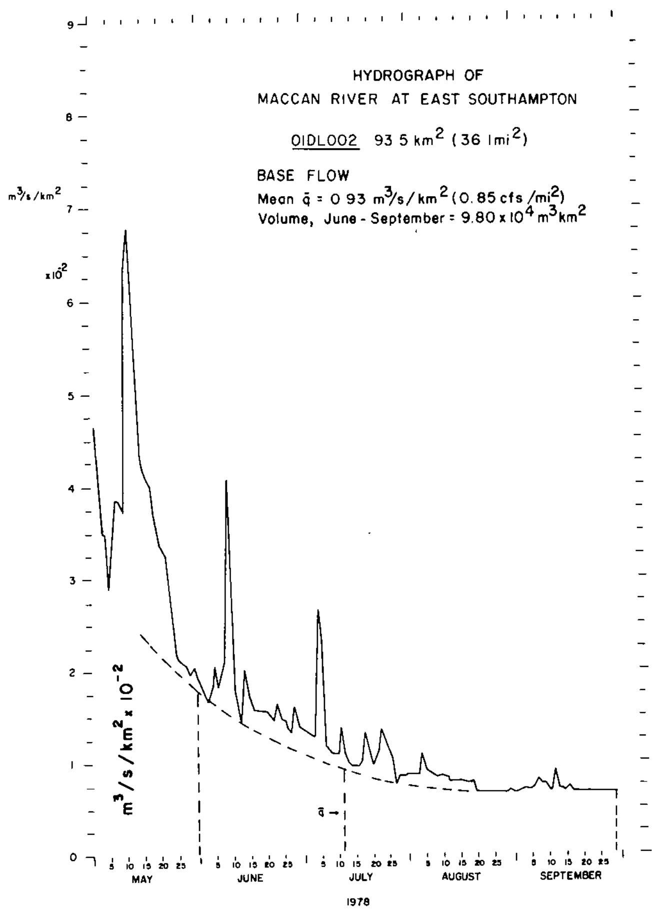


Figure B.4

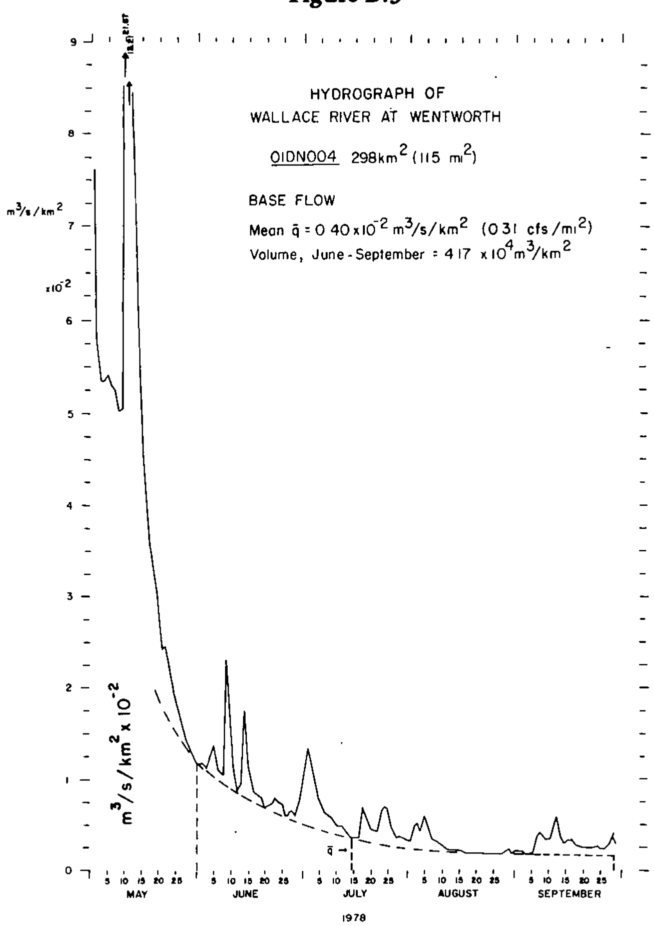


Figure B.5

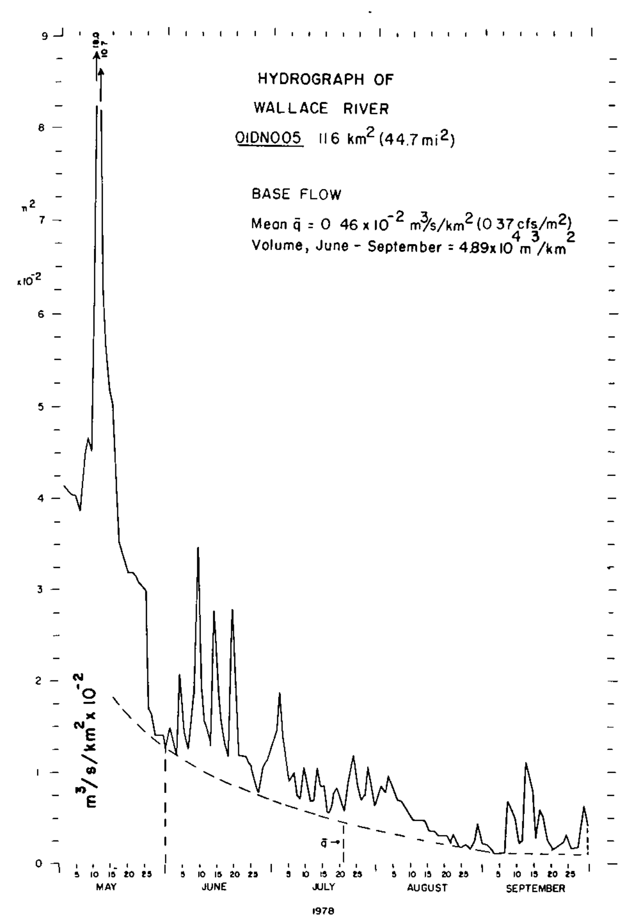


Figure B.6

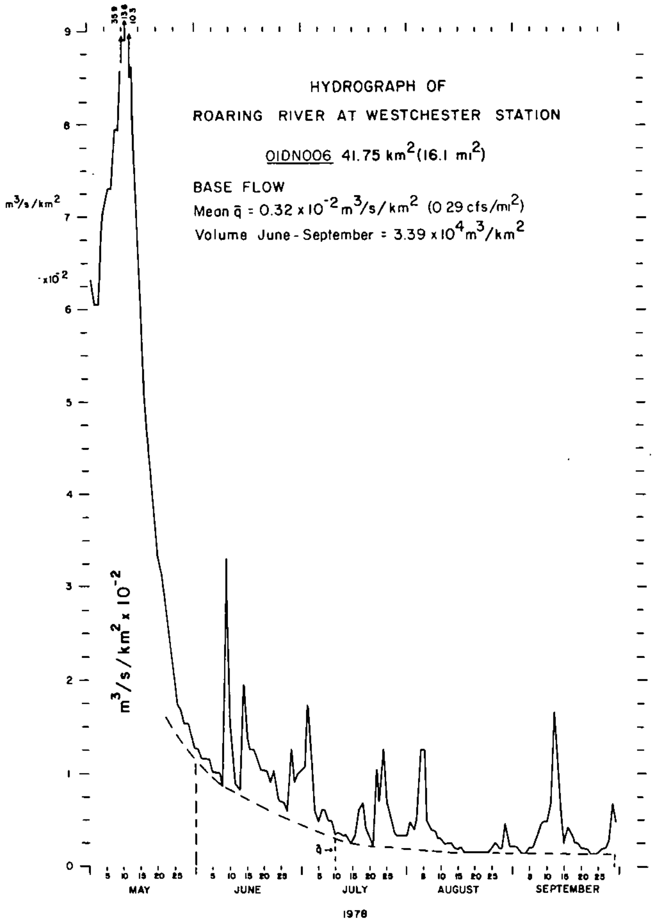


Figure B.7

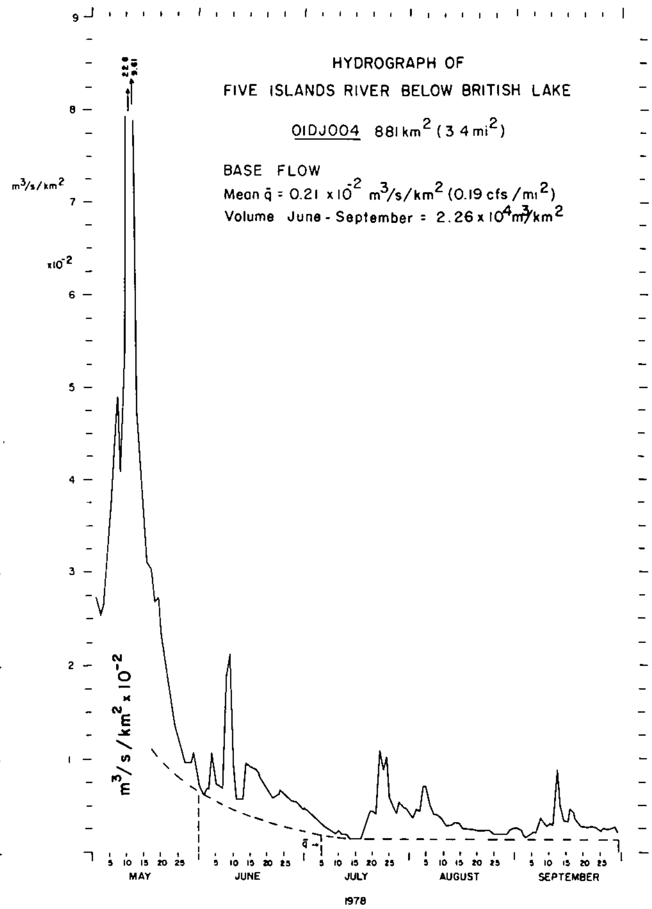


Figure B.8

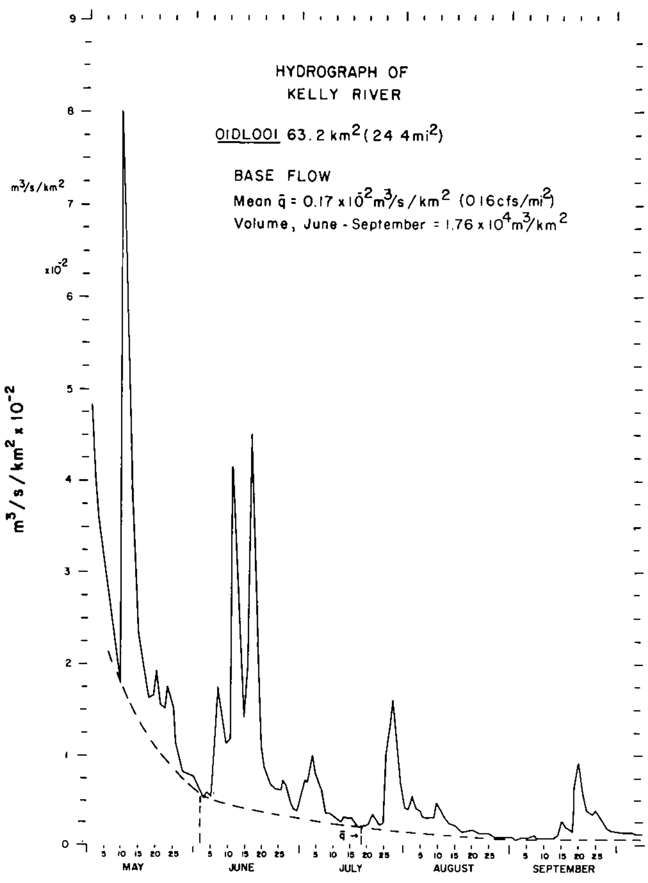
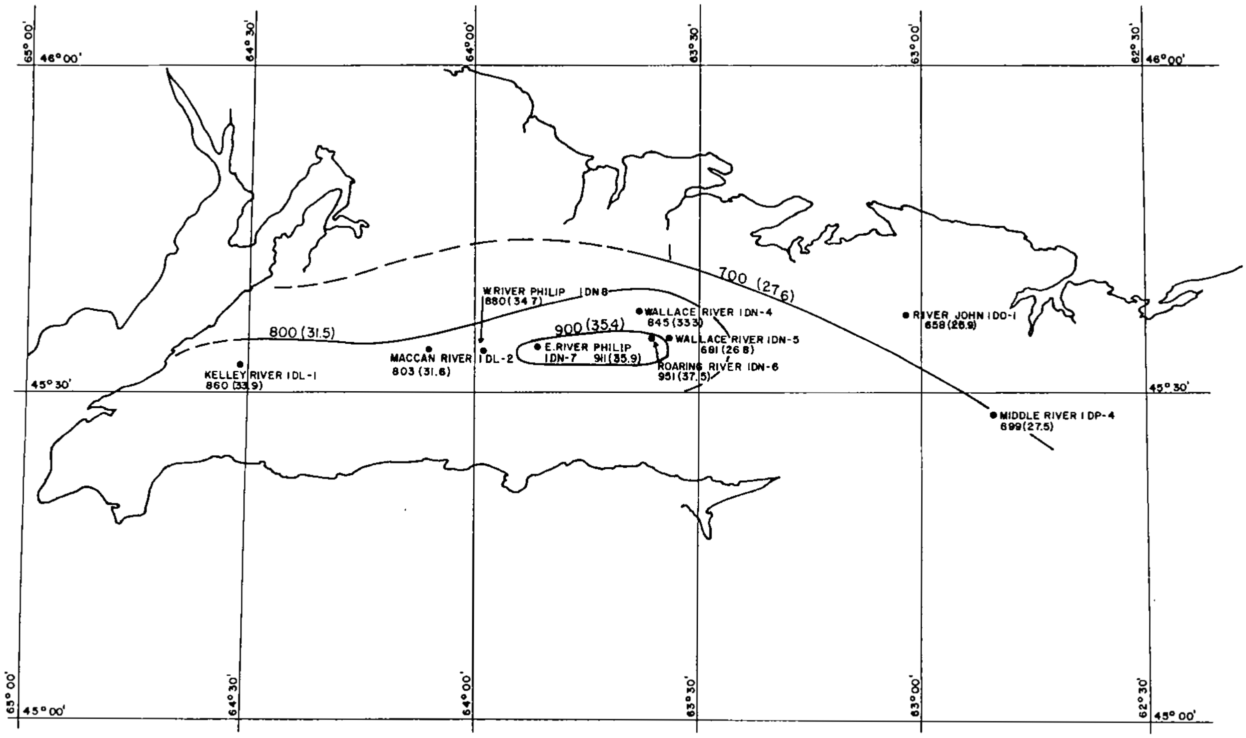
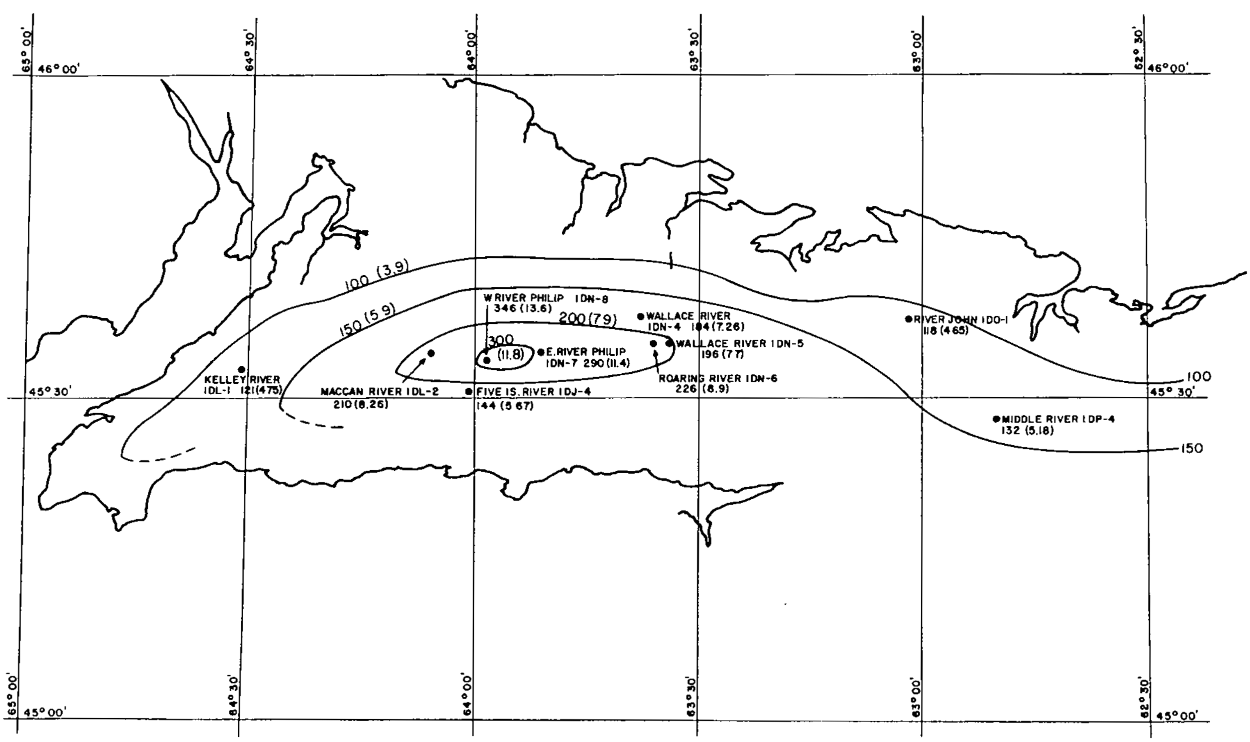


Figure B.9



● center of gravity, horizontal projection of drainage area.
860 mm on Drainage Area
(33.9) in. " " "

Figure B.11 Iso-Runoff Curves of Total Runoff, 1978



121 mm on Drainage Area
(4.75) in " " "
● center of gravity, horizontal projection of drainage area.

Figure B.10 Iso-Runoff Curves of Summer Runoff, 1978

APPENDIX C

Test Well & Control Well Data Summary

Appendix C.1
Test Well & Control Well Statistics

Well No.	Location	U.T.M. Grid	Year Drilled	Well Depth m	Well Diameter m	Casing Length m	Static Water Level m	Transmis-sibility $m^3/(day.m)$	Long Term Yield L/s
Pictou Group									
TH No. 1	Tyndal Rd.	138858	1977	76.2	0.20	6.1	6.7	179	37.9
TH No. 3	Hastings	163730	1977	48.8	0.15	9.3	7.9	6.4	2.27
	Amherst (Victoria)	044745	1979	122.0	0.25		6.4	30.	20.1
	Amherst (Anson Av.)		1978	152.5					
	Amherst (Willow)	075757	1976	137.2	0.25	29.3	7.6	42.	22.7
OX-8B-76	Oxford	321653	1976	111.3	0.25	38.4	12.5	18.	13.6
	Amherst	052749	1967	211.9	0.20	7.9	0.6	27.	7.6
	Amherst Golf	087776	1975	51.8	0.15	-	6.1	8.	7.6
	Course				0.15	-	2.4	2.	0.76
	Northport	342864	1974	106.7					
	Beach				0.15	35.1	2.4	1.8	1.52
Cumberland Group									
	Springhill	157527	1978	67.7	0.20	12.2	11.0	5.2	1.9-3.0
	Springhill	182544	1978	104.0	0.20	12.2	26.8	21.	7.6
	Springhill	167515	1967	152.5	-	-	overflow	49.	22.7
TH No. 11	Springhill	187528	1978	91.5	0.20	13.7	2.7	28.	10.6
TH No. 12	Springhill	191510	1978	126.5	0.20	18.3	5.6	12.	4.9
TH No. 14	Mt. Pleasant	340719	1979	77.7	0.20	7.3	overflow	15.	7.6
Riversdale Group									
	Nappan Agri-cultural Well C	046670	1969	45.7	0.15	-	2.4	51.	7.6
Boss Point Formation									
	Collingwood	268507	1979	38.1	0.15	-	6.1	3.	0.76
	OX-1-75	344649	1975	79.9	0.15	19.1	13.7	11.	2.65
	Town of Oxford	344649							
	Town of Oxford No. 1	344649	1947	109.8	-	-	4.6	16.-21.	7.6
	Town of Oxford No. 2	344649		-	-	-	4.9	15.-20.	7.6
	Town of Oxford No. 3	344649	to	-	-	-	4.6	6.	5.0
	Town of Oxford No. 4	344649		112.2	-	-	9.1	5.	4.
	Town of Oxford No. 5	344649	1969	109.2	0.41	27.7	14.3	15.-30.	7.6-11.4
Surficial									
TH No. 13	Springhill	191510	1977	13.7	0.20	10.7	2.4	300.-600.	15.2-19.0
	Oxford	325630	1974	11.3	0.13	11.3	6.1	600.	4.6

Appendix C.2

Wells Not Tested—Statistics

Well No.	Location	U.T.M. Grid	Year Drilled	Well Depth m	Well Diameter m	Casing Length m	Static Water Level m	Potential Yield L/s
Pictou Group								
TH No. 2	Beecham Rd.	243874	1977	48.3	0.15	9.5	8.8	1.90-3.79
TH No. 4	Mansfield	262759	1977	76.2	0.20	6.1	overflow	15.2-37.9
TH No. 6	East Fort Lawrence	055827	1977	76.2	0.15	9.5	1.8	1.52
TH No. 7	West Fort Lawrence	015768	1977	38.1	0.15	17.4	6.1	0.38
Cumberland Group								
TH No. 8	Springhill (Rodney)	173503	1978	97.6	0.15	9.1	51.8	0.38
TH No. 9	Springhill (Rodney)	179534	1978	79.3	0.15	7.6	16.5	0.38
	Springhill (Town)	182560	1978	97.6	0.15	8.5		3.79
TH No. 10	Springhill	185528	1978	61.0	0.15	15.2	12.2	7.58-15.2
TH No. 15	Thomson Station	356952	1978	62.5	0.15	6.1	1.2	0.11
Riversdale Group								
TH No. 16	Collingwood	266495	1978	49.4	0.15	15.9	3.0	0.11
Surficial								
TH No. 5	Upper Nappan	065721	1977	12.2	0.15	10.7	6.1	0.38 hole abandoned
TH No. 16A	Collingwood	266495	1978	12.2	0.15	-	3.0	- hole abandoned
	Collingwood	258500	1969	39.0	0.15	39.0	7.3	2.27 no screen

APPENDIX D

Tables of Chemical Analysis

CHEMICAL ANALYSES OF SURFACE WATERS CUMBERLAND COUNTY

Appendix D — Table D1

Station and Sample No.	Lab Index No	Grid Location	Date Sampled	Source	Depth of Sample	Na	K	Mg	Ca	Fe	Mn	SO_4	Cl	F	SiO_4	NO_2 + NO_3 as N (mg/litre)	Total PO_4 (mg/litre)	Dissolved PO_4 (mg/litre)	TOC	Humic Acid	Hardness as $CaCO_3$ (Analyses in mg/litre)	Alkalinity as $CaCO_3$	Total Solids	Total Dissolved Solids	Suspended Solids	Color TCU	Turbidity JTU	Conductivity Umhos/cm	pH Lab	Temp °C	Cations (ions in meq/litre): Ca	Cations: Mg	Cations: Na + K	Total Cations	Anions: SO_4	Anions: Cl	Anions: CO_3 + HCO_3	Total Anions
				Shinimikas River																																		
1		262757	Aug.17/78	Ibbitson Brook		5 2	0 78	1 5	13 4	0 44	0 050	5 6	5 2			0 018	0 026	0.047			40 5	41 2	64.2	63 9	0 3	10	0 7	112	8.1	21 2	0.669	0.123	0.246	1 04	0.108	.1467	0.824	1 08
2		271768	"	Beherrel Brook		4.0	0 81	1.2	10.3	0.76	0 36	1 9	4 4			0 026	0 028	0 043			32 7	31.0	108.9	106 5	2 4	50	2.7	83	7.9	27 5	0 514	0.099	0 195	0.807	0 092	.1241	0 620	0836
3		287 792	"			10 2	0 88	2 4	18 6	0 15	0.050	15 4	7 6			0.012	0 017	0 017			56 7	57.8	55.5	50.8	4 7	18	1 2	173	8.1	22.2	0.928	0.197	0 466	1.59	0 158	.2144	1 16	1.53
4		293 795	"	at gravelled highway		10.3	0 88	2.4	18.2	0 15	0.050	13 7	7 5			0 014	0 015	0 013			55 7	57 4	101.9	101.8	0 1	16	0 7	172	8 1	23 5	0.908	0 197	0 471	1 58	0 285	.2116	1 15	1.65
5		296 800	"			11 3	0.98	3 5	19 5	0 19	0.050	14 0	7 1			0 012	0 015	0 009			63.5	58 2	104 6	102.8	1.8	23	1 1	172	7.8	22.0	0 973	0.288	0 517	1.78	0.292	.2003	1.16	1 66
6		291 802	"			13 4	1.30	2 4	14 6	0 83	0 27	2 1	23 0			0.026	0 096	0.018			48 3	35 1	241.1	191 8	49 3	65	9 0	159	7.5	22.5	0.729	0 197	0 616	1.54	0.044	.6488	0 702	1 40
7		297 803	"	at Shinimikas		1 2	0 96	3 5	19 8	0 16	0.050	16 0	7 7			0 013	0 012	0 008			64 2	59 0	101 9	99.9	2 0	18	0 9	176	7.8	22 2	0.988	0 288	0 077	1 35	0.333	.2172	1 18	1.73
				River Philip																																		
8a		397 488	Jan 30/78	near Rose		1 9	0 20	0.6	1 9	0.036	0.006	3 8	2 4			0 034	0 007	0 010			7.5	3.4	14 9	14.0	0 9	5	0 7	27	6.2	0.8	0.095	0.049	0.087	0.232	0.079	.0677	0.068	0.215
9a		360 488	"	Sugarloaf Brook near highway		2.0	0 20	0 6	2 1	0 048	0.012	3.8	2 4			0 013	0.010	0 012			7.6	3.6	15 5	14 2	1 3	4	0.5	28	6 4	2.4	0 105	0.049	0 092	0.246	0.079	.0677	0 072	0.219
10a		345 492	"	at Jackson		2.0	0 19	0 5	2 2	0 036	0.006	2 6	3 4			0 009	0 008	0 009			7 8	3 6	16 2	15.5	0 7	8	0.7	28	6 2	1.4	0 110	0.041	0 092	0.243	0.541	.0959	0.072	0.222
11a		319 501	"	Bulmer Brook		1 8	0 15	0.5	2.4	0 557	0 012	3 7	2 6			0 014	0.004	0 006			9 1	3 6	17 2	16 8	0.4	5	0 4	28	6 3	1.8	0 120	0 041	0 082	0.243	0.077	.0733	0 072	0.222
12a		272 507	"	Jct E and W River Philip		2 1	0 20	0 5	2 4	0 308	0.030	3.8	3.3			0.008	0 008	0 009			8 9	5 4	13 1	10 9	2.2	8	1 3	28	6 3	1.4	0 120	0 041	0 097	0.257	0 079	.0931	0 108	0.280
13a		272 506	"	West River Philip above junction		2 5	0.30	0 7	2 2	0.172	0 006	4 1	3.1			0.002	0.008	0 010			8 7	5 0	22 1	21 3	0 8	7	1.0	33	6.4	1 8	0 110	0.058	0 117	0 284	0 085	.0875	0.100	0 273
14a		278 531	"	near River Philip Centre		2 3	0 31	0 6	1 9	0.059	0.006	3 3	3 2			0 003	0.017	0 012			7 2	3.8	20 5	18.3	2 2	8	1 0	29	6 3	1 4	0 095	0 049	0 108	0 252	0.069	.0903	0.076	0 235
15a		296 564	"	below Polly Brook		2 5	0 28	0 6	2 0	0 082	0.006	3 6	3 6			0 004	0 014	0 009			7 7	3.5	24 1	18 4	5 7	8	1 4	31	6 2	1.0	0.010	0 049	0.116	0 265	0 075	.1016	0 070	0 247
16a		301 576	"	near River Philip		2 5	0 19	0 4	1 1	0 219	0.024	3 5	3.2			0.004	0 014	0 008			8 5	1 9	27 1	23.7	3.3	30	1.8	24	5 7	0 0	0.055	0 033	0 114	0 202	0 073	.0903	0.038	0 201
17a		310 604	"	below Oxford Junction		2 6	0 26	0 6	1 8	0 297	0.024	3 8	2 8			0 007	0 013	0 007			7 5	3.4	28 3	22 4	5 9	15	2.7	29	6 2	0.5	0 090	0 049	0.120	0 259	0 079	.0790	0.068	0 226
18a		324 650	"	Black River above highway		9 7	0.41	1.0	4 0	0 218	0 041	9 5	16 1			0.008	0 011	0 003			14 6	3 6	53.1	48 2	4 9	30	3.5	91	6 1	0 0	0 200	0.082	0 433	0 714	0 198	.4542	0.072	0 724
19a		327 648		Bridge at Oxford		13 1	0.36	0 7	5 5	0.138	0.006	12 4	21 3			0.010	0 017	0 006			16 8	4 3	69.7	59 6	10 1	18	4 8	117	6.2	0 6	0.275	0.058	0 579	0.911	0 258	.6009	0.086	0 945

CHEMICAL ANALYSES OF SURFACE WATERS CUMBERLAND COUNTY

Appendix D – Table DI

Station and Sample No	Lab Index No	Grid Location	Date Sampled	Source	Depth of Sample (m)	Na	K	Mg	Ca	Fe	Mn	SO_4	Cl	F	SiO_4	$NO_2 + NO_3$ as N	Total PO_4 (mg/litre)	Dissolved PO_4 (mg/litre)
8b			June 1/78	River Philip		2.1	0.24	0.8	2.1	0.088	0.003	2.3	3.0			0.011	0.070	0.032
9b			"			2.0	0.19	0.6	1.9	0.032	0.003	2.3	3.2			0.018	0.061	0.034
10b			"			2.3	0.24	0.6	2.4	0.046	0.003	2.4	3.1			0.018	0.053	0.032
11b			"			2.0	0.19	0.6	2.6	0.032	0.003	1.8	2.8			0.018	0.042	0.023
12b			"			2.3	0.26	0.6	2.5	0.046	0.003	2.2	4.0			0.015	0.047	0.057
13b			"			3.2	0.35	0.9	2.6	0.032	0.003	2.2	5.8			0.018	0.073	0.040
14b			"			2.8	0.35	0.8	2.4	0.046	<0.003	2.4	3.8			0.015	0.057	0.032
15b			"			3.1	0.35	0.8	2.4	0.060	<0.003	2.0	4.3			0.013	0.051	0.033
16b			"			3.1	0.35	0.8	2.5	0.032	<0.003	2.3	4.6			0.014	0.064	0.063
17b			"			3.3	0.37	0.8	2.5	0.074	0.003	2.2	4.6			0.009	0.047	0.046
18b			"			64.3	1.20	3.7	14.1	0.028	0.073	29.4	95.9			0.004	0.029	0.016
19b			"			29.8	0.54	1.0	8.5	0.074	0.003	18.7	42.8			0.003	0.046	0.033
8c	79357		Oct. 3/78	River Philip	0.6	3.8	0.6	1.6	5.6	0.15	0.05	5.0	7.2	0.1		0.1	0.04	<0.02
9c	79356		"		0.15	2.5	0.3	1.0	3.4	0.06	0.01	3.0	3.5	<0.1		<0.1	0.04	<0.02
10c	79355		"		0.9	2.9	0.4	1.1	5.2	0.10	0.01	4.0	4.5	0.1		0.1	0.08	0.02
11c	79354		"		2.4	2.8	0.2	1.0	5.6	0.03	0.03	3.5	3.5	<0.1		<0.1	0.03	0.03
12c	79353		"		0.3	3.0	0.4	1.0	5.2	0.06	<0.01	3.0	4.5	<0.1		0.1	0.09	0.07
13c	79352		"			4.4	0.4	1.4	5.6	0.07	0.04	3.0	7.5	.02		0.1	0.02	<0.02
14c	79351		"		1.4	3.8	0.4	1.3	5.6	0.03	<0.01	3.0	6.0	0.1		<0.1	0.03	<0.02
15c	79350		"		0.6	4.3	0.4	1.4	4.8	0.08	0.01	3.0	6.3	0.1		<0.1	0.04	<0.02
16c	79349		"		0.8	4.5	0.4	1.4	5.8	0.07	0.01	2.5	6.3	0.1		<0.1	0.05	<0.02
17c	79348		"		1.1	5.0	0.5	1.4	5.2	0.05	0.01	4.0	7.0	0.1		<0.1	0.05	<0.02
18c	79347		"		1.2	110.0	2.1	5.5	24.0	0.25	0.25	47.0	185.0	0.1		<0.1	0.08	<0.02
19c	79346		"		0.3	87.0	1.1	1.8	29.0	0.10	0.04	60.0	145.0	0.1		<0.1	0.08	<0.02

Station and Sample No	TOC	Humic Acid	Hardness as $CaCO_3$	Alkalinity as $CaCO_3$	Total Solids	Total Dissolved Solids	Suspended Solids	Color TCU	Turbidity JTU	Conductivity Umhos/cm	pH Lab	Temp °C	Ca	Mg	Na + K	Total Cations	SO_4	Cl	CO_3 + HCO_3	Total Anions
		Analyses in mg/litre											Ions in meq/litre: Cations				Anions			
8b			8.9	6.8	35.1	25.3	9.8	8	0.5	33.0	6.9	9.9	0.105	0.066	0.098	0.268	0.048	0.085	0.136	0.269
9b			7.2	5.1	25.2	23.7	1.5	5	0.3	31.0	6.8	9.8	0.095	0.049	0.092	0.236	0.048	0.090	0.102	0.240
10b			8.6	6.9	20.6	19.3	1.3	8	0.4	34.0	7.0	10.2	0.120	0.049	0.106	0.275	0.050	0.088	0.138	0.276
11b			8.8	7.1	27.4	26.4	1.0	7	0.2	33.0	7.0	9.5	0.150	0.049	0.092	0.271	0.308	0.079	0.142	0.259
12b			9.0	7.2	17.2	16.2	1.0	7	0.5	34.0	7.2	10.1	0.125	0.049	0.107	0.281	0.046	0.113	0.144	0.303
13b			10.2	8.6	26.4	25.8	0.6	5	0.2	44.0	7.0	10.0	0.130	0.074	0.148	0.352	0.046	0.164	0.172	0.381
14b			9.1	7.5	24.5	23.3	1.2	7	0.7	38.0	6.9	11.0	0.120	0.066	0.131	0.316	0.050	0.107	0.150	0.307
15b			9.3	7.5	24.2	22.8	1.4	7	0.4	38.0	6.9	11.5	0.120	0.066	0.144	0.329	0.042	0.121	0.150	0.313
16b			9.4	7.7	26.2	24.0	2.2	7	0.4	38.0	6.9	11.5	0.125	0.066	0.144	0.334	0.048	0.130	0.154	0.332
17b			9.7	7.7	28.1	25.8	2.3	10	1.0	40.0	7.1	12.0	0.125	0.066	0.153	0.344	0.046	0.130	0.154	0.330
18b			50.7	17.0	254.9	248.2	6.7	18	1.8	465.0	7.1	15.0	0.699	0.304	2.83	3.83	0.612	2.71	0.340	3.66
19b			25.5	9.3	129.5	126.4	3.2	11	1.4	235.0	7.0	13.0	0.424	0.082	1.31	1.82	0.389	1.21	0.186	1.78
8c		6.0	21.0	12.0		40.0	1.0	10	1.2	55.0	7.1	7.3	0.279	0.132	0.181	0.592	0.104	.2031	0.240	0.547
9c		5.0	13.0	9.2		24.0	0.5	10	1.6	35.0	7.0	7.3	0.170	0.082	0.117	0.369	0.063	.0987	0.184	0.345
10c		5.0	18.0	12.0		36.0	0.5	10	1.8	45.0	7.0	7.3	0.260	0.091	0.136	0.486	0.083	.1269	0.240	0.450
11c		5.0	18.0	14.0		33.0	0.3	10	1.1	45.0	7.4	7.3	0.279	0.082	0.127	0.489	0.073	.0987	0.280	0.452
12c		5.0	17.0	13.0		38.0	0.8	10	1.4	45.0	7.4	7.3	0.260	0.082	0.141	0.483	0.063	.1269	0.260	0.449
13c		4.0	20.0	15.0		43.0	0.3	10	1.7	57.0	7.3	7.3	0.279	0.115	0.202	0.596	0.063	.2116	0.300	0.574
14c		4.0	20.0	15.0		41.0	0.3	10	1.0	50.0	7.3	7.3	0.279	0.107	0.176	0.562	0.063	.1693	0.300	0.532
15c		4.0	18.0	15.0		42.0	0.8	10	2.1	53.0	7.3	7.3	0.240	0.115	0.197	0.552	0.063	.1778	0.300	0.540
16c		4.0	20.0	16.0		40.0	3.0	10	2.4	54.0	7.2	7.3	0.289	0.115	0.206	0.611	0.052	.1778	0.320	0.550
17c		4.0	19.0	15.0		39.0	1.0	10	2.8	61.0	7.3	7.3	0.260	0.115	0.230	0.605	0.083	.1975	0.300	0.581
18c		15.0	83.0	26.0		422.0	3.5	10	3.8	720.0	7.3	7.3	1.20	0.452	4.84	6.49	0.979	5.22	0.520	6.72
19c		4.0	80.0	17.0		364.0	1.8	15	2.8	600.0	7.2	10.1	1.45	0.123	3.81	5.38	1.25	4.09	0.340	5.68

CHEMICAL ANALYSES OF SURFACE WATERS CUMBERLAND COUNTY

Appendix D - Table D-1

Station and Sample No	Lab Index No	Grid Location	Date Sampled	Source	Depth of Sample (metres)	Na	K	Mg	Ca	Fe	Mn	SO_4	Cl	F	SiO_4	NO_2 + NO_3 as N (mg/litre)	Total PO_4 (mg/litre)	Dissolved PO_4 (mg/litre)	TOC	Humic Acid	Hardness as $CaCO_3$	Alkalinity as $CaCO_3$	Total Solids	Total Dissolved Solids	Suspended Solids	Color TCU	Turbidity JTU	Conductivity Umhos/cm	pH Lab	Temp °C	Cations (meq/litre): Ca	Mg	Na + K	Total Cations	Anions (meq/litre): SO_4	Cl	CO_3 + HCO_3	Total Anions
20a	79337	168 515	Jan.31/78	Maccan River at old reservoir	0.5	4.6	0.59	1.5	2.9	0.26	0.03	6.1	7.1			.175	0.02	0.020			14.2	6.0	44.7	40.2	4.5	10	2.4	57.0	6.5	0.5	0.145	0.123	0.215	0.483	0.127	.2003	0.120	0.447
21a	79338	153 502	"	Leamington Brook	0.15	2.3	0.30	0.9	1.8	0.18	0.03	4.5	2.1			.097	0.017	0.024			8.6	4.8	21.7	20.2	1.5	6	0.5	31.0	6.5	2.0	0.090	0.074	0.108	0.272	0.092	.0592	0.096	0.249
22a	79339	092 484	"	Road to South Brook	0.5	2.6	0.30	0.9	1.8	0.33	0.03	4.2	3.1			.099	0.016	0.023			8.7	4.0	20.1	18.6	1.5	5	0.9	32.0	6.4	1.3	0.090	0.074	0.121	0.285	0.087	.0875	0.080	0.255
23a	79340	062 490	"	at Station 01DL002	0.9	2.6	0.29	0.9	1.8	0.90	0.01	4.2	3.3			.077	0.016	0.022			9.5	4.4	20.7	19.1	1.6	5	1.0	32.0	6.5	1.0	0.090	0.074	0.121	0.285	0.087	.0930	0.088	0.268
24a	79342	028 494	"	Outlet of East Brook		4.5	0.68	2.4	5.7	0.23	0.07	16.5	6.7			.137	0.017	0.014			24.5	4.0	53.1	50.4	2.7	33	2.3	80.0	6.4	0.5	0.284	0.197	0.311	0.793	0.344	.1890	0.080	0.613
25a	79341	027 496	"	Total to Southampton		2.5	0.30	0.8	1.8	0.07	0.01	4.5	3.0			.093	0.016	0.022			7.8	5.0	22.3	20.5	1.8	8	1.0	31.0	6.3	1.0	0.090	0.066	0.117	0.272	0.094	.0846	0.100	0.278
26a	79343	035 525	"	Midway Moses and Haig Brooks	0.3	2.9	0.37	1.0	2.7	0.14	0.01	7.0	3.9			.089	0.013	0.018			11.2	4.1	26.1	23.3	2.8	15	1.5	41.0	6.2	0.5	0.135	0.082	0.200	0.417	0.146	.1100	0.082	0.338
27a	79344	035 556	"	Midway Barren and Pugsley Brooks	1.2	2.9	0.37	1.0	2.6	0.13	0.02	5.8	4.6			.059	0.016	0.018			10.8	3.9	31.4	22.5	8.9	15	2.1	41.0	6.3	0.5	0.130	0.082	0.200	0.412	0.121	.1298	0.078	0.329
20b			June 6/78	Maccan River		5.6	0.87	2.4	4.0	0.17	0.13	2.5	10.4		0.008	8.325	0.062	0.054			20.5	14.1	51.9	48.6	3.3	18	1.5	72.0	7.2	13.1	0.200	0.197	0.266	0.663	0.052	.2934	0.282	0.628
21b			"			2.5	0.33	1.0	2.1	0.032	0.003	2.4	3.7		0.021	21.000	0.072	0.060			9.5	7.3	27.0	25.1	1.9	9	0.3	35.0	7.2	9.5	0.105	0.082	0.117	0.304	0.050	.1044	0.146	0.300
22b			"			3.0	0.34	1.1	2.2	0.046	0.007	2.4	4.2		0.015	14.800	0.059	0.043			9.9	8.8	23.8	23.0	0.8	14	0.3	39.0	7.0	10.5	0.110	0.091	0.139	0.340	0.050	.1185	0.176	0.345
23b			"			3.0	0.34	1.1	2.2	0.060	0.003	2.4	4.3		0.013	12.500	0.071	0.054			10.0	7.7	25.8	22.5	3.3	14	0.4	40.0	7.1	11.0	0.110	0.091	0.139	0.340	0.050	.1213	0.154	0.325
24b			"			11.3	1.09	3.3	9.1	0.37	0.024	22.3	14.6		0.003	3.331	0.039	0.025			37.0	17.4	111.4	108.4	3.0	80	2.1	151.0	7.4	12.7	0.454	0.272	0.520	1.245	0.464	.4119	0.348	1.224
25b			"			3.1	0.35	1.0	2.5	0.10	0.010	2.5	4.5		0.010	10.200	0.054	0.051			10.5	7.7	33.2	32.1	1.1	18	0.5	40.0	7.1	11.5	0.125	0.082	0.144	0.351	0.052	.1269	0.154	0.333
26b			"			4.4	0.48	1.3	3.6	0.13	0.017	8.0	5.8		0.009	9.034	0.043	0.032			14.7	9.4	47.7	46.6	1.1	30	0.7	58.0	7.1	12.2	0.180	0.107	0.204	0.490	0.121	.1636	0.188	0.472
27b			"			4.7	0.50	1.4	3.9	0.13	0.007	8.2	5.9		0.010	10.400	0.056	0.047			15.5	9.7	48.1	47.0	1.0	28	0.9	60.0	7.2	12.5	0.195	0.115	0.217	0.527	0.123	.1664	0.194	0.483
20c	79337		Oct 3-4/78	Maccan River	0.5	6.4	1.2	2.9	7.0	0.35	0.11	6.0	13.0			<0.1	0.11	<0.02		7.0	30.0	18.0		60	12.3	20	6.3	94	7.4	7.3	0.349	0.239	0.309	0.897	0.125	.3667	0.360	0.852
21c	79338		"		0.15	3.1	0.4	1.6	4.2	0.05	0.01	4.0	3.5			<0.1	0.03	<0.02		4.0	17.0	14.0		32	3.3	20	2.0	40	7.3	7.3	0.210	0.132	0.145	0.486	0.083	.0987	0.280	0.462
22c	79339		"		0.5	4.0	0.4	1.7	4.4	0.02	<0.01	4.5	5.5			<0.1	0.04	<0.02		4.0	18.0	14.0		40	0.3	15	1.0	47	7.3	9.0	0.220	0.140	0.185	0.544	0.094	.1552	0.280	0.529
23c	79340		"		0.9	4.2	0.4	1.7	4.4	0.03	<0.01	3.5	5.5			<0.1	0.47	<0.02		4.0	18.0	14.0		36	0.5	15	3.8	49	7.3	10.1	0.210	0.140	0.193	0.542	0.073	.1552	0.280	0.508
24c	79342		"		0.5	6.0	0.5	1.8	6.2	0.08	0.01	7.0	8.5			<0.1	0.05	<0.02		5.0	23.0	15.0		56	1.8	20	1.7	73	7.3	8.4	0.309	0.148	0.274	0.731	0.146	.2396	0.300	0.686
25c	79341		"		0.3		2.2	5.5	22.0	0.08	0.02	55.0	40.0			0.1	0.06	<0.02		9.0	77.0	49.0		220	0.3	25	2.8	340	7.9	5.6	1.10	0.452	1.67	3.22	1.15	1.13	0.980	3.25
26c	79343		"		0.3	8.5	0.6	2.2	7.4	0.10	0.02	11.0	11.0			<0.1	0.07	<0.02		6.0	28.0	18.0		61	3.5	25	4.8	90	7.3	7.8	0.369	0.181	0.385	0.935	0.229	.3103	0.360	0.899
27c	79344		"		1.2	8.3	0.6	2.2	7.2	0.08	0.02	11.0	11.0			<0.1	0.04	0.04		6.0	27.0	18.0		72	0.8	15	2.3	92	7.4	7.8	0.359	0.181	0.376	0.917	0.229	.3103	0.360	0.899
28		158 863	Aug.23/78	Paradise Brook (Branch of Tidnish R.)		3.8	0.41	1.4	6.2	0.40	0.050	2.1	5.6			23.0	0.060	0.007			22.1	19.2	63.6	50.2	13.4	90	4.5	58.0	7.3	25.1	0.309	0.115	0.176	0.600	0.044	.1580	0.384	0.588
29	87100	378 588	July 10/79	Tillet Brook near Thompson Station		4.4	0.3	0.7	2.4	0.20	0.03	1.2	4.5	<0.1		<0.1	0.09	0.05	9.5	13.0	9.0	9.0	50.8	49.0	1.8	85	1.3	35.0	6.8	16.7	0.120	0.058	0.199	0.377	0.025	.1269	0.180	0.332
30	87101	258 629	July 10/79	Black River near Oxford		54.0	1.0	2.6	15.0	0.17	0.05	28.0	91.0	<0.1		<0.1	0.02	0.02	12.0	17.0	48.0	15.0	241.0	239.0	2.3	75	1.1	380.0	7.2	22.2	0.749	0.214	2.38	3.34	0.583	2.57	0.300	3.45
31	87102	129 753	July 10/79	Nappan River at Hastings		4.7	0.4	1.0	8.4	0.28	0.05	5.0	5.0	<0.1		<0.1	<0.08	<0.02	18.0	35.0	25.0	21.0	70.5	68.0	2.5	150	1.8	64.0	7.2	23.3	0.419	0.082	0.215	0.716	0.104	.1411	0.420	0.665
32	87103	111615	July 10/79	Little Fork		6.7	0.4	0.8	4.1	0.17	0.08	1.2	9.5	<0.1		<0.1	0.04	0.07	9.5	17.0	14.0	11.0	60.0	52.0	8.0	70	1.4	55.0	7.2	23.8	0.205	0.066	0.302	0.572	0.025	.2680	0.220	0.513

CHEMICAL ANALYSES OF GROUNDWATERS CUMBERLAND COUNTY

APPENDIX D – Table D2

Station and Sample No.	Lab Index No.	Grid Location	Present Owner	Depth of Sample	Depth of Well (metres)	Aquifer	Date Sampled	Ca	Mg	Na	K	SO_4	Cl	F	Si	NO_3 + NO_2 as N	NH_3 as N	PO_4 ortho	Fe	Mn	Pb	Cu	Zn	As
								Analyses in mg/liter																
1	73339	148858	Tyndal Road, Test Hole No.1		76.2	Pictou	Mar 23 / 78	34.0	11 0	5 0	0 8	3.2	12.0	<0.1	12.0	<0.1	<0 1	0.17	0 05	0 02	0.02	0.03	<0 01	
2	87248	055821	East end, Fort Lawrence,TH # 6		76.2		Jul 12/79	64.0	4 9	8 2	0 9	3 5	7.0	0.1	14.0	<0.1	<0.1	0 03	0 68	0 09	0.005	<0 01	<0.01	
3	59272	075757	new well, Willow St., Amherst		122 0		Nov 4/76	28.0	8 7	5.5	1.0	6.0	6.0	0 1	15 0	0 6	<0.1	0.03	<0.10	<0.05	<0.005	<0.005	<0.005	
4	71879	262769	Mansfield, Test Hole No 4		39 6		Jan 17/78	30 0	2 8	10.0	1 1	8.3	5.0	0 1	10.0	<0 1	<0 1	0 04	0.22	0.22	<0.005	<0.005	0 01	
5		127760	Bill Scott, well # 4		22.0			25	4.1	10	3.4	13	11											
6	55337	321653	test well Ox-88-76 Oxford		111.3		Jul 6 / 76	24.0	6.4	10	2 1	14 0	5 5	0.1	8 0	<0.1	<0.1	0.16	.1	.4	<0.005	0 01	0.009	
7	74052	163730	Hastings, test sample # 3, at 72 hrs.		91.5		Apr 1 / 78	1 0	0.1	150	3.7	51	34	1.3	7.5	<0 1	0.1	0 53	5.5	0 19	<0.01	0.02	0 22	
8	87249	243874	Beecham Rd. Test Hole No. 2		48 8		Jul 12 / 79	2 8	0.3	157.0	1.8	37 0	.8.0	1 3	6.3	<0.1	<0 1	0.11	0.94	0 19	<0.005	<0.01	<0 01	
9	39501	410803	Heather Beach		45.7		Sept 5/ 74	2 5	0.5	160.0	2 5	29 0	30 0	0.7	7.6	<0 1	<0 1	0 10	0.4	0 4	0.01	0.04	0.29	
10	43269	263929	T. Evans,		18.3		Apr 30/75	1.5	0.4	194.0	3.0	136.0	30 0	0.6	8 0	<0 1	<0.1	0.14	0.40	0 40	<0.005	0.03	0.02	
11		342864	North Port Provincial Park		106 7		Jun 11/74	0 4	0 2	160	1.0	57	31			0.1			0.4	0 01				
12	87247	015768	Fort Lawrence (West) T.H # 7		38.1		Jul 12/79	720 0	408 0	3700.0	61.0	680.0	7500.0	0.8	14 0	<0.1	1.5	<0 02	4.50	4.70	<0.005	0.02	0 07	
13	43268	263929	T Evans,		101 2		Apr 30/75	35 0	7 6	950.0	11 0	1760.0	616 0	1.4	6 0	<0 1	<0.1	0 02	0 40	0.10	<0.005	0.05	0.11	
14	67501	124755	Scott, Hastings		122 0		Aug 10/77	164 0	24 0	910 0	5 6	80 0	1575.0	2 5	7 1	<0.1	<0 1	0 23	18.30	1.10	0.006	0.02	0.11	
15	73427	185528	Springhill, Test Hole # 10		61.0	Cumberland	Mar 30/78	15	2 1	25	2 3	7 8	5 3	0 3	11	<0 1	<0 1	0 05	11.0	0 60	0 05	0 04	0 12	
16	74905	187528	Springhill, Test Hole # 11		91.5		May 10/78	27	4 2	14	1 9	7 5	6 5	0 1	13	<0 1	<0 1	<0 02	<0 02	0 10	0 005	<0 01	0 08	
17	43328	170572	Schaffer Garage, Springhill		33.5		May 2/75	28	3 6	15	2 5	20	14	0 2	9	<0 1	<0 1	0 03	0 5	0 3	<0.005	0 02	0 09	
18	78232	186522	David Brown, Springhill		19 8		Aug 31/78	12	1 7	20	2 3	4 5	9	0 2	9 1	0 2	<0 1	0 12	0 15	0 09	<0.005	<0 01	0 17	
19		167515	Springhill, Penitentiary		152 5		June 1/67	17 3	1.8	25 2		14	39						0. 9	0 07				
20	82459	340719	Mt Pleasant, Test Hole # 14		77.7		Jan /79	18	7 8	3 8	2 3	2 5	4 0	0.1	10	<0 1	<0 1	0,04	0 56	0 41	<0.005	<0 01	<0 01	

Station and Sample No.	Alkalinity as $CaCO_3$	Hardness as $CaCO_3$	Total Solids	Total Dissolved Solids	Color T C U.	Turbidity J T U	Conductivity Umhos/cm	Ph Lab	Cations: Ca	Cations: Mg	Cations: Na + K	Cations: Total Cations	Anions: SO_4	Anions: Cl	Anions: CO_3 + HCO_3	Anions: Total Anions
	Analyses in mg/liter								Ions in meq/liter							
1	114	130.0	142	135	10	2.2	250	7.8	1 70	0 905	0 238	2 84	0 067	0 338	2 280	2 68
2	170	181.0		206	15	5.5	320	7.8	3 19	0 403	0 380	3 98	0 073	0 198	3 40	3 67
3	105	107.0	120	119	5	1.2	240	7.9	1 40	0 716	0 265	2.38	0 125	0 169	2 10	2 39
4	97	86.0		127	20	150.0	190	7.3	1 40	0 230	0 463	2.190	0 173	0 141	1 94	2 254
5	78								1 25	0 337	0 530	2 107	0 271	0 310	1.56	2 141
6	97	86	139	136	5	1.9	213	7.3	1 20	0 527	0 489	2 21	0 292	0.155	1 94	2.387
7	326	4.1		449		68	630	9.3	0 050	0 008	6.35	6 40	1 062	0.959	6.52	8 54
8	320	8 2		441	40	7.5	600	9.0	0 14	0 035	6 98	7.04	0.770	0 236	6.40	7 40
9	280	8.2	419	413	30	4.6	715	9 2	0 135	0 041	7 024	7 19	0 604	0 846	5.60	7 05
10	244	5.5	543	541	20	43	864	9.4	0.075	0.033	8.52	8.624	2.832	0 846	4 880	8.56
11	260	2		430			680	9.2	0 020	0.017	6.986	7.022	1.187	0 875	5 200	7.263
12	610	3500.0		14267	10	1 4	20710	7.1	35 93	33.56	162 5	232.0	14.16	211 58	12.20	237.9
13	207	119.0	3956	3956	20	2.5	5940	8.1	1.75	0.625	41.61	43 98	36.64	17.38	4.140	58.16
14	230	510.0	3658	3390	400	200.0	4900	7.5	8 18	1 97	39 73	49 88	1.67	44.43	4 60	50.7
15	94	47	364	140	20	120 0	142	7 7	0 749	0 173	1 146	2 068	0 162	0.150	1.90	2.192
16	104	86	147.3	145	10	1 0	210	8 0	1 347	0 346	0 658	2 350	0 156	0.183	2 08	2 42
17	94	85	147	146	25	5 5	238	7 9	1 40	0 296	0 716	2 41	0 416	0 395	1 88	2 69
18	63	36	90	88	5	4 3	145	7.8	0 609	0 140	0 929	1 68	0 094	0 254	1.26	1 608
19	82	50 8					370	8.3	0.863	0 148			0 292	1 100	1 64	3.032
20	78	78	116 3	90	5	11	165	8.1	0.898	0 642	0.224	1.76	0.0521	0.113	1 56	1 72

CHEMICAL ANALYSES OF GROUNDWATERS CUMBERLAND COUNTY

APPENDIX D – Table D2

Station and Sample No	Lab Index No.	Grid Location	Present Owner	Depth of Sample	Depth of Well (metres)	Aquifer	Date Sampled	Analyses in mg/liter																								Ions in meq/liter							
																																Cations				Anions			
								Ca	Mg	Na	K	SO_4	Cl	F	Si	$NO_3 + NO_2$ as N	NH_3 as N	PO_4 ortho	Fe	Mn	Pb	Cu	Zn	As	Alkalinity as $CaCO_3$	Hardness as $CaCO_3$	Total Solids	Total Dissolved Solids	Color T.C.U.	Turbidity J T U	Conductivity Umhos/cm	Ph Lab	Ca	Mg	Na + K	Total Cations	SO_4	Cl	$CO_3 + HCO_3$	Total Anions
21	37403	094652	Fenwick Provincial Park		15 4	Cumberland	June 17-18/74	31	6 1	70	3 2	10	41	0 1		<0 1			0 7	0 1					61	104		187			270	76	1 55	0 502	0.386	2 44	0.208	1.16	1 22	2 59
22	75572	173503	Springhill, Test Hole # 8		97.6		June 7/78	8 6	4 3	5.8	0 4	2 5	4 0	0 1	16	<0 1	<0 1	0 08	0.11	<0 01	<0.005	<0 01	0.06		42	40	71.5	67	15	38	81	7 9	0 429	0.354	0 263	1.045	0 052	0 113	0.84	1 004
23	75188	191510	Springhill, Test Hole # 12		126.5		May 19/78	7,4	0 8	25	1.1	2.5	6 6	0 3	9 7	<0 1	<0 1	0.02	0 20	0 04	<0.005	<0 01	<0 01		69	22	103	100	15	4.7	138	8 2	0 369	0 066	1.12	1.55	0.052	0 186	1 38	1 62
24	82809	356592	Thompson Station, Test Hole #15		62 5		Dec 15/79	14	2 6	125	69	25	85	4 2	16	<0 1	0 2	0 57							155	46	784	784	750		600	8 8	0 699	0 214	7 202	8 12	0 521	2 408	3 10	6.018
25	81968	082604	Brine		18 3		Jan 11/79	13	4 5	23	3 3	75	3 0	0 2	8.1	<0 1	<0 1	0 02	0 06	0 06	<0.005	<0 01	0 05		94	51	124 9	123	5	7.2	194	7 8	0 649	0 370	1.09	2.104	0.156	0.085	1 88	2 12
26	86051	029489	Southampton				June 12/79	46	5.6	.71	2.0	8 5	180	<0.1	6 3	1 5	<0 1	<0 02	0 18	0 03	<0.005	0 13	0 09		27	139	407	405	10	0 98	650	6.6	2 305	0 461	3 14	5 906	0 177	5.078	0 54	5.79
27	86046	310604	D Rushton		16 8	Riversdale	June 11/79	38 0	5 2	13 0	2.8	8 5	8 5	<0 1	11.0	<0 1	<0.1	<0 02	0 12	0 19	<0.005	<0 01	0 03		135	117		168	15	2 4	300	8 1	1.906	0 428	0 637	2 96	0 177	0 240	2 70	3 12
28	86048	153685	N Webb		19 8		June 11/79	40 0	7 1	22 0	2 4	21 0	3.0	0 1	12.0	<0.1	<0 1	0 17	0 24	0 08	0 01	<0.01	0 01		155	130		206	10	1 4	325	7 6	2.006	0 584	1 018	3 608	0.437	0.085	3 10	3.62
29	86050	078680	G Coates				June 11/79	22.0	3 6	3 9	0 7	8 5	4 0	<0 1	6 8	0 7	<0 1	0 02	0 32	0 03	<0.005	<0 01	0 24		62	71		99	15	1 1	144	6 8	1.108	0 296	0 188	1 58	0 177	0 113	1 24	1.53
30	86053	268513	B Lloyd				June 12/79	18 0	1 6	4 8	1 0	1 5	2 5	<0 1	8 5	<0.1	<0.1	<0 02	0 08	0 03	0.005	0.12	0 06		56	51		77	20	3.6	112	7 3	0 898	0.132	0 234	1 26	0 0312	0.071	1.12	1 22
31	86881	046670	Nappan Experimental Farm		45.7		June 27/79	38 0	4 6	7 4	1 3	15.0	5.5	0 2	15 0	<0 1	<0 1	<0 02	0 12	0.29	<0.005	<0 01	<0.01		112	114		162	15	0 76	240	7.6	1 906	0 378	0 355	2 63	0 312	0 155	2 24	2.703
32	86049	084665	W Linas				June 11/79	38 0	10 0	6 5	4 9	8 5	3 0	<0 1	6 1	<0.1	<0 1	0 02	0 24	0 03	<0.005	<0 01	<0 01		157	137		168	20	1 8	275	8.1	1.896	0.823	0.408	3 127	0.177	0 085	3 14	3.402
33	48572	344649	Town of Oxford, OX-1-75		79 9		Nov 18/75	20 0	5.2	74 0	3 6	16 0	133.0	0 2	15 0	0 4	<0 1	0 14	0 30	0 07	0 007	0 03	0 01		56	72	368	307	5		515	7 7	0 998	0 428	3 311	4 74	0.333	3 75	1 12	5.205
34	87250	266495	Village of Collingwood, T.H.#16		49 4		July 12/79	8 0	0 8	407 0	3 9	12 0	570.0	0 9	5 9	<0 1	<0 1	0 02	6 60	0 50	0 02	0.11	0 04		150	24		1153	30	6 5	1900	8.7	0 399	0.066	17 81	18 27	0 249	16 1	3 00	19.3
35	86043	045691	Wallace Smith, Nappan			Windsor	June 11/79	108	27	63	12	320	69	0 2	5 8	<0 1	<0.1	0 02	0 38	0 09	0 02	<0 01	0.17		80	382		690	25	2 9	975	7 8	5 39	2 22	3 05	10 66	6 66	1.95	1 60	10 2
36	86045	318631	H Knol, Oxford				June 11/79	22	8 6	3 6	3 8	10	7 0	0 1	6 7	0.6	<0 02	<0 02	0 03	0 01	<0.005	<0 01	0 02		82	91		128	15	0 12	185	8 1	1.10	0.707	0 254	2.06	0 208	0 196	1 64	2 06
37	86044	074681	Coles, Fenwick			Middleborough Formation	June 11/79	4 8	1.4	9 6	5 9	41	23	0 7	7.4	<0 01	<0 1	0 05	0 14	0 04	0 005	<0 01	<0 01		175	18		283	10	1 3	450	8 4	0 24	0 115	4.33	4 68	0.854	0.649	3 50	5.002
38	86047	243713	G Gilroy, East Leicester		15 2		June 11/79	86	5 5	12	1 0	7 5	8 2	<0 1	8.1	0 8	<0.1	0 04	0 07	0 01	<0.005	0 04	0 27		140	238		334	10	0 33	525	7 4	4 29	0 452	0 548	5 29	0 156	2 32	2.80	5 27
39	86052	264450	R Fuller, Collingwood		70 1	Cobequid	June 12/79	18	3.5	4 1	0 6	7 5	3 0	<0 1	9 8	<0 1	<0 1	<0 02	0 11	<0 01	<0.005	0.03	0.30		56	60		91	10	0 58	124	7 9	0.898	0 288	0 194	1 38	0.156	0.085	1.12	1.36